# OF THE FACULTY OF ENGINEERING OSAKA CITY UNIVERSITY

VOL. 58

DECEMBER 2017

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VOL. 58

### DECEMBER 2017

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#### Power Distribution Protocol Among Power Plants and Consumers in Energy Packet Networks

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#### (Received September 30, 2017)

#### **Synopsis**

Power distribution protocol among power plants and consumers in electric energy packet networks is proposed. Energy packet networks have advantages of affinity with decentralized power plants such like a photovoltaic power generation and of manageability of energy coloring in the process of power distribution. Differing from conventional data packet networks, this protocol provides the energy packet networks with simultaneous multipoint-to-multipoint power transmissions among power plants and consumers and with the power transmission procedure triggered by an occurring of a consumer demand. The aspect of decentralized control of data packet networks is succeeded for reliability of power distribution against partial failure of the network. The operations of the energy packet network based on the proposed protocol are confirmed by computer simulations.

KEYWORDS: smart grid, power packet, energy packet, power packet, energy packet, Transmission protocol.

#### 1. Introduction

Smart grid technologies have been investigated for the purpose to enhance efficiency and reliability of current power systems with smooth integration of renewable and alternative energy sources[1]. As one of the basics of this upcoming power grid, electric energy packet transmission is proposed to distribute electric power over the network[2,3,4].

The power networking with electric energy packets has advantages as follows:

First, it has affinity with decentralized generating plants such like a photovoltaic power generator or wind turbine generator. In current power systems, where power lines are always filled with electric signal of specified voltage, reverse power flow from decentralized plants causes voltage fluctuations that degrade power source quality to neighboring customers[5]. On the other hand, reverse power flow with electric energy packets never cause such voltage fluctuations because of their independency of other energy packets.

Second, it has manageability of energy coloring in the process of power distribution. For consumers, energy coloring is necessary to identify which power source the incoming energy is generated by and how far the source is located[6,7]. This information assists the consumers to select the power source or electric power itself of the lowest environmental load concerning greenhouse gas emissions or such global scale problems.

However, in energy packet networks, differences from data packet networks cause subjects to be solved. In my previous work[8,12], a scheme for power networking with electric energy packets is proposed to solve the problem of packet discarding caused by packet collisions or routing buffer overflow. In addition, the scheme eliminates the power loss accumulation caused by store and forward of energy packets at successive routers.

In this paper, as one of the residual subjects of energy packet networking, a protocol is proposed for reasonable process of power distribution among power plants and consumers. This protocol must be investigated because of the differences from that for the conventional data packet transmission as follows:

First, in contrast to the data packet transmission that is basically point-to-point, the power transmission possibly be multipoint-to-multipoint. This difference is caused by the aspects of the packet payloads in both cases. The payload of a data packet is a message distinctive for individual recipient. Whereas, that of an energy packet is only an electrical power that cannot be distinguished from other ones. Therefore, in energy packet networks, every consumer is possible to satisfy its power demand with energy packets transmitted from various power plants simultaneously, or equivalently, every power plant may transmit its surplus power by series of energy packets addressed to various consumers that express power demand coincidentally.

Second, though the procedure of data packet transmission always begin with a call of a transmitter, that of energy packet transmission must be triggered by a consumer demand. This means that there must be some preceding process before the transmission of each energy packet with a specified destination as its packet

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header. This preceding process must begin with an expression of a power demand by a consumer and the determination of power plants follows. This determination specifies the destination of energy packets transmission and payload volume of the electric power. If various demands are expressed by different consumers coincidentally, the determination of each power plant for these consumers may depend on their location, each demand volume, power transmission path congestion, or so.

To realize theses aspects of the power transmission protocol, the proposed protocol specifies two kinds of process of power network operation: First, the process of information accumulation of all the nodes to each power plant. Second, the process of energy packet transmission among power plants and consumers. Based on the first process, every node constructs and updates its own extended forwarding table (or EFT). This table basically indicate routing information for energy packet transmissions in the network. In addition, the table indicates the current power demand and distance of every consumer. Based on this EFT, in the second process, each power plant determines the target consumers and performs multipoint-to-multipoint transmissions of energy packets to the consumers. This second process is triggered by a consumer demand appears at the EFT.

Because these processes are executed individually by each node in the network, the aspect of decentralized control of conventional data packet network is succeeded for reliable power distribution against partial failure of the network.

In section 2, the first process of the proposed protocol: EFT operation is explained. In section 3, the second process: energy packet transmission is explained. In section 4, simulation results are described that confirm the energy packet network operation with the proposed power distribution protocol.

#### 2. POWER DISTRIBUTION PROTOCOL: EFT OPERATION

As described in the previous section, the proposed power distribution protocol consists of following two processes:

1. The process of information accumulation and EFT construction and update at each node.

2. The process of energy packet transmissions among power plants and consumers.

In this section, the former process of the power distribution protocol is explained. First, an example of power network configuration is indicated with overview of energy packet transmissions and information exchanges among the nodes. Second, based on this example of power network, details of EFT operation is explained including the configuration of the table and its construction and update.

#### 2.1 Power network configuration

An example of the configuration of the energy packet network is shown in Fig. 1. This network consists of end users, power routers, and a power gateway. These nodes are connected by power communication links. In this figure, five end users A E are indicated. They usually consume power, or some of them possibly be decentralized power plants provided they have surplus power over their own consumption. The figure denotes the consumers (B, C, and E) and power plants (A and D) by white and gray circles, respectively. On the other hand, four power routers F, H, I, and J are indicated. Each of them receives an energy packet and forward it to an adjacent node connected with the router directly (this adjacent node is called next hop). The next hop possibly be another power router or a consumer as the energy packet destination. The double circle in the figure denotes the power gateway G. In this example of the power network, the power gateway is assumed to execute following operations:



#### Fig. 1. An example of power packet network.

1. To connect this power network with an adjacent outer network. If the outer network is conventional one with continuous power signal, the gateway decomposes the continuous signal into energy packets with specified configuration of the inner network.

2. To stock its own rechargeable battery with excess power supplied by outer power network. This power storage at the gateway node assists the arbitrary power consumption of the inner network to some extent especially when power supply from outer network halts because of some troubles.

In addition to these inherent roles of the power gateway, it also executes the routing process by relaying incoming energy packets to the next hop.

The power communication link consists of an electric wire for power transmission and a data cable for information exchange between its terminal nodes. In this network configuration, because the data cable is assumed to be divided from the electric wire, the media for data transmission may be another candidate for smart grid communications[1]. In addition, the information exchanges may follow the protocol standards for the smart grid communications recommended by ETSI[13].

#### 2.2 Extended forwarding table

The proposed power distribution protocol is based on the EFT (extended forwarding table) that every node in the network individually construct and update repeatedly. This table consists of current information of routing for the energy packet transmissions and that of all consumers including their power demands and distances.

The examples of the EFT are shown in Fig. 2 according to the network configuration in Fig. 1. The upper and lower part of this figure show the EFT owned by the power plant A and power router F in Fig. 1, respectively. In both tables, the first line denotes tags of table contents as follows:

dst: The destination node for the power transmission. (In the following items, dst denotes this destination node.)

nxt: The next hop node to the dst that specifies one of adjacent nodes on the most preferable power transmission path to the destination.

hop: Hop count to the dst.

mtr: The metric to the dst that indicates a value considered when a power plant determines a target consumer for its power transmission. For example, if only the distance to the dst is considered, this metric equals to the distance. Or, if the power transmission path congestion is also considered, the metric alternates accordingly.

EFI	EFT of power plant A							
dst	nxt	hop	mtr	dist[km] c/p/r/g		pow[W]		
В	F	2	0.15	0.18	с	-350		
D	F	4	1.85	2.10	р	2500		
E	F	4	1.77	1.65	с	-250		
F	F	1	0.08	0.07	r	-		
G	F	2	1.21	1.15	g	9840		
EFT	EFT of power router F							
dst	nxt	hop	mtr	dist[Km]	c/p/r/g	pow[W]		
Α	Α	1	0.08	0.07	р	1850		
В	В	1	0.07	0.06	с	-350		
D	G	3	1.73	1.61	р	2500		
E	Ι	3	1.65	1.87	с	-250		
J	J	1	1.19	1.22	r	-		

EFT of power plant A

← basic contents → ← additional contents →

#### Fig. 2. Examples of EFT of power plant A and power router F in Fig. 1.

Above four contents are the basics of the forwarding table of routing method of DSDV (Destination-Sequenced Distance-Vector Routing) that is a typical scheme for mobile network routing[10]. Therefore, these four contents are mentioned as the basic contents. Whereas, additional three contents are counted in the EFT (these are mentioned as the additional contents):

dist: The distance to the dst along with the transmission path.

c/p/r/g: The information about the dst that indicates which class the node belongs to. These four character represent consumer, power plant, power router, and power gateway, respectively.

pow: If the class of the dst is power plant, this value indicates the surplusage for the power transmission of the dst, or if the class is consumer, this indicates its power demand.

The second and the succeeding lines indicate the entries toward every node in the network . (From now on, an entry toward an node means that an entry with the node as its destination.)

When a power plant determines a target consumer as the power transmission destination, the power plant transmits the energy packets and power routers relay them according to their EFT until the packets arrive at the consumer.

For example in Fig. 1, if power plant A determines consumer E as the target, A searches the target E in its own EFT (upper part of Fig. 2) and finds the next hop F. Then A assembles the energy packets addressed to E and transmits them to the next hop F. Because the entry toward E indicates that the next hop is node I in the EFT of power router F (lower part of Fig. 2), the router F relays the received energy packets to the next hop I. The same relay process is repeated according to the EFT of routers until the energy packets arrive at the destination consumer E.

#### 2.3 EFT construction and update

EFT is constructed and updated at each node individually based on information exchanges between adjacent nodes. Along with the repetition of this EFT operation over the network, each EFT entry converges the correct information even though the entry toward a distant node in the network.

The EFT operation corresponds with that of conventional forwarding table in DSDV routing method where only the basic contents contribute the operation[14]. Additional contents are gradually spread over the network along with the repetitive information exchanges between adjacent nodes in the network.

The overview of the EFT operation is explained as follows:

1. At the beginning of the EFT operation, each node records the initial entry in its own EFT. This initial entry indicates the owner node itself. An example of this initial entry is shown at the right side of Fig. 3. This part of figure shows the initial entry in EFT of node Z. The content 'seq' represents the sequence number that indicates the newness of the information attached with.

2. Each node receives the EFT data from one of adjacent node, and updates its own EFT based on the comparison of each entry with the received one. The process of this each entry update is as follows:

a. If the node has not the entry with the same 'dst' as the received one, adds the entry to its own EFT.

b. If the received entry of the same 'dst' has larger (or newer) sequence number than its own one, overwrite it with the received one.

c. If the received entry of the same 'dst' has smaller (or more preferable) metric than its own one, overwrite it with the received one.

d. If the received entry has passed the above screenings, discard the received one.

3. The node receives the EFT data from another adjacent node and returns to the stage 2.

An example of this EFT update is shown in Fig. 3. In this figure, node A intends to update its entry toward Z based on information exchanges with B and D. This entry is initially made by the node Z as shown at the right side of the figure. According to the second stage in the EFT operation above indicated, node A first compares its own entry with that from B. As the result, the entry from B is discarded because of its smaller sequence number. Then, according to the third stage, node A compares its entry with that from D. Because the entry from D has larger sequence number, A overwrite its entry with that from D even though it has larger metric.



Fig. 3. An examples of EFT entry update by node A.

#### 3. POWER DISTRIBUTION PROTOCOL: ENERGY PACKET TRANSMISSION

In this section, the proposed protocol for energy packet transmissions among power plants and consumers is explained. First, overview of the protocol is described. Second, the detailed procedure for each consumer to satisfy its power demand is described. Third, the procedure for each power plant to transmit energy packets to consumers is described. Finally, an example of power distribution procedure among power plants and consumers is described.

#### 3.1 Overview of energy packet transmission protocol

As mentioned in section 1, the energy packet transmissions must be multipoint-to-multipoint in the power network and the process of the power transmissions must be triggered by an occurring of a consumer demand. Based on these essential requirements, the proposed power distribution protocol is designed to satisfy the following conditions.

1. According to the protocol, energy packets are transmitted from power plants to consumers in multipoint-to-multipoint configuration.

2. The power transmission procedure is triggered by an occurring of a consumer demand.

3. Each power transmission and routing is planned by individual node in the network and no center station is necessary.

4. Each power supplying gradually increase or decrease to avoid misadjustment to unexpected fluctuations of consumer demands.

The third condition is inherent of conventional data packet networks and must be taken over by the energy packet networks because of its reliability of network operations against a partial failure of the network caused by disasters or terrorisms.

In the fourth condition, the unexpected fluctuations of consumer demands may be caused by the alternation of their power consumptions or by power transmissions from other power plants in the network. Though the former problem cannot be resolved, the latter one can be handled by negotiations among power plants to make their accumulated power equalized just to the consumer demands. However, because the negotiations among nodes possibly induce traffic congestions of data cables and take unreasonable time until the convergence, the process of the negotiations among power plants is not adopted in the proposed power transmission protocol.



Fig. 4. Procedure of each consumer to satisfy its power demand.

#### 3.2 Energy packet transmission: consumer procedure

The procedure for energy packet transmissions is explained for consumers and power plants, individually. First, the procedure for each consumer is expressed by the flow chart shown in Fig. 4. This process proceeds as follows (descriptions are tagged by corresponding numbers in the flow chart):

(1) Each consumer examines itself whether or not the power demand exist.

(2) If exists, the consumer records the demand volume on the initial entry of its EFT and transmits the data to neighbor nodes for their EFT update.

(3) (Because this stage is not the process of individual consumer, enclosed by a dashed rectangle in the flow chart.) The demand is propagated to every power plant in the network along with the EFT updates among nodes.

(4) The consumer examines the arrival of a notice from a power plant that indicates the energy packet transmission to the consumer.

(5) If the notice arrives, the consumer increases or decreases its power demand volume recorded in its EFT according to the notice description.

(6) The process returns to the first stage.

In the fifth stage above described, the cases of increase or decrease the power demand may occur because of the following reasons:

- Power demand increase: Because a power plant stops its continuous transmission of energy packets to the consumer, the node increases its power demand. The power plant possibly lost its surplus power or changed the power transmission destination for some reasons.
- Power demand decrease: Because a power plant increases its energy packet transmission to the consumer, or because some another plant begins to transmit energy packets to the same node, the consumer decreases its power demand.

#### **3.3 Energy packet transmission: power plant procedure**

The procedure for each power plant is expressed by the flow chart shown in Fig. 5. This process proceeds as follows:

(1) Each power plant waits the decision timing when the plant makes decisions about the energy packet transmissions.

(2) The power plant examines itself whether or not it has a surplus power to satisfy consumer demands.

(3) If the plant has a surplus power, it scans the entries in its EFT and make up a list of all consumers. The list consists of the power demand of each consumer and its distance from the power plant.

(4) The plant determines the way of energy packet transmission to each consumer (the details are described later).

(5) According to the determination, the plant send the notice to each consumer that the way of power transmission is changed.

(6) The power plant transmits energy packets to each consumer according to the determination executed in the fourth stage. This transmission continues until the next decision timing. For example, if 1[W] is transmitted to a consumer and each payload of energy packet equals 1[J], the packet transmission repeats every 1[sec].

(7) The process returns to the first stage.

The decision timing in the first stage above, and the transmission power increasing or decreasing at the timing in the succeeding stages concern the fourth condition mentioned before on the power distribution protocol. The condition requires gradual alternation of the power volume. For example, the interval of the decision timing is set to 0.1[sec], and the step of power alternation is set to 1[W], the alternation cannot exceed 10[W/sec].

In the fourth stage above, the power plant determines the way of energy packet transmission. This way is classified according to the previous way of power transmission and current state of each consumer as follows.

- If a power transmission has been continued to the consumer and the consumer has no power demand, this means the power transmission and consumption keep equivalent. Therefore, the plant does not change the way of the power transmission.
- In this case, if the consumer has a power demand, the plant increases the power volume of the transmission. For example, raise the frequency of the energy packet transmission.
- On the other hand, if the power transmission was not executed to the consumer and it has a power demand, the plant begins to transmit energy packets to the consumer.

#### 3.4 Example of power distribution procedure

Based on the protocol described in previous subsections, an example of power distribution procedure is described in Fig. 6 among power plants and consumers in Fig. 1.

The followings are assumed in Fig. 6:

(1) Each of power plants A and D has an initial surplus power.

(2) Each of consumers B and E has an initial power demand.

(3) At the beginning of the procedure, no energy packet transmission exists.

(4) The determination of target consumer by each power plant concerns the power demand and distance of the consumer.



Fig. 5. Procedure of each power plant to transmit energy packets to consumers.

Based on these assumptions, the power distribution procedure shown in Fig. 6 proceed as follows (descriptions are tagged by corresponding numbers in the figure):

(1) First, the power demands of consumer B and E spread over the network along with repetition of EFT update among adjacent nodes. Power plants A and D receive these informations.

(2) At the predetermined decision timing, power plants A and D determine their power transmission destination as the same consumer E. This decision depends on the power demands of consumers and distances to them .

(3) Power plants A and D transmit their decisions to the consumer E as a notice. This notice is transmitted directly through the intermediate communication links. According to this notice, consumer E decreases its power demand.

(4) Power plants A and D begin to transmit their energy packets to the consumer E. To satisfy the gradual increase of transmitted power volume, the transmitted power is a least unit (several watts or so) and the series of packets conveying this least power continues until the next decision change.

(5) At this decision timing, because of the power demand decrease at consumer E, power plant A determines the new target as neighboring consumer B. Beyond this timing, A transmits energy packets to consumer B and E

simultaneously. Another power plant D keeps the target as E and increases its power transmission to twice of the least unit.

(6) Both consumers are noticed these decisions of power plants and decrease their power demands accordingly.

(7) Both power plants continue power transmissions according to their latest decision of the destinations and power volume of their energy packets.



#### Fig. 6. An example of power transmission procedure among power plants and consumers in Fig. 1.

#### 4. COMPUTER SIMULATION

For the purpose to confirm the operations of energy packet network with the proposed power distribution protocol, computer simulations are executed. The overview of the simulations, and the simulation results are described in this section.

#### 4.1 Overview of computer simulations

The aspects of the power network operation to be confirmed with the proposed protocol are as follows:

1. Are the power demands of consumers finally satisfied with the energy packet transmission procedure that is triggered by themselves?

2. At the decision timing, each power plant determines a target consumer concerning the power demand of each consumer and its distance. There must be an appreciation ratio between these two essentials. Does this appreciation ratio affect the power network operation? And is there the optimal value of the ratio?

3. Do the multipoint-to-multipoint transmissions of energy packets appear during the power network operation?

For the purpose to confirm these aspects, an elemental system model for the simulations is adopted as shown in Fig. 7.



## Fig. 7. A system model of power distribution network with energy packet transmissions for computer simulations.

This system model consists of six end users numbered 1 to 6, and eight power routers. Among the end users, two power plants 1 and 5 are indicated by gray circles. The others indicated by white circles are consumers. Initial surplus power or initial power demand is indicated in watts with each power plant or consumer, respectively. As shown in the figure, the longest distance between adjacent power routers is set to 100[m]. Other dimensions are proportional to what the figure actually indicates.

As the simulation goes on, each power plant increases its power transmission to the consumers that have power demands. Equivalently, each consumer decreases its power demand provided some surplus power exists among the power plants. Because the summation of initial surplus powers and power demands is set to zero, these powers gradually approach zero and absolutely become zero at the end of the simulation. Concerning this simulation scenario, these assumptions are set:

1. Only the power transmission of each power plant decreases its surplus power, and only the power reception of each consumer decreases its power demand. No other causes exist that fluctuate their surplus powers or power demands.

2. The least unit of power transmission increase is set to 1[W], and the interval of decision timing of each power plant is set to one simulation step. Therefore, if the step equals 0.1[sec] in actual power network operation, and if each energy packet conveys 1[J] of power, the increase of least unit causes an addition of one energy packet at every ten decision timing interval.

In addition, each power plant determines a target consumer concerning the power demand of the consumer and its distance. For this determination, the evaluation function Eij for each power plant i and consumer j is adopted. Eij is defined as follows:

$$E_{ii} = r_{dist} \cdot D_{ii}^n + (1 - r_{dist}) \cdot P_i^n \tag{1}$$

In this equation, Dnij denotes the normalized distance of consumer j from power plant i. From the actual distance Dij, the normalization converts its average and standard deviation into 0 and 1, respectively. Similarly, Pnj denotes the normalized power demand of consumer j. rdist denotes the appreciation ratio of Dnij that takes 0 to 1.

At every decision timing, each power plant i calculates Eij of all consumers according to (1) and select the target consumer j that yields the smallest Eij.

#### 4.2 Simulation results

Fig. 8 shows the simulation result of the power network performance versus the appreciation ratio rdist . Left and right vertical axis represent the total transmission length and the satisfiability time, respectively. Horizontal axis represents the appreciation ratio rdist. Because the total transmission length is sensitive to small value of rdist , the horizontal axis is scaled logarithmic.

The total transmission length is derived by integrating every energy packet transmission path length in the network. This value is proportional to the power dissipation by Joule loss along with the energy packet transmissions. Whereas, the satisfiability time means the elapsed time in simulation steps from the beginning of the simulation when the power demand of a consumer becomes zero.



Fig. 8. power network performance versus the appreciation ratio  $r_{dist}$ .

As the figure shows, the total transmission length roughly decrease as rdist increases. This is because at large rdist, power plants tend to determine their target consumer with smaller distance. On the other hand, at large rdist, satisfiability times of four consumers become sparse. Especially when rdist equals the maximum value 1, consumer 6 firstly satisfies its power demand at 60 simulation steps. This is mainly because the consumer 6 is located closest to the power plant 5. As shown by the figure, the maximum satisfiability time always equal 350 regardless of rdist. This is because at this time, the surplus powers of power plants are exhausted and coincidently the power demands of consumers become zero according to the assumption mentioned before.



Fig. 9. Surplus power and power demand alternations versus elapsed time when  $r_{dist}$  equals 0.1.

The satisfiability times mean that the power demands of consumers are finally satisfied with the proposed protocol. This simulation result confirms the first aspect of the power network operation described in the previous subsection. However, the optimal value of rdist, that is mentioned in the second aspect, is not found apparently. Therefore, in the following simulation results, 0.1 is adopted as a moderate value of rdist instead. This value is indicated by a dashed line in Fig. 8.



Fig. 10. Breakdown of power supply from each power plant to consumers versus elapsed time of simulation.

Fig. 9 shows the simulation results of the surplus power and power demand alternations versus elapsed time when rdist equals 0.1. Left and right vertical axis represent the power demand of consumers and the surplus power of power plants, respectively. Horizontal axis represents the elapsed time from the beginning of the simulation. The alternation of power demands and surplus powers are indicated by solid lines and dashed lines, respectively.

As the dashed lines show, each surplus power of power plant decreases monotonically. Because a power demand always exist in the network until the simulation finishes, each surplus power decreases 1[W] a step. On the other hand, each power demand sometimes stay constant for a while. During this while, none of the power plants transmit their power to the consumer. Otherwhiles, the consumer receives a power and its power demand gradually approaches zero.

The breakdown of power supply from each power plant to consumers is shown in Fig. 10. Vertical axis represents the power supply and horizontal axis represents the elapsed time of the simulation. Each numbered area indicates the breakdown of power supply to the consumer with the corresponding number. Whereas, the power source is indicated by display colors. A white area and a gray area indicate power plant 5 and 1, respectively. Depending on their initial surplus power, power supply from plant 1 and 5 finish at 200[step] and 350[step], respectively.

power fro	m plant 5	power fro	m plant 1
consumer power[W]		consumer power	
3	35	2	28
4	96	3	103

#### Fig. 11. Breakdown of power supply from each power plant at elapsed time 130[step].

As the figure shows, the power network operation of multipoint-to-multipoint transmission is confirmed from this simulation result. For example, when the elapsed time is 130[step] as indicated by the vertical dashed line, power plant 5 transmits energy packets to consumers 3 and 4, simultaneously. Especially, 96[W] of power is transmitted to consumer 4 as shown in the figure. At the same time, consumer 3 also receives energy packets from power plant 1. The breakdown of the whole transmitted power at 130[step] is shown in Fig. 11.

#### 5. CONCLUSION

Power distribution protocol among power plants and consumers in electric energy packet networks is proposed. The proposed power distribution protocol consists of two processes: The process of information accumulation and EFT (extended forwarding table) construction and update at each node, and the process of energy packet transmissions among power plants and consumers.

These processes are simulated on an elemental system model with assumptions for the network operation. From the simulation results, these points are confirmed. First, the power demands of consumers are finally satisfied with the energy packet transmission procedure that is triggered by themselves. Second, the power network performance is affected by appreciation ratio rdist that is an essential factor in the determination of each power plant on its target consumer. Third, the multipoint-to-multipoint transmissions of energy packets surely appear during the power network operation.

In further studies, these points should be investigated. First, though omitted in this paper, the power transmission path congestion should be counted in the metric in each entry of EFT. This subject is essential especially in the pulsed power network [9] for there is a hard limit of packet number in each power link. Second, though only power demand and distance of consumers are counted in this paper at the determination of power plants on their target consumers, other various factors should be considered including the preferable type of the power plant, upper limit of electricity charge, or so. For the purpose to consider these personal demands of consumers, more actual and complicated power system design is necessary. Third, though the optimal value of appreciation ratio rdist is not found apparently, the optimization of power distribution network should be investigated depending on the coordination of the ratio rdist and the metric evaluation mentioned above.

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#### Method of Evaluating Dialogue Robots for Visually Impaired and Elderly People

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(Received September 30, 2017)

#### **Synopsis**

To support the daily living of visually impaired people, we have been conducting research on pedestrian navigation, mainly audio guidance by a "Verbal map." In collaboration with "Verbal map," we plan a dialogue robot that can guide a person in a plaza space. As the first step, this study establishes an evaluation experiment to quantify the degree of pleasant feeling a person has when talking with a robot.

This paper first presents the research background and objectives. Chapter 2 describes the evaluation experiment method. In chapter 3, using results of the experiment conducted, we specifically examine a function evaluation questionnaire and measurements of the psychological load. Finally, this report provides a summary of the research.

**KEYWORDS**: Dialogue experiment, AI, Function evaluation, Psychological load, Movement support, Barrier free

#### 1. Research Background and Objectives

There is a continuing movement in support of daily life for visually impaired people (e.g., traveling to work, going to hospital, shopping, eating out) under poor circumstances. With the spread of smartphones, sighted people can better enjoy a town walk in unknown places because of pedestrian navigation. However, visually impaired people remain reliant on Braille blocks and their own memory. When going to unknown places, visually impaired people must be guided by a sighted person. This current state presents important obstacles to visually impaired people's active movement. Therefore, we have conducted research on pedestrian navigation, mainly an audio guidance "Verbal map" as movement support for the daily living of visually impaired people. Takahashi et al.<sup>10</sup> describe effects of the verbal map audio AR application. Although it functions well in a linear space such as a road, the route guidance directions are difficulty in a plaza space. Therefore, using verbal map, we plan a dialogue robot that provides guidance in a plaza space within a public facility.

The population of visually impaired people is small. It is not practical to cover the costs of setting up the dialogue robot for visually impaired people alone. Therefore, it is also necessary to target sighted persons using it. Currently, elderly people do not go out frequently. As a result, their body condition is adversely affected. Furthermore, venturing out of home imposes a mental load. Elderly who are shut-ins are becoming an important social problem. Other benefits of going out might include maintenance of independent living and reduction in hospital visits and nursing burdens. For this reason, elderly people are added as targeted users of dialogue robots.

We expect that visually impaired people and elderly people can feel pleasant when meeting and talking to

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dialogue robots and that they will increasingly engage in dialogues with robots themselves. We also expect to enhance the motivation of visually impaired people and elderly people using the dialogue robot.

This study was conducted to develop the dialogue robot dialogue functions. The artificial intelligence (AI) function can enhance motivation to go out when added to a commercially available dialogue robot as an application. This study was conducted to establish an evaluation experiment method to clarify whether the function engenders enhanced motivation to go out. We use a dialogue robot "RoBoHoN" (Sharp Corp.), which can express feelings by changing the tone. The study contents are the following three.

- 1) Referring to a dialogue system that incorporates user preferences<sup>2</sup>), we create a dialogue scenario with tone set in predetermined conversation contents. Then we perform an evaluation experiment.
- 2) In the experiment, we attempted to evaluate whether the tone of RoBoHoN is perceived by the subject correctly and to evaluate how the subject's feeling of use and satisfaction change through dialogue task. The instrument consists of both a function evaluation questionnaire and psychological tests.
- 3) We examine the validity of the experimental protocol and psychological tests, as a whole.

# 2. Evaluation experiment method(1) Outline flow of an evaluation experiment

An outline flow of an evaluation experiment is presented in Figure 1. The evaluation instrument consists of a function evaluation questionnaire (Table 1) and a psychological test.

First, a psychological test (1) is conducted immediately after the start of the experiment. Then we start a dialogue task with RoBoHoN. Every time a dialogue task is completed, a function evaluation questionnaire is administered. This process is repeated J times. Psychological test T was administered at the midpoint of repeat (J/2). After all dialogue tasks are completed, the principal researcher conducts hearing research. Subsequently, a psychological test (2) is applied. Finally, after administrative procedures are completed, a psychological test (3) is administered. The experiment is finished.

In the dialogue task, RoBoHoN talks based on predefined dialogue scenario with the subject. Details of the dialogue scenario are presented in 2. (2).

The function evaluation questionnaire assesses whether the tone of RoBoHoN is perceived by the subject with the correct feeling. Details are presented in 2. (3).

The psychological test measures the psychological load of the subject. The instrument is STAI<sup>3</sup>. We would also like to measure the psychological load for every dialogue task iteration like the function evaluation questionnaire. However, many more questions exist than those of the function evaluation questionnaire. When questions continue, it is possible that stress is imposed on the subject by fatigue. Therefore, the psychological load during the dialogue task is measured only at the midpoint of the task (psychological test T). In psychological test (1), we measure STAI-Y1 and Y2. In psychological test (3), we measure STAI-Y1. Details are presented in 2. (4).

In the function evaluation questionnaire and psychological test, it is natural that the subject should silently read and answer the questions. However, in this experiment, the subjects are visually impaired people. Therefore, the experimenter reads the question and asks the subject to answer.



Figure 1 Flow of the evaluation experiment

#### (2) Dialogue Scenario

Kobayashi et al.<sup>2</sup> report that user satisfaction of the dialogue system improves by considering the user's preferences and human relations.

Jimenez et al.<sup>4</sup>, points out a problem by which a person's interest in the robot decreases over time. For example, this study has reported that one factor of a person's interest in the robot decreases when the robot performs the same action. To stop that, a method exists to express feelings as if robot has feelings. Furthermore, some reports describe that a robot with an emotional expression model can perform interaction with people effectively and reports describe that it tends to give much familiarity. Therefore, a dialogue scenario is created by combining a predefined dialogue theme considering a user's preferences and human relations and tone expressing feeling. Dialogue lengths of two types are created: short dialogue (about five utterances) and long dialogue (about eight utterances). The utterance interval is set to 5 s, which the subject is regarded as able to respond to asking from RoBoHoN. We set a tone that does not match the content of the conversation. We create a scenario that gives a sense of incompatibility because we confirm whether the tone of RoBoHoN is perceived by the subject correctly, or not, and evaluate whether the tone influences the subject's satisfaction.

RoBoHoN is set as a boy of about five years old. Therefore, the set is based on words and casual phrases such as those used by children.

#### 1) Dialogue theme

When the subject talks with RoBoHoN, prepare the following dialogue themes.

- Weather
   Birthplace
   Favorite food
- Breakfast Hobby Family
- Trip News Year-end and New Year holidays
  - -15-

#### 2) Tone

RoBoHoN used for this study is a dialogue robot equipped with a function to express feelings by "tone" and "motion." Subjects in this experiment are visually impaired people. Therefore, feelings are expressed only by the tone function. Tone is created by combining a type of feeling and level of feeling. Types of feelings of four kinds are used: Standard, Happiness, Sadness, and Anger. The level of feeling can be set in four stages. A large number represents a high feeling level. To clarify the difference in tone, the level of feeling is set at the highest feeling level (level 4).

#### (3) Function evaluation questionnaire

The function evaluation questionnaire is shown in Table 1. It consists of 10 items. Questionnaire item 1 is intended to check whether the tone of RoBoHoN is perceived as the correct feeling (Q 1). And, 9 items exist to investigate feeling of use and satisfaction of the subject (Q 2–10). In addition, answers to questions 2–10 are evaluated on four levels: 1, Dissatisfied; 2, Slightly dissatisfied; 3, Slightly satisfied; 4, Satisfied.

Questionnaire items used to investigate the feeling of use and satisfaction of the subject from evaluating the user satisfaction of the dialogue system by Kobayashi et al.<sup>2)</sup> and Sugo et al.<sup>5)</sup> were used on the questionnaire. Specifically, the items include "Do you want to use it again?," "Could you hear the talk ?," "It was easy to talk?"

Furthermore, in the dialogue scenario used in this experiment, tones are combined with a predetermined dialogue theme that incorporates the user preferences and human relations. Therefore, we added an item to evaluate how a subject feels if a change exists in tone. Specifically, "Were you able to talk without getting tired?"

	Table 1 Question of function evaluation questionnaire				
No.	Evaluation questionnaire item				
1	Which did you feel about the RoBoHoN's feeling? Happiness, Sadness, Anger, Standard, Do not know				
2	Do you want to use it again?				
3	Could you hear the talk?				
4	Is it easy to talk?				
5	Is the flow of talk natural?				
6	Did you feel that you were interested?				
7	Was the feeling suggested?				
8	Did you feel friendly?				
9	Were you able to talk without getting tired?				
10	Are you satisfied as a companion?				

 Table 1
 Question of function evaluation questionnaire

#### (4) Measurement of psychological load – Use of STAI

We measured using psychological test STAI<sup>3</sup> to ascertain how the psychological load of the subject changes by talking with RoBoHoN. STAI comprises scales of two types: STAI-Y1 for measuring State-anxiety and STAI-Y2 for measuring Trait-anxiety. Each question has 20 items, giving an indication in four stages. Each question is rated on a four point scale, with higher scores indicating greater anxiety.

STAI-Y1 that measures State-anxiety evaluates "how do you feel right now?" State-anxiety is a transient situation reaction to an event that arouses anxiety. State-anxiety changes at that time. In situations of perceived threat, State-anxiety is high. In situations where there is no danger at all or little danger, State-anxiety is low. In addition, some reports of the relevant literature describe that it is useful to investigate how a person was feeling at a very recent time, and evaluates how a person expects to feel in certain scenes that might be confronted in the future or in various virtual scenes.

STAI-Y2 that measures Trait-anxiety evaluates "how do you feel in general?" Trait-anxiety perceives various threatening situations in the same way. It shows a tendency to respond in the same way to such a situation. It has stable characteristics. It shows stable individual differences in anxiety tendencies.

Actually, STAI-Y1 was created to respond sensitively to implementation conditions. Therefore, we started with STAI-Y1 when STAI-Y1 and STAI-Y2 are executed simultaneously.

In this study, STAI-Y2 score is made using a psychological test (2) that can be expected to be close to the normal value is set as the reference value. We decided to measure the movement of psychology from the

transition of the score deviation of STAI conducted at the beginning of the experiment (psychological test (1)), at the midpoint of the experiment (psychological test T, psychological test (2)), and at the end of the experiment (psychological test (3)).

STAI is commercially available for psychological tests and applications in psychosomatic medicine. Previous reports show that it is applicable to evaluate psychological stress as in this experiment. However, because the adequacy of repeated measurements is unknown, it is the subject of this study.

## 3. Evaluation experiment result (1) Experiment outline

The experiment protocol is depicted in Figure 2. First, we conducted psychological test STAI-Y1(1) and Y2(1). Furthermore, the subject took a practice dialogue to become accustomed to RoBoHoN for approximately 10 min. Subsequently we set dialogue task and function evaluation questionnaire as 1 cycle. Then tasks 1-3 were conducted. After task 3 at the midpoint of the task, STAI-Y1-T was conducted. Tasks 4-6 were conducted again. After the tasks had been completed, the principal researcher conducted the hearing research for approximately 20 min. Then STAI-Y1(2) and Y2(2) were conducted. Finally, after administrative procedures were completed, STAI-Y1(3) was conducted and the experiment was finished. The total time necessary for the experiment was about 80 min.



Figure 2 Experimental protocol

In a dialogue scenario, there are six scenarios combining the dialogue theme (four items: Weather, Birthplace, Food, Year-end, and New Year holidays) and the tone (four items: Standard, Happiness, Sadness, Anger). Weather and birthplace were setting types of two tones to ascertain whether the tone of RoBoHoN is perceived as correct feeling. Patterns of dialogue scenario and task order are presented in Table 2. An example of a dialogue task is presented in Table 3.

The contents of dialogue practice show that the subject becomes accustomed to RoBoHoN as follows.

- Subject name and face photo registration (Let RoBoHoN recognize face of the subject.).
- Instruct to sing a song.
- Instruct to dance.
- Search for weather information (today, tomorrow, by region).
- Search for news.
- Search for event information.
- Search for movie information.

Subjects were 10 people (visually impaired people). Attributes of the subjects are presented in Table 4. The experiment period is January 12–24, 2017. The experiment conditions are shown in Figure 3.

	Table 2 Fattern of dialogue scenario and task ofder						
		Tone					
		Standard Happiness Sadness		Anger			
Dialogue theme	Weather	1	4				
	Birthplace			5	3		
	Food			2			
	Year-end and New Year holidays		6				

Table 2Pattern of dialogue scenario and task order

X Subjects A and B did not experiment on tasks 2 and 6.

Table 3 Example of a dialogue task

	Task, 1; Subject, A					
Speaker	Utterance content					
RoBoHoN	What is today's weather?					
Subject	Sunny.					
RoBoHoN	That's good! Which do you like better, sunny or rainy?					
Subject	Snow.					
RoBoHoN	Me too! Which do you like better, cold or hot?					
Subject	Cold.					
RoBoHoN	That's good! Are you going out recently?					
Subject	I am out.					
RoBoHoN	It's cold outside, so please go out with a warm.					
Subject	Sure.					

Subject	Sex	Age	Degree of disability	Date
А	male	40	Blindness	January 12
В	male	39	Blindness	January 12
С	female	64	Blindness	January 13
D	male	50	Low vision	January 17
Е	female	39	Blindness	January 17
F	male	23	Blindness	January 17
G	male	70	Low vision	January 20
Н	female	70	Blindness	January 20
Ι	male	53	Low vision	January 24
J	female	52	Low vision	January 24

 Table 4
 Attributes of the subject (Visually impaired people; 10-people)



Figure 3 Situation of experiment

## (2) Validity of function evaluation method1) Function evaluation questionnaire result

Average mark of functional evaluation questionnaire (Average of answer values to questions 2–10: maximum 4 points, minimum 1 point) is presented in Figure 4.

As a result, we grouped 10 people into the following four types.

Satisfied – constant : G

Satisfied – fluctuate: C, D, E, H

Dissatisfied - constant : A, I

Dissatisfied - fluctuate: B, F, J

Judging from the hearing research after the experiment, when the score of function evaluation questionnaire was bad, the influence of scenario and the influence of feeling were apparent.

Influences of the scenario were the following.

- When response of the subject was not in time for RoBoHoN utterance, and when RoBoHoN utterance progressed unilaterally.
- When conversation contents between the subject and RoBoHoN do not match.
- After response of the subject, when "the interval" was long until RoBoHoN utterance.

Influences of feelings were the following.

- When RoBoHoN felt sad.
- When the tone of RoBoHoN and conversation content do not match.

#### 2) STAI result

Change in the score deviation of STAI is shown in Figure 5. Results show that we can divide groups according to the degree of anxiety decrease types. First, we can divide and group them into two types, "Degree of anxiety gradually decreases." and "During the experiment, the degree of anxiety increases."

The latter is even more, we can divide and group them into two types, "The degree of anxiety increases by dialogue with RoBoHoN (Y1-T\*)," "The degree of anxiety increases by dialogue with the principal researcher (Y1(2)\*)." Additionally, we can divide even groups in two types: with the degree of anxiety higher than usual, and the degree of anxiety lower than usual (Figure 6).



Figure 4 Average mark of a functional evaluation questionnaire



Figure 5 Change in the score deviation of STAI





#### 3) Consistency of function evaluation questionnaire result and STAI result

Results obtained from the function evaluation questionnaire and STAI are compared and presented in Table 5. A and F belonging to "The degree of anxiety increases by dialogue with RoBoHoN" belong to "dissatisfied" in the function evaluation questionnaire. Therefore, probably the functional evaluation questionnaire and the psychological test result are mutually consistent.

Additionally, among the members assigned to "The degree of anxiety increases by a dialogue with the principal resercher," C, D, and E were "satisfied," B and J were "dissatisfied." In other words, probably C, D, and E were satisfied both functionally and psychologically. However, B and J were dissatisfied for this dialogue function, but dialogue with RoBoHoN was more psychologically satisfactory than dialogues with the principal researcher. We received one comment from a respondent that "I would like to use it if the dialogue function develops further." The subject expected that, in the future, we would think that the degree of anxiety in the dialogue with RoBoHoN was low.

		Function evaluation questionnaire group				
			Satis	sfied	Dissatisfied	
			Constant	Fluctuate	Constant	Fluctuate
STAI group	The degree of anxiety	Anxiety-high	G		Ι	
	gradually decreases	Anxiety-low		Н		
	The degree of anxiety increases through dialogue with RoBoHoN	Anxiety-low			А	F
	The degree of anxiety increases	Anxiety-high		С, Е		
	the principal researcher	Anxiety-low		D		B, J

 Table 5
 Function evaluation questionnaire result and the score deviation of STAI result

\* The sign of the cell is the subject label

#### (3) Effect of tone

When the dialogue robot is doing route guidance or chat, we conducted hearing research to ascertain whether it was a better to have a feeling function. Results of hearing research are presented in Table 6. Regarding route guidance, 7 out of 10 people, and as for chat, 9 out of 10 people, it was better for the dialogue robot to have a feeling function.

Table 7 presents questionnaire responses distribution of whether tone of RoBoHoN is perceived correctly by the subject (Question of function evaluation questionnaire: no. 1). Excluding the answer of "standard" "?," Many people answered as correct feeling in all scenarios. As a result, we were able to check that the tone of the RoBoHoN was perceived as correct feeling. In addition, scenarios in which the subject felt "sadness," an evaluation tended to decrease.

Subject	Route guidance	Chat
А	×	0
В	0	0
С	0	0
D	0	0
Е	0	0
F	×	×
G	×	0
Н	0	0
Ι	0	0
J	0	0

 Table 6
 Possibility of the robot to have feeling function

 $\circ$ , It is better to have feeling.  $\times$ , It is better not to have feeling.

Table 7Distribution of the answer of feeling communication(Question of a function evaluation questionnaire: no.1)

					Answer			
_			Standard	Happiness	Anger	Sadness	?	Total
	Weather	Standard	6	4	0	0	0	10
Dialogue theme	Weather	Happiness	1	6	0	0	3	10
	Year-end and New Year holidays	Happiness	5	2	0	0	1	8
	Birthplace	Anger	3	1	3	0	3	10
	Birthplace	Sadness	3	1	0	4	2	10
	Food	Sadness	2	0	0	4	2	8

#### 4. Conclusion

In this study, we established an evaluation experiment method to clarify psychological effects of visually impaired people and elderly people talking to the dialogue robot. We were able to obtain the following knowledge. An evaluation experiment method using a function evaluation questionnaire and a psychological test did not elicit contradictory results. We ascertained the characteristics of each group. Therefore, this method is probably effective.

Additionally, we confirmed that the protocol used for this experiment is useful because there was no major difficulty in the timing and repeated measurement of STAI used in psychological test. We were able to measure the psychological load of the subject.

During dialogue, it will be desired that the robot expresses emotions. We confirmed that the tone was perceived as correct feeling. From this perspective, we expect that setting up the dialogue robot with a feeling

function in a public facility so that people can enjoy route guidance and chat, it can engender enhanced motivation for visually impaired people and elderly people to venture from their homes.

Future challenges are explained below. When we administered a function evaluation questionnaire and psychological test, some subjects showed ambiguous reactions and took time to answer. As reasons for such reactions and low evaluation results, we inferred the following.

- From the beginning, because the expectation of the dialogue function with the robot was great, the subject felt disappointed because the response of robot was worse than the subject had assumed.
- "The interval" of dialogue was early or late and did not match the pace of the conversation.
- Conversation contents did not match.

To address these problems, first, it is necessary to consider "the interval" in dialogue. Then, it is necessary to create and classify dialogue scenarios so that dialogue according to the type of user can be conducted. In addition, contents of this conversation were only chat. Therefore, it is necessary to clarify how an evaluation changes depending on the expressions of feeling in route guidance.

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#### Understanding the nature of walking and cycling for transport in Japan

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(Received September 30, 2017)

#### **Synopsis**

The following document is a summary of the existing academic articles available in English. The literature review was conducted for the purpose of gaining an understanding of cycling and walking behaviors in Japan. This was background research in order to acquire theoretical knowledge for the further study, which aimed to establish whether people in Japan (where cyclists regularly mix with pedestrians on sidewalks) show different attitudes and perceptions of comfort while travelling on segregated or unsegregated shared-use paths and to identify whether it is dependable purely on technical aspects of path design (i.e. physical characteristics) or/and whether the travel behavior generated by traffic law has impacts on it.

KEYWORDS: Cycling, Walking, Active Travel, Japan, Traffic Law, Shared-use, Comfort, Level of Service

#### **1. Introduction**

This literature review provides a deeper understanding of cycling and walking behavior in Japan, with the focus on the following themes: statistical data on cycling an walking for transport, transport policy, traffic law, traffic education, factors that may be affecting levels of walking, promoting cycling, challenges of cycling and shared-space, safety, design guidelines, shared-use paths, level of service and perceptions of comfort.

#### 2. Literature Review

#### 2.1 Cycling and Walking in Japan

Cycling and walking are popular modes of transport in Japan. Figure 1 shows the share of representative transport mode by trip distance according to 2015 Nationwide Person Trip Survey. Walking and cycling constitute as the majority modes for trips up to 3km, and cycling makes up a significant proportion of trips up to 10km.



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Figure 2 and 3 show in more detail the breakdown of representative transport modes for commute trips to work and school. Figure 2 shows that in the most recent years (since 1990s) levels of cycling remain stable, while walking is gradually declining. Figure 3 shows more detailed data for Japan's main cities. Osaka city stands out for particularly high levels of cycling.



Source: Census(Ministry of Internal Affairs and Communications Statistics Bureau) \*Including motorcycle Figure 2. Mode Share for Commuting To Work/School: Trends since 1970s.



Bicycle Rail+Bicycle

Source: Census 2010(Ministry of Internal Affairs and Communications Statistics Bureau) Figure 3. Mode Share of cycling for Commuting to Work/School by City. Figures 4, 5, 6, 7 and 8 show the mode share by distance for trips for different purpose, including: 'commuting', 'personal errands', 'going to school', 'business' and 'going home'. Interestingly, for each of these purposes cycling and walking make up a large proportion of the trips for short distances. Going to school (Figure 6) shows particular reliance on walking and cycling for the widest variety of distances.



Source: 2015 Nationwide Person Trip Survey

Figure 4. Mode Share by Distance for Commute (MLIT)



Figure 5. Mode Share by Distance for Personal Errands.





Figure 7. Mode Share by Distance for Business.





Furthermore, cycling in Japan is more popular among women than men. The only group where opposite is observed is men aged 5-14 (11% male cyclists to 8% female cyclists). Similar applies to walking, with particularly high proportion for women in all age groups.





Figure 9. Modal share among men by age group.





Figure 10. Modal share among women by age group.

Interestingly, 'the Japanese transportation system is the high number of multimodal bicyclepublic transit trips, particularly in large urban centers' (Andrade et al., 2011). A similar pattern is observed for walking: Mitsui et al. (2009) state the relationship between higher levels of pedestrian activities in urban areas and the existence of well-organized public transportation systems. Other factors include the inconvenience of owning a private car in large cities due to parking shortages and high cost of car maintenance (Mitsui et al., 2009).

It is important to emphasize, that the high levels of cycling and walking are achieved simultaneously with provision of 'highly efficient' and accessible public transport network (rail and subway in particular) (Andrade et al., 2011). In fact, it can be speculated that active travel modes and public transport in Japan complement each other. However, there is also a direct association with longer distances to public transport stations (Andrade and Kagaya, 2012).

Andrade and Kagaya (2012) identified the socio-demographic characteristics associated with the choice to cycle. It was found out that in Japan people living in single-person households are more likely to choose non-motorized modes of travel. Moreover, people who cycle for other purposes and those who exercise on a regular basis are more likely to commute by bicycle. Simultanously, there is no link with car ownership and the decision to cycle (Andrade and Kagaya, 2012). However, it is important to emphasize that this applies to Sapporo and differences are prominent between major cities, smaller urban areas and rural areas.

People choose to rely on bicycles for multiple reasons (Figure 11), including the most often quoted: efficiency (shorter travel time), exercise, financial savings and practicality (ability to stop by on the way).


Source: Web survey carried out by National Institute for Land and Infrastructure Management in Jan 2012.

Figure 11. Reasons for using a bicycle (MLIT).

#### 2.2 Transport Policy in Japan

In the past, transport policy in Japan focused primarily on road development (MLIT, 2015). In more recent years, the main challenges policy-makers have been facing include 'the prevention of global warming, preservation of natural resources and energy, social and economic impacts of a dwindling birth rate, changes in population demographics (aging and shrinking population), development of a safe and comfortable transportation system, streamlining and globalization of physical distribution, expanding inter-regional gap between outlying regions and urban centers and funding issues concerning road maintenance and improvements' (Japan Research Center for Transport Policy, 2015). Hence, there has been a significant shift towards more environmentally-friendly approach (Kanemoto, 2002).

The Ministry of Land, Infrastructure and Transport (MLIT) is the key government department at the national level in Japan responsible for transport (Enoch and Nakamura, 2008). Some of the key policies include (International Transport Forum Summit, 2012) :

- Compact city development using public transport
- Construction of high-speed railways
- Ensuring transportation to/from remote island
- Expanding ITS (Intelligent Transport System)
- Improvement of cycling environment
- Improving railway stations as transport hubs
- Developing railway-station-based community rental cycle system in urban area
- Expanding smart interchange
- Developing highway bus and rail ride in Tokyo
- Improving bus punctuality
- Publication of low carbon city development guidance
- Road development and improvement of access roads to airports and harbours

In general, transport problems tend to be approach holistically, making transport policies the key driver for change. The primary focus is 'on law enforcement and education options, rather than on auto-based engineered solutions like air bags' (Hayakawa et al., 1999).

Even though cycling is very popular in Japan, there are only a 'few Japanese transportation policies and strategies address cycling'(Andrade and Kagaya, 2012). There is no transport walking policy. The policy which significantly affects the pedestrians is the 'barrier-free policy', which is one of the general principles of universal design policy (MLIT, 2005). It focuses on achieving barrier free conditions in order to make public transportation systems more accessible.

#### 2.3 Traffic Law in Japan

Traffic law in Japan is defined by the Road Traffic Act which was enacted in 1960. It is a document which aims at 'preventing dangers on the road, promoting the safety of other traffic and its smooth flow, and contributing to the prevention of obstacles due to road traffic' (Saito et al.). In the context, where shared use space (between all road users) is such a common occurrence, traffic law becomes the key to creating a safe street environment.

The pedestrians (which also includes wheelchair users) are expected to use sidewalks or pedestrian lanes when available. If they are not, they should use the right hand side of the road. Other rules include: never running out into the road, not skipping/running when walking on the road, crossing at junctions with traffic lights or pedestrian crossings, using pedestrian bridges or underpasses where available, following traffic lights and always check for safety, not cross where it is forbidden and never crossing the road diagonally or without checking. In bad weather and at night, pedestrians are advised to wear bright clothing to increase visibility. However, this is not regulated by law.

There are also additional rules for using railway crossings (which are common). Pedestrians are obliged: to always stop in front of the crossing and ensure it is safe to cross, be aware and careful at all times, not cross when the warning bell sounds or the barrier begins to descend and not play on or nearby the tracks. Moreover, children are required to cross under supervision (Gifu Prefectural Police Headquarters, 2007).

In terms of cycling, Japanese law is more complex. It regards bicycles as light vehicles (Road Traffic Act; Article 17 Clause 1)' (Suzuki and Nakamura, 2017) 'and cyclists have to use roads along with normal motor vehicles according to the Road Traffic Law' (Yamanaka and Namerikawa, 2007). However, while 'cyclists are required to ride on vehicle roads, but may also ride on sidewalks for safety reasons [JFS, 2008]' (Andrade et al., 2011).

A bicycle is allowed to run on a sidewalk as an exceptional rule for safety reasons, in order to protect cyclists from fatal traffic accidents (Andrade et al., 2011), (Suzuki et al., 2012): 'the Road Traffic Act allowed people to bicycle on sidewalks legally in December, 1978'. This law was introduced as a response to an increasing number of bicycle fatalities observed in the 1960s and an increasing trend of people cycling on sidewalks illegally for their own safety. 'At the peak around 1960, there were approximately 1,800 deaths every year for a period of more than 10 years. This was equivalent to a little less than 20% of all fatalities by traffic accidents at that time'. Initially, it was tested as an experimental solution in Yokohama and Kawasaki cities in June, 1970 and proved successful in reducing fatalities (Suzuki and Nakamura, 2017). However, it is essential to emphasize that when this law was first established, the intention was to introduce a network of bikeways, which is yet to happen, due to challenges such as space restrictions. (Suzuki and Nakamura, 2017).

Currently, the Road Traffic Act identifies three cycling facilities: roadways, bikeways, and sidewalks. First, "people must operate a vehicle on a roadway when it is separated from a sidewalk or a side strip (Road Traffic Act; Article 17)". Because a bicycle is a type of vehicle, people must bicycle on the roadway. Second, "when a bikeway is developed, people must ride a bicycle or a tricycle on it (Road Traffic Act; Article 63 Clause 3, there is an exception)". And third, "A person can bicycle on a sidewalk when it is permitted legally (Road Traffic Act; Article 63 Clause)" (Suzuki and Nakamura, 2017). The rules regarding that have been reviewed and updated in 2008: 'permitted legally' now stands for 'within and area with road signs or other signposts indicating permission to do so', 'if the rider is under 13 years old' and

'in unavoidable circumstances due to roadway of traffic conditions' (Japan International Training Cooperation)

Yet, in practice, most cyclists take on different ways depending on the traffic quantity (Tokuyasu et al., 2015) making cycling on sidewalks is a common practice. According to research conducted in Tokyo in 2003 'there are more people that believe they must bicycle on sidewalks as the general rule (45%) than people that know the rule (27%). Moreover, while pedestrians should be given priority, 'in reality people often honk to get pedestrians out of the way.' (Suzuki and Nakamura, 2017). Tokuyasu et al. confirmed the issue with following the law stating that in practice 'most of cyclists take on different ways depending on the traffic quantity' (Tokuyasu et al., 2015).

Furthermore, there is also a traffic law, which refers to how a bicycle can cross an intersection. Once again, this was introduced after identifying that 'the majority of bicycle traffic accidents occur at intersections between turning automobiles and bicycles from sidewalks' (Hirotaka and Koike, 2014). The cyclists are not obliged to follow pedestrian signs, but are free to cycle along the car traffic. Another innovative policy was designed to reduce bicycle theft: the 'bicycles must be registered with local authorities, with the licence fee included in the sale price' (Enoch and Nakamura, 2008).

Considering the challenges (see Section 2.7) Japanese government continues to review the existing law. In the last few years the road traffic law has been tightened up, including strengthening criminal punishments. These include:

Traffic Rules	Penalty
Riding a bicycle on a right side of the road	Imprisonment for up to three months or a fine of up to 50,000 yen
Riding on a sidewalk when circumstances are not 'exceptional'	Imprisonment for up to three months or a fine of up to 50,000 yen
Not yielding to pedestrians and/or cycling slowly on a sidewalk	A fine of up to 20,000 yen or pecuniary penalty
Cycling under influence of alcohol	Imprisonment of up to five years or a fine of up to one million yen
Riding double on a bicycle (except with a child under 6 years old)	A fine of up to 20,000 yen or pecuniary penalty
Cycling side by side	A fine of up to 20,000 yen or pecuniary penalty
Cycling without lights (headlights and rear lights or reflectors) during evening hours	A fine of up to 50,000 yen
Not obeying traffic lights	Imprisonment for up to three months or a fine of up to 50,000 yen
Not stopping and checking for safety at an intersection	Imprisonment for up to three months or a fine of up to 50,000 yen

Table 1. Traffic Rules and Penalties.

Other safety measures include children under 13 to be instructed by their guardians to wear helmets, cyclists should not use their mobile phones or umbrellas while cycling. (https://www.jitco.or.jp/download/data/leaflet\_English.pdf)

Figure 12 identifies all signs for cyclists and pedestrians:



Figure 12. Signs for Pedestrians and Cyclists (National Police Agency).

#### **2.4 Traffic Education**

In Japan, the primary safety concern is fatalities and injuries suffered by children and young people (aged 24 or less). Therefore, traffic safety education and awareness activities play a crucial role in delivering a safer transport network.

The implementation system is based on the concept of 3Es of traffic safety: 'Engineering (in the form of traffic management and traffic engineering techniques), Enforcement (of the law) and Education, focusing on people, who constitute one of the causal factors in traffic accidents' (Nishiuchi, 2014).

E of Traffic Safety	Measures
Engineering	The installation of traffic safety facilities (these consist of facilities put in place by public safety commissions (the police), including traffic lights, regulatory signs, road markings, and traffic control centers; and facilities put in place by road managers, such as footbridges, sidewalks, warning signs, carriageway markings, guard rails, street lights, delineators, and traffic safety mirrors)
Enforcement	Enforcement of the law (traffic control and enforcement), education (through promoting and maintaining appropriate behaviour and attitudes to traffic)
Education	Traffic safety classes at elementary, junior high, and high schools and traffic safety events (organized by prefectural governments, municipalities, and prefectural police forces). Educating professionals involved in promoting traffic safety education activities; producing teaching materials (manuals compiled by the national government, prefectural government, or municipality)

Table 2. E of Safety and Measures (Nishiuchi, 2014).

#### 2.5 Factors Affecting Levels of Walking

Referring to Muraleetharan and Hagiwara (2002) factors that affect the walking behaviours of pedestrians include the distance to their destination, the personal attributes of the pedestrian, the trip purpose, familiarity with the route, the presence of recreational points of interest, and environmental conditions (Muraleetharan and Hagiwara, 2002). Interestingly, in Japan, there is no significant association between perception of crime safety and walking. The reason for that could be potentially small variations in perceptions of safety among the Japanese: Japan is generally regarded as safe (Inoue et al., 2010).

Further study investigating the associations between perceived neighbourhood environment and walking among adults was conducted. 'Among Japanese adults, living in walkable communities, as defined by high residential density, good land use mix, and good street connectivity, is an important factor in walking for transport'. On the other hand, walking facilities (eg, sidewalks), aesthetics, and traffic safety are important factors in walking for leisure. For women, there is a significant association between walking to work and the environment. The reasons suggested are that potentially 'women are more likely to work within walking distance'. Similar was observed for walking for other purposes (daily errands), which can be explained by women's role in managing households (Inoue et al., 2010).

Moreover, in Japan, the levels of walking are significantly affected by the relatively high proportion of elderly adults. This age group tends to have different lifestyle (for example they no longer commute to work, have reduced childcare obligations) and a lower level of fitness compared to younger age groups. The research was conducted which looked into the factors correlated to transportation walking among the elderly. Two environmental attributes were identified: social environment and aesthetics. 'In addition, bicycle lanes, access to exercise facilities, and household motor vehicles were significantly associated with transportation

walking... Among men, significant correlates of this type of walking were bicycle lanes, crime safety, traffic safety, aesthetics, and household motor vehicles. Among women, access to shops, access to exercise facilities, and social environment were related to this type of walking.'. Interestingly, the neighbourhood environmental characteristics that were proven the be associated with levels of transportation walking previously (residential density, access to public transport) did not show any association for elderly adults. 'These results indicate that transportation walking among elderly adults might have similar characteristics to recreational walking.' (Inoue et al., 2011).

#### 2.6 Promoting Cycling in Japan

In the recent years Japan has been experiencing a rapid increase of bicycle users. This primarily due to changing lifestyles: people are becoming more environmentally and/or health conscious. Bicycle is no longer seen just a supporting transportation tool (Suzuki et al., 2012). It has also been affected by the Great East Japan Earthquake in 2011: in terms of urban mobility, that was a turning point. The natural disaster and urgent need to rebuilt 'has provided the opportunity for a paradigm shift away from the conventional automobile-dependent society toward a new mobility society, a movement to switch from automobiles to public transportation and bicycles'. (Hirotaka and Koike, 2014).

Even though, levels of cycling in Japan are high, there are still ongoing efforts to promote it even further. These include:

- Establishing 98 'Bicycle Road Model Districs' by MLIT and NPA in 2007to 'promote the development of bicycle roads, bicycle lanes, and sidewalks shared by cyclists and pedestrians' (MLIT)
- Introducing cycle hire schemes. They have been increasing in popularity since 1990s, after the successful implementation in the cities of Toyama (Toyama Prefecture), Kitakyushu (Aichi Prefecture), Saitama (Saitama Prefecture) and Fujisawa (Kanagawa Prefecture). (Andrade et al., 2011). By October 2016, there have been 100 cities with public bicycle systems (Suzuki and Nakamura, 2017). The purpose of installing the public bicycles is the improvement of the transport network, connected with public transport stations (questionnaire survey by MLIT in 2016, shown in Figure 8.). However, the number of ports available still remains low compared to other countries (Suzuki and Nakamura, 2017).
- Public and private companies (such as Nagoya city office) 'have been encouraging its employees to commute by bicycle, by for example increasing bicycle commuting allowances [JSF, 2010]'. This practice is not common yet. (Andrade et al., 2011)
- Cities are adopting local plans to promote cycling further. For example, Utsunomiya City introduced the Basic Plan to Utilize Bicycles in 2003. The measures pursued include: the formation of a citywide bicycle route network, provision of bicycle parking facilities near railway stations and bus stops and short-term parking spots and introduction of community rental cycle system. In 2010 it introduced Utsunomiya Bicycle City Promotion Plan, which vowed to continue these measures and also support the promotion of environment, health, sports, and tourism through cycling (Hirotaka and Koike, 2014). However, in many cases Japanese 'urban transportation plans often treat bicycle and walking as a single mode, despite the numerous bicycle users [Hyodo et al., 2000]'. (Andrade et al., 2011)
- Introducing measures to promote safer cycling: for example an active campaign has been taking place to promote the use of helmets among senior cyclists. Tochigi Truck Association has donated 1000 bike helmets to be donated to the elderly free of charge( Hirotaka and Koike, 2014).
- Collaborations between cities and the Regional Offices of the Ministry of Land, Infrastructure, Transport and Tourism. This allows to introduce new, experimental solutions, for example blue arrow-shaped pavement markings to guide bicycles, introduced on the National Highway No.4 in Utsunomiya (Hirotaka and Koike, 2014).

- Monitoring: the majority of new measures introduced are monitored in order to measure their effectiveness. These include some of the measures listed above. The desired outcomes include increase in cycling and reduction in accidents.

Moreover, surveys have been conducted which suggest that cycling in Japan could be promoted further through 'implementing exclusive cycle routes, along with improving existing cycle lanes and increasing the number of free bicycle parking lots, would contribute to more cycle-friendly journeys' (Andrade and Kagaya, 2012).

#### 2.7 Challenges of Cycling and Shared-Space

The presence of high levels cycling and omni-present shared space result in a variety of issues. In the recent years the situation has been gradually getting worse to the point that 'violations of traffic rules and etiquette by users of bicycles and other familiar modes of transport' have been identified as a social problem. (Nishiuchi, IATSS). Some of the most prominent challenges include:

- Safety issues (Section 1.8)
- 'Illegal parking around stations and shopping malls: this contributes to increasing traffic congestion and the number of accidents in surrounding areas.
- High numbers of abandoned bicycles within urban areas. This is caused by the fact that in Japan, the costs of fixing a bicycle are high compared to purchasing a new one. (Andrade et al., 2011)

However, Japanese national and local governments appear to efficiently identify these issues and effectively respond to them through introduction of policies and regulations. (Andrade et al., 2011) (Hirotaka and Koike, 2014).

#### **2.8 Safety (Statistics and Perceptions)**

The accident statistics with cyclists and pedestrians involved remain very high. 'At present, the number of cyclists has been increasing all over the world, and the collision accidents which rested in cyclists has been recognized as one of social issues in Japan' (Tokuyasu et al., 2015). The causes of collisions include 'by the faults and/or the bad manner of a cyclist, such as ignoring a traffic light, operating a smartphone, and over speed etc.' (Tokuyasu et al., 2015).

While 'one possible reason for the differences in risk environments is the poor separation between cars and other traffic users in Japan. Approximately 75% of Japan is mountainous, making its population density extremely high. Because most roads in Japan go through heavily populated urban areas, isolating pedestrians and bicyclists from motor vehicles is very difficult' (Koshi, 1988).

Referring to Hayakawa et al., 'despite this increased exposure, Japanese accidents tend to be less lethal'. The potential reason is that, traffic congestion leads to lower speeds of vehicles (Hayakawa et al., 1999). In fact, despite high figures, Japan has been observing a steady decrease in road fatalities since 1990 (International Transport Forum, 2016). Table 3 shows the trend.

	1990	2000	2010	2013	2014	2014 % change from			
						2013	2010	2000	1990
Cyclists	1 509	1 278	938	813	738	-9.2	-21.3	-42.3	-51.1
Moped users	1 320	944	459	357	321	-10.1	-30.1	-66.0	-75.7
Motorcyclists	1 920	903	570	503	489	-2.8	-14.2	-45.8	-74.5
Passenger car occupants	3 887	2 903	1 201	1 086	1 053	-3.0	-12.3	-63.7	-72.9
Pedestrians	3 955	2 955	2 016	1 871	1 753	-6.3	-13.0	-40.7	-55.7
Others	2 005	1 427	644	535	484	-9.5	-24.8	-66.1	-75.9
Total	14 595	10 410	5 828	5 165	4 838	-6.3	-17.0	-53.5	-66.9

Table 3. Road Fatalities By Road User Group.

Despite, relatively high number of accidents, cycling is regarded as safe in Japan, primarily because cyclists 'ride on sidewalks rather than share roadways with motorized vehicles' (Andrade and Kagaya, 2012). This perception of safety 'plays an important role in the decision to cycle (by travelers in Sapporo)' (Andrade and Kagaya, 2012).

Yet, Suzuki and Nakamura (2017) argue that cycling on a sidewalk is unsafe, despite the common perception otherwise. In fact, the statistics report an increase in accidents between cyclists and pedestrians. Based on that they draw a conclusion that 'it seems that the Japanese situation, cycling on sidewalks is safer than the other countries where people bicycle on roadway, but as you can see the reverse is true. Because of them, we can say that bicycling on sidewalks is not always safe' (Suzuki and Nakamura, 2017). Figure 13 shows that while the total number of traffic accidents decreased by 30% between 2002 and 2012, the bicycle-pedestrian accidents have increased by 30%.



Source: NPA statistics



#### 2.9 Design Guidelines

Japan has published a number of design guidelines for pedestrian and cycling facilities.

For walking, the technical guideline to design a pedestrian space has been enacted in the law of Road Construction Ordinance, with the focus on pedestrian safety. It specifies the width of lane for pedestrians and/or cyclists with a requirement of over three meters. It is believed that this dimension will reduce the rate of collisions in pedestrian space (Tokuyasu et al., 2015).

In November 2012, the Road Bureau of the Ministry of Land, Infrastructure, Transport and Tourism and Traffic Bureau of the National Police Agency issued the 'Bicycle Usage Environment Creation Guidelines for Comfort and Safety'. The document adapted the core of Road Traffic Law that 'a bicycle is a vehicle, which in principle, travels on vehicle road': it therefore, focused on comfortable and safe provision of road space for cyclists, hence promoting segregation between cyclists and pedestrians. Figure 14 shows the proposed types of facilities, depending on the road conditions (Kobayashi et al.).

Another official document is "Guideline for developing bicycle parking facilities" published by MLIT, which puts a lot of emphasis on promotion and development of public bicycle systems. Cycle hire schemes are seen as a potential solution to illegal bicycle parking and a way to save parking lots and a measure of improving the transport network through promoting multi-modal trips (bicycle parking at the stations) (Suzuki and Nakamura, 2017).

	A: Roads where automobiles travel fast	B:Road other than A and C	C:Roads where automobiles travel slowly and the automobile traffic volume is low
Necessity for separation of bicycles and automobiles	Structural separation	Visual separation	Mixed
Type of Bicycle traveling space	Bicycle track	Bicycle lane	Mixed use on vehicle lane (As necessary, the road shoulder is colored, or belt-shaped road markings or pictograms are placed inside the vehicle lane on the left side.
Criteria	Automobile speed higher than 50 km/h For example, road with a speed limit of 60 km/h where speed restrictions are not enforced	Road that is not covered by conditions A and C For example, road where a speed limit of 50km/h is enforced, etc.	Automobile speed of 40 km/h or less, and traffic volume of 4,000 or less

Figure 14. Types of Facilities: Different Levels of Segregation and How to Choose a form of improvement according to traffic conditions.

#### 2.10 Shared-use Paths

Referring to the Japanese traffic law (Section 2.3) sharing space is allowed in certain circumstances. In reality, mixed-use is very common. Figure 15 shows the types of unsegregated and segregated facilities and a total length of provision in Japan.



Figure 15. Segregated and Unsegregated Paths: Types and Total Lengths (MLIT)

Zhe et al. has pointed out the disadvantages and advantages of shared-use paths in Japanese context. He points out how cycle/pedestrian shared use negatively affects safety of pedestrians and enforces the reduction of cyclists speed. However, on the other hand, he mentions the association between shared-use and high levels of cycling in Japan for variety of purposes and among women and elderly, emphasizing the advantage of safety and freedom for utility cyclists (Zhe et al., 2008). This fits into what some other researchers claim, stating that 'the possibility of sharing side- walk space with pedestrians appears to have a strong positive impact on cycling' (Andrade and Kagaya, 2012).

Yet, in the recent years, there has been a tendency to encourage segregation as a more viable option. Currently, most cities still lack extensive cycling networks (infrastructure). Cycling facilities are primarily parking and designated zones within road intersections (Andrade et al., 2011). Due to high levels of cycling, and consequently, safety concerns, 'in 2008, the Ministry of Land, Infrastructure, Transport and Tourism of Japan [MLIT] has launched a plan to establish an extensive bicycle lane network nationwide' (Andrade et al., 2011)

Interestingly, Misui (2012) pointed out that the plan to introduce a cycling network might become more achievable with time. He suggested that the social demand for improved cycling traffic space will continue. Meanwhile, the demand for automobile traffic is expected to decline due to population decline. 'Future maintenance of excess road capacity may produce excessive burden on the future generations and reallocation of the road space from automobile traffic space to bicycle traffic space is the pressing issue' (Misui, 2012).

#### 2.11 Level of Service

Highway Capacity Manual defines Level of Service as 'a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience' (Highway Capacity Manual, 2010). It identifies six levels, from A to F: A represents the best operating conditions and F the worst. HCM considers a diversity of transport modes, including walking and cycling, however it is applicable primarily to American roads which represent significantly different conditions than Japan or Europe.

Hence, considering the high levels of walking and cycling in Japan, multiple studies were conducted in attempt to define the level of service. Research has been conducted, which confirmed that 'in order to promote cycle use in urban areas, improvement level of service for cycling on streets is considered to be an integral part of (...) policy' (Yamanaka and Namerikawa, 2007). Tsukaguchi et al. have also emphasized the importance of level of service for promoting walking stating that 'regional environment, amount and level of service of urban amenities and attributes of the residents form main elements that contribute toward the attitudes toward walking and pedestrian behaviour in general' (Tsukaguchi et al., 2007).

Zhe et al. have completed a study which evaluated the level of service of shared use paths, focusing on users' safety and comfort with consideration for traffic volume on the path. By using a video survey of shared use streets, the authors analysed the relationship between cycling speed, frequency of hindrance and traffic density or traffic volume of street users. In conclusion, the author proposed the conditions necessary to apply shared use of bicycles and pedestrians on the sidewalks, considering the traffic flow of pedestrians and bicycles per width of sidewalks' (Zhe et al., 2008).

In Japan, level of service can play particularly important role in promoting active travel. While people would usually choose the shortest route to get to their destination, some cities in Japan (for example Sapporo) are designed on a grid. Considering that the distance no longer plays a significant role, it was proved that the probability that a route will be selected increases as the average overall LOS of that route increases. The research was conducted for walking. It was proven that the likelihood that a route will be selected decreases with increases in the length of the route. The results suggest that when pedestrians choose routes, they consider the overall LOS in combination with the lengths of sidewalks and crosswalks (Muraleetharan and Hagiwara, 2002).

#### 2.12 Perception of Comfort

The concept of comfort appears in multiple guidelines and studies conducted in Japan.

The study on improvement of comfort of road space looked closer at the perceptions of pedestrians, cyclists, other road users and roadside residents. It identified the importance of barrier-free pedestrian space, autonomous mobile support and improvement of comfort for living roads. It also suggested the diversification of needs among the road users leading to road space reconstruction. Interestingly, it emphasized that to create road environment that is people-centred the comfort is the key. This was followed by looking at specific situation in Japan: with aging population the perception of comfort and needs are changing.(NILIM, 2006).

For cycling, in 2012, the Ministry of Land, Infrastructure, Transport and Tourism (MLITT) and the National Police Agency published an official guideline for development of safe and comfortable cycle facilities. It was revised in 2016. This document covers 'the planning of bicycle traffic space, design of bicycle traffic space, enforcement of bicycle traffic rules, and comprehensive action to promote bicycle usage' (Hirotaka and Koike, 2014).

The document identifies three types of bicycle facilities: "bicycle path" (two-way bicycle tracks on the both sides of a road), "bicycle lane" (a one-way bicycle lane on the left side of a roadway), and "local discretionary lanes or pictographs" (a sign for clarifying cycling space on a roadway). This guideline also further emphasizes the need for segregation, by mentioning the planning process of a bicycle network (Suzuki and Nakamara, 2017).

The research into pedestrian comfort also evolves around segregation. Referring to Yamanaka and Namerikawa (2017) the key to increasing the comfort of pedestrians lies in improving the pedestrian and cycling facilities (for example sidewalks). The measures include 'separation of pedestrians and cyclists, removal of on- street bicycle parking and barriers on sidewalks' and 'making priority system appropriate in traffic rules for bicycles on urban streets and of junctions.' (Yamanaka and Namerikawa, 2007).

#### 3. Discussion

Cycling and walking are very popular modes of travel in Japan: they constitute as the majority modes for trips up to 3km, and cycling makes up a significant proportion of trips up to 6km. 'The Japanese transportation system is the high number of multimodal bicycle-public transit trips, particularly in large urban centers' (Andrade et al., 2011). A similar pattern is observed for walking.

Traffic law is defined by the Road Traffic Act. The pedestrians (which also includes wheelchair users) are expected to use sidewalks or pedestrian lanes when available. If they are not, they should use the right hand side of the road. A bicycle is allowed to run on a sidewalk as an exceptional rule for safety reasons, in order to protect cyclists from fatal traffic accidents (Andrade et al., 2011), (Suzuki et al., 2012): 'the Road Traffic Act allowed people to bicycle on sidewalks legally in December, 1978'. Yet, in practice, most cyclists take on different ways depending on the traffic quantity (Tokuyasu et al., 2015) making cycling on sidewalks is a common practice and unsegregated shared-use omni-present.

The negatives of shared-use include the affect on safety of pedestrians and enforcing the reduction of cyclists speed. In fact, in the recent years the 'violations of traffic rules and etiquette by users of bicycles' have been identified as a social problem. (Nishiuchi, IATSS). The accident statistics with cyclists and pedestrians involved remain very high.

However, there is also an association between shared-use and high levels of cycling in Japan for variety of purposes and among women and elderly, emphasizing the advantage of safety and freedom for utility cyclists (Zhe et al., 2008).

Interestingly, Japan has managed to achieve the targets set by the UK for the future: high cycling modal share especially for short distance trips, domination of multi-modal trips with cycling and walking stages, high numbers of women and the elderly walking and cycling on regular basis. This has been done without many design guidelines, but with the focus on education and by ensuring people feel safe (through allowing cycling on sidewalks).

Hence, while in Japan, in the recent years, there has been a tendency to encourage segregation as a more viable option, further research is needed to understand if promoting shared-use could be the key first-step to promoting cycling and walking in the UK.

#### 4. Acknowledgement

This literature review was a part of the 3-month academic fellowship awarded by Japan Society of Promotion of Science to Pola Berent.

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# **Abstracts of Papers**

# **Published in Other Journals**

#### Mechanical and Physical Engineering

#### Static Analysis of Single/Double Effect Combined Absorption Solar Cooling System

Hiroyuki NAKAGAWA, Ryota SATO, Nobuya NISHIMURA and Kazutaka TERAO

*Proc. of the International Sorption Heat Pump Conference 2017*, ID:AB-SY3-1155, Tokyo, JAPAN, (2017.8) (on USB).

Solar-assisted absorption chiller-heater can be driven with renewable solar energy. This system can reduce amount of city gas consumption which needed to operate the absorption machine. But, it has not been clear quantitatively how much impact on the system performance by using solar energy. In this paper, to identify this system's characteristics and to examine the effectiveness of solar energy, static simulation model of solarassisted absorption chiller-heater was constructed and simulation results were compared with experimental results.

### A Novel Production Method for Foundry Cores by Molding Polysaccharide-Coated Sand Using Superheated Steam and Air

Hiroyuki IYOYA, Isamu IDE, Shinji NISHIDA, Toshinari Nishimura, Katsuhiro OGURA and Kyosuke MOTOYAMA

Proceedings of 2nd Nordic Baltic Drying Conference (NBDC 2017), (9 pages on USB Memory) (June 2017, Hamburg, Germany)

Foundry cores are used to create pores inside a foundry, and are usually produced by shell molding, i.e., molding in a heated die. However, foundry cores tend to worsen working conditions because decomposed binder materials are released during molding and casting of high-temperature melted metal. To solve this problem, a novel environmentally friendly and highly productive method for producing foundry cores is developed. This method uses sand coated with polysaccharides made using starch as a naturally occurring binder and superheated steam as both the humidifying and drying media. In this study, we construct a laboratory-scale apparatus with a temperature-controlled cylindrical die for performing basic experimental studies on the molding process. The experimental molding results show the effects of the initial die and sand temperatures and the mixture ratio of superheated steam and air on process and product quality.

#### **Development of Two New Types of Retroreflective Materials as Countermeasures to Urban Heat Islands** Hideki SAKAI and Hiroyuki IYOTA

Int. J. Thermophys, (2017) 38:131 (10 pages) (Published online 11 July 2017)

In this study, the side effects of high-reflective and ordinary retroreflective materials, used as countermeasures to urban heat islands, are discussed. In addition, two retroreflective materials are proposed in order to avoid these adverse effects. These materials could be applied to roads and building exteriors to reduce their heat absorption from solar radiation. The first proposed type is the directional retroreflective material, which reflects light only during summer; therefore, it reduces the cooling load in summer, reduces the heating load in winter, and prevents light pollution at night. However, its structure is complicated and fragile; thus, it is suited for small areas, such as roofs and walls. The second type is the rough-surface retroreflective material, which shows weak retroreflectivity but can withstand distortion; thus, it is suited for roads. These two types require little maintenance, because they have no moving parts. Hence, these materials would not experience any breakdown, which is a great advantage for roads and building materials. Combining high-reflective, ordinary retroreflective, directional retroreflective, and rough-surface retroreflective materials, and assigning each type to the appropriate application would form an advanced mitigation system against urban heat islands.

#### Development of Measuring Device for Thermal Environment in an Oven for Food Processing

Kazuma KODAMA, Taro OZAKI, Akihiro MORIKAWA, Hiroyuki IYOTA and Tetsuo TSUJIOKA

#### Trans. of the Society of Instrument and Control Engineers, 52(12), pp.707-712 (2016)

Several types of ovens have been widely used for food processing and cooking. In this process, foods in an oven are heated by combination of heat transfers such as convection, conduction and thermal radiation. The quality of food products are affected by these heating conditions. In food factories, temperature inside the oven and baking time are adjusted by empirical human operations based on measured temperatures only at fixed-point. Therefore, it can be effective to measure the thermal environment where the food actually placed/moved in the process in real time. We have developed an electronic circuit board and a measuring device having wireless data communication function to measure the thermal environment parameters of temperature, humidity, wind speed, radiation contribution rate, vibration of the food inside the oven. We have performed the practical experiment with a reel oven working at food industry over 175°C for 1800s. The results show that the thermal environment nearby the food in the oven can be measured and temperature profiles also can be traced.

#### Effect of the Surface Texture Treatment (Wavy Plate) on the Liquid Film Flow on a Plate of Packings

Yoshiaki ISO (IHI Corp.), Ryosuke IKEDA (IHI Corp.), Mitsutoshi YAMAMOTO (IHI Corp.), Kenji KATOH and Tatsuro WAKIMOTO

Japanese Journal of Multiphase Flow, Vol. 30, No. 5, pp. 475-482 (2017) (in Japanese)

Gas liquid interfacial flows, such as liquid film flow (also known as wetting flows on plates), are encountered in many industrial processes including absorption, distillation and so on. The present study focuses on detailed descriptions of the transition phenomena between the film flow and the rivulet flow, as well as how such phenomena are affected by surface texture treatments on plates. This study uses a numerical simulation of Computational Fluid Dynamics (CFD) with the volume of Fluid (VOF) model as well as an experimental measurement technique. Through the comparison of two geometry cases (smooth surface and wavy surface) which are the models simplified from typical structured packings, the numerical and experimental results show that surface texture treatments can help to prevent the liquid channeling and can increase the wetted area. The main reason for increasing the wetted area on the wavy surface is that the liquid film break up is inhibited due to the increasing of liquid film thickness on the plate as well as the spreading of the liquid flow in spanwise direction by the wavy surface geometry.

#### Influence of a Side Walls on Dryout of Falling Liquid Film Flowing Down on a Plate

Kenji KATOH, Changing XU, Yoshiaki ISO (IHI Corp.), Ryosuke IKEDA (IHI Corp.) and Tatsuro WAKIMOTO

Japanese Journal of Multiphase Flow, Vol. 31, No. 2, pp. 171-178 (2017) (in Japanese)

A theoretical and experimental study was conducted to investigate the influence of side wall on the dryout of liquid film flowing on an inclined plate. The film surface forms a meniscus having a minimum thickness near the side wall. The thin film causes the decline of dynamic pressure of flow and the dryout may happen at higher flow rate. In this study, the meniscus profile near the side wall was theoretically analyzed from the energy minimum principle under the condition of force balance between gravitational and viscous force. Here we considered the system energy contributed from the work related to wetting behavior, the work resulted from the increase of gas-liquid interfacial area, the kinematic energy of film flow, as well as the liquid potential energy. The calculated results of meniscus radius and minimum film thickness roughly agree with the results of experimental measurement and CFD.

#### Effect of Wettability on Dynamics of a Rotating Cylinder When Plunging into Water

Tatsuro WAKIMOTO, Yoshiaki UEDA (Setsunan Univ.), Kenji KATOH and Manabu IGUCHI

Advanced Experimental Mechanics, Vol. 2, pp. 59-64 (2017)

To investigate the dynamics of the object plunging into water, the sequential images of water entry of rotating hydrophilic and hydrophobic cylinders were captured with high speed cameras, and the underwater trajectories of the cylinders were measured at various impact angles, velocities, and rotational rates. The captured images

reveal that the hydrophobic cylinder splashes sheet-shaped water and turns to the left opposite to pre-impact moving direction while the hydrophilic cylinder continues moving in the right direction without the splash. The hydrophobic cylinder commonly produces a fully developed air cavity behind, although the hydrophilic one generates it only at the impact velocity higher than a critical value. The hydrophilic cylinder with the high impact velocity turns more rightward, and the fast rotation of the cylinder changes the trajectory leftward regardless of wettability. From the captured images and the estimated force by trajectory analysis, it can be deduced that the changes of the trajectory are due to the reaction force of the splash, additional hydrostatic force induced by the cavity, and lift force by Magnus effect.

#### Measurement of Dynamic Surface Tension for Liquid Metal by Capillary Jet Method

Tatsuro WAKIMOTO, Kenji KATOH, Yoshiaki UEDA (Setsunan Univ.) and Manabu IGUCHI

International Journal of Heat and Fluid Flow, Vol. 66, pp. 243-248 (2017)

Most liquid metals are easily oxidized, causing their surface tensions to vary over time. In this study, a novel method for measuring dynamic surface tension during the oxidization of liquid metals is proposed. This method is based on the phenomenon that the descent trajectory of a capillary jet ejected horizontally from a small orifice at a slow speed depends on the surface tension as well as both the inertial and gravitational forces. We derived a theoretical model to predict the jet trajectory and determined the dynamic surface tension of the liquid metal by matching the predicted theoretical trajectory with an experimentally measured one. Actual measurements for Wood's alloy at various oxygen concentrations demonstrated that the surface tension decreases to an equilibrium value on a time scale of 10-11 ms at oxygen densities of less than 1.5%, whereas it increases for a time scale of 10-17 ms at greater oxygen densities. This method has ability to measure dynamic surface tension with time scale of 1.5 - 55 ms at accuracy of  $\pm 1.5$  ms and the ability is suitable for measuring dynamic surface tension of liquid metal in oxidation process.

#### **Development of a 300 L Calibration Bath for Oceanographic Thermometers**

S. BABA(JAMSTEC) , K. YAMAZAWA(NITE) , T. NAKANO(AIST) , I. SAITO(AIST) , J. TAMBA(AIST), T. WAKIMOTO and K. KATOH

International Journal of Thermophysics, Vol. 38, No. 11, Article 164 (2017)

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been developing a 300 L calibration bath to calibrate 24 oceanographic thermometers (OT) simultaneously and thereby reduce the calibration work load necessary to service more than 180 OT every year. This study investigated characteristics of the developed 300 L calibration bath using a SBE 3plus thermometer produced by an OT manufacturer. We also used 11 thermistor thermometers that were calibrated tobe traceable to the international temperature scale of 1990 (ITS-90) within 1 mK of standard uncertainty through collaboration of JAMSTEC and NMIJ/AIST. Results show that the time stability of temperature of the developed bath was within  $\pm 1$  mK. Furthermore, the temperature uniformity was  $\pm 1.3$  mK. The expanded uncertainty (k = 2) components for the characteristics of the developed 300 L calibration bath were estimated as 2.9 mK, which is much less than the value of 10 mK: the required specification for uncertainty of calibration for the OT. These results demonstrated the utility of this 300 L calibration bath as a device for use with a new calibration system.

### Control Method for Helicopters Cabled to Ground Station with Compensation of Disturbance Caused by Cable Tension

#### Atsushi IMADU, Takanori SAKAI, Tadao KAWAI

#### Journal of Robotics and Mechatronics, 29(4), pp. 737-745(2017).

This paper suggests cable tension compensation control for helicopters cabled to the ground station. This method can be applied to human operated system and reduces required control skill. In this method, cable tension vector is measured by a force sensor and an angle sensor mounted on the helicopter. Thrust and helicopter attitude to

balance with resultant force of the tension and the gravity force are calculated and added to control input by PID control. Simulation and experimental result illustrate validity of the proposed method.

## *in vivo* Tomographically Diagnosing Technique of Early Cancer using 2-Color Optical Coherence Dosigraphy

Yu NAKAMICHI, Souichi SAEKI, Takafumi HIRO, Masunori MATSUZAKI

Journal of Biomechanical Science and Engineering, Vol. 12, No. 2, 16-00591, (2017)

The endoscopic optical coherence tomography (OCT) has been developed for early detection of digestive system cancer. However, it is difficult to detect cancerous tissue due to complicated speckle patterns contributed by optical properties of scattering and absorption in the morphological images of OCT. In our previous papers, 2-color optical coherence dosigraphy (2C-OCD) was proposed, which quantified OCT signal as scattering and absorption coefficients and could provide drug distribution at the micro-scale spatial resolution. In this study, an in vivo tomo-graphically diagnosing technique of early cancer is presented, in which 2C-OCD is applied to cancerous tissue with selective uptake of photosensitizer. The feasibility study was demonstrated and investigated, based on 2C-OCD visualization of the subcutaneous tumor-implanted nude mice with photosensitizer AlPcS administered. Consequently, it was confirmed that drug absorption coefficient obtained by 2C-OCD was correlated with fluorescence intensity from accumulated AlPcS (r = 0.918), comparing with their histological images. Additionally, 2C-OCD could diagnose tumor tissue significantly with sensitivity of 82.5% and specificity of 78.3%, respectively. Therefore, 2C-OCD can detect photosensitizer infiltration into cancerous tissue, and thus has a promising modality for in vivo tomographically diagnosing technique of early cancer.

#### Micro-Tomographic Study on Viscoelastic Behavior of articular cartilage using Dynamic Optical Coherence Straingraphy

#### Daisuke FURUKAWA, Souichi SAEKI, Ryohei NISHINO, Suguru MISHIMA

Journal of the Japanese Society for Experimental Mechanics, Vol. 17, No. 1, pp.52-56 (2017) (in Japanese)

Rheological behavior of interstitial fluid in epidermal tissue, including blood micro-circulation, can vary skin mechanics in micro scale, i.e. visco-elasticity. Therefore, an in vivo quantitative measurement of fluid velocity is necessary to clarify their properties. In this paper, we constructed OCDV (Optical Coherence Doppler Velocigraphy), which is a method of tomographic micro-visualizing interstitial fluid velocity using a high frequency modulated low coherence interferometer. The tomographic detection of modulated Doppler frequency can determine fluid velocity profile within tissue. An optimal signal processing of OCDV was evaluated alternately on short time FFT and Hilbert transform, and validated by measuring the fluid velocity of Intralipid solution (2%) in micro channel. Consequently, Hilbert transform has further advantages in the accuracy even with a rapid scanning system than short time FFT. OCDV was suggested to be effective to diagnose flow velocity profiles in tissue non-invasively and tomographically.

### Study on Micro-tomography of Temperature using FEM-based Inverse Analysis applied to Optical Coherence Straingraphy

#### Souichi SAEKI, Daisuke FURUKAWA, Ryuki KUNIMOTO

*The 19th International Conference on Electronics, Materials, and Packaging (EMAP)*, USB-memory, 2-5 (2017) Electronic devices such as LSI have been being improved in terms of high efficiency and integration of micro and power semiconductor elements. However, there remains serious problems associated with microscopic fracture attributed to thermal strain, which arises with the increase of quantity and density of exothermic Joule heating generated from heat sources and electric wires. Therefore, it is quite necessary to perform the optimum thermal management and design, microscopically and non-destructively. Recently, Optical Coherence Tomography (OCT) has been improved as a biomedical diagnostic modality. This can tomographically visualize a spatial variation field of refractive index inside tissue, as a back-scattering intensity distribution at 1 to 10 micrometer resolution. Electronic devices such as LSI have been being improved in terms of high efficiency and

integration of micro and power semiconductor elements. However, there remains serious problems associated with microscopic fracture attributed to thermal strain, which arises with the increase of quantity and density of exothermic Joule heating generated from heat sources and electric wires. Therefore, it is quite necessary to perform the optimum thermal management and design, microscopically and non-destructively. Recently, Optical Coherence Tomography (OCT) has been improved as a biomedical diagnostic modality. This can tomographically visualize a spatial variation field of refractive index inside tissue, as a back-scattering intensity distribution at 1 to 10 micrometer resolution. As shown by Fig. 1, OCTH is based on FEM-based inverse analysis using tomographic deformation vector field data obtained by OCSA. Inverse analyzing region of interest (ROI) is set arbitrarily on OCT images, which is discretized to finite elements in consideration of FEM model such as material properties, e.g. Young's modulus, Poisson's ratio and thermal expansion coefficient. A global element equation subjected to thermal expansion can be built under 2-dimensional plane stress and deformation boundary problems. By interpolating tomographic deformation vectors to every nodes, temperature variation can be solved as a FEM-based inverse analysis due to given material properties. Moore-Penrose pseud inverse matrix, mainly defined by shape functions and element discretization, is used selectively to estimate the temperature variation field as a direct inverse analysis. The absolute temperature variation can be calculated from temperature calibration by local measurement. In order to validate OCTH, the numerical experiment was carried out using simulated OCT images constructed by both Monte Carlo simulation and FEM thermal stress analysis. FEM analysis was conducted using a chip embedded board model, in which a silicon CPU and a copper wire were embedded as heat sources in the both side and filled with an epoxy seal. A simulated OCT image was calculated by Monte Carlo simulation for random scattering intensity profile, then the synthetic OCT images were prepared by speckle pattern movement according to deformation field obtained by FEM.

#### Study on Micro-tomographic Visualization of Blood Flow Velocity in Capillary Vessels using Optical Coherence Interferometer Optical Coherence Doppler Velocigraphy

Daisuke FURUKAWA, Souichi SAEKI, Yusuke HARA, Susumu AOKI, Takafumi ITO and Yoshiaki NISHINO

XXVI Congress of the International Society of Biomechanics 2017, USB-memory, pp. 114 (2017)

The skin aging process, e.g. wrinkles and saggings, caused by not only aging but also ultraviolet irradiation, could be related to the depression of metabolic function. The microcirculation system should be an important guideline of skin care for the anti/smart-aging. Rheological behavior of interstitial in epidermal and dermal tissue, including blood micro-circulation, can vary skin mechanics in micro scale, i.e. visco-elasticity. Therefore, an in vivo quantitative measurement of capillary blood flow velocity is crucial to clarify their properties. The purpose of this study is to visualize the tomographic flow velocity of red blood cell in capillaries below human epidermal skin using Optical Coherence Doppler Velocigraphy, i.e. OCDV. This is constructed on a low coherence interferometer, which is based on Hilbert transform and adjacent auto-correlation. The paper presents the result of applying OCDV to human forearm skin inside, it was possible to provide blood flow velocity of capillary vessels non-invasively as an in vivo micro-tomographic imaging.

#### Construction on Tomographic Micro-visualizing System of Delivered Drug Concentration inside Biological Tissue using 2-Color Coherence Interferometer

Naoya KUSUMOTO, Daisuke FURUKAWA, Ryohei NISHINO and Souichi SAEKI

XXVI Congress of the International Society of Biomechanics 2017, USB-memory, pp. 529 (2017)

Recently, clinical treatments applying Drug Delivery System (DDS) have been being developed. However, it is quite difficult to in vivo diagnose spatiotemporal distribution of drug infiltration. An example of chemical substance, "water", has significant influence on human body due to physiological carrier media. Therefore, in vivo quantitative measurement of moisture content is necessary to classify skin mechanics. In this study, we propose 2C-OCM (2-Color Optical Coherence Moisturegraphy), which is composed of two-band light sources having different optical absorption properties of moisture content. RSOD (Rapid Scanning Optical Delay line) is

implemented as a depth scanner of interferometer, which can modulate the two-band lights to different frequencies. In order to verify 2C-OCM, it was in vivo applied to the dorsum of hand skin with varying moisture condition of tissue.

### Micro-tomographic Diagnosis of Skin, Cartilage, Atherosclerosis, Tumor and Regenerative Tissue using Multi-functional OCT

#### Souichi SAEKI

#### 8th OCARINA International Symposium, O-4, p. 14 (2017)

In atherosclerosis, malignant neoplasm and osteoarthritis and so on, since the disease condition should reach progressive stages with the microscopic tissue degeneration of biomechanical and biochemical tissue characteristics, the development of the non-invasive micro-diagnostic system has been required to carry out clinically tomographic visualization at the micro scale. Recently, Optical Coherence Tomography (OCT), based on the low coherence interferometry, has been being improved as a 3-dimensionally and tomographically subsurface imaging of micro structural biological tissue with high resolution of 1 to 10µm. However, biomechanical properties; vulnerability and visco-elasticity, and biochemical characteristics; drug infiltration and water content, have never estimated exhaustively, because OCT can provide only morphological tissue distribution as scattering intensity profile generated from spatial variation of refractive index. In this presentation, a tomographically diagnostic method "Multi-Functional OCT" [1], is proposed and in/ex vivo performed as a 3-dimensional non-invasive detection with micro scale, which can offer the biomechanical properties of "strain" by "OCSA" and "stress" by "OCSE" [2], "velocity" by "OCDV" [3], and the biochemical characteristics "delivered drug" and "water content" by "OCD" and "OCM" [4], the biological tissue characterization of fibrous/lipid by "ARV" [1], respectively.

### Study on 3-Dimensional Micro-tomographic Visualizing of Blood Flow Velocity in Capillary Vessels Using Optical Coherence Doppler Velocigraphy

Daisuke FURUKAWA, Ryohei NISHINO, Naoya KUSUMOTO, Souichi SAEKI, Yusuke HARA, Masatsugu SHIBA, Susumu AOKI, Takafumi ITO andYoshiaki NISHINO

#### 8th OCARINA International Symposium, P-36, p. 73 (2017)

The skin aging process, e.g. wrinkles and saggings, caused by not only aging but also ultraviolet irradiation, could be related to the depression of metabolic function. The microcirculation system should be an important guideline of skin care for the anti/smart-aging. Rheological behavior of interstitial in epidermal and dermal tissue, including blood micro-circulation, can vary skin mechanics in micro scale, i.e. visco-elasticity. Therefore, an in vivo quantitative measurement of capillary blood flow velocity is crucial to clarify their properties. The purpose of this study is to visualize the tomographic flow velocity of red blood cell in capillaries below human epidermal skin using Optical Coherence Doppler Velocigraphy, i.e. OCDV [1]. This is constructed on a low coherence interferometer [2], which is based on Hilbert transform and adjacent auto-correlation. In order to validate OCDV system, this was in vivo applied to human forearm skin under the condition of control and avascularization using a tourniquet, respectively. As a result of skin tomography obtained by OCDV, a cross-sectional imaging of doppler velocity was found to display networks of capillary blood vessels inside dermal tissue, where low intensities were distributed in a morphological OCT image. It was confirmed that blood velocity further decreased in upper dermis under avascularization than control condition. In summary, OCDV system could be quite useful for a micro-tomographic imaging of blood flow velocity of capillary vessels inside skin.

### Construction on Tomographic Micro-visualizing System of Delivered Drug Concentration inside Biological Tissue using 2-Color Coherence Interferometer

Naoya KUSUMOTO, Daisuke FURUKAWA, Ryohei NISHINO, Souichi SAEKI and Takeshi NAGASAKI 8th OCARINA International Symposium, P-17, p. 49 (2017)

Recently, clinical treatments applying Drug Delivery System (DDS) have been being developed. However, it is quite difficult to in vivo diagnose spatiotemporal distribution of drug infiltration. An example of chemical substance, "water", has significant influence on human body due to physiological carrier media. Therefore, in vivo quantitative measurement of moisture content is necessary to clarify skin mechanics. In this poster presentation, we propose 2C-OCD/OCM (2-Color Optical Coherence Dosigraphy & Moisturegraphy), which is composed of two-band light sources having different optical absorption properties of delivered drug and water, respectively. These methods are capable of tomographically in vivo diagnosing delivered drug concentration and the moisture content, respectively. The present system, i.e. OCM, is constructed around an optical fiber interferometer based on Time-Domain OCT [1], and can simultaneously acquire two interference signals only by a single channel. RSOD (Rapid Scanning Optical Delay line) is implemented as a depth scanner in reference arm so that it can provide video-rate tomography by rotating a galvanometer mirror. In addition, light of each wavelength, which is diffracted by a grating, is focused on different position on the surface of scanning mirror by an achromatic lens, so can modulate lights of the two-band wavelength to respective different frequencies. In order to verify 2C-OCM, it was applied to the dorsum of hand skin under the condition of control and moisture saturated skin for 30 minutes. Consequently, it was concluded that 2C-OCM has a promising potential of diagnosing tomographic concentration of chemical substance, i.e. drug, inside skin tissue.

#### Study on Tomographic Micro Mechanical Diagnosis of Osteoarthritic Cartilage using Dynamic Optical Coherence Straingraphy

Kazuma KOTANI, Kiichi HASEGAWA, Hiroaki KOBAYASHI, Souichi SAEKI, Suguru NAKAMURA, Mitsuhiko IKEBUCHI, Hiroaki NAKAMURA, Nobuo NIIMI, Yoshito TSUKAHARA

8th OCARINA International Symposium, P-16, p. 48 (2017)

Many of the elderly are predisposed to develop osteoarthritis (OA), although it is quite difficult to diagnose the early-grade OA even by latest imaging modalities. The purpose of this study is to develop a clinical diagnosing system, which can tomographically and non-invasively visualize mechanical properties of articular cartilage, i.e. visco-elasticity, in micrometer resolution. We constructed "Dynamic Optical Coherence Straingraphy (D-OCSA)" composed of Optical Coherence Tomography (OCT) and a mechanical loading devise [1]. This can discriminate mechanical propertied by applying the proposed image processing to continuous OCT images, which should contain huge hidden information as dynamical behavior of deformed cartilage. In this poster presentation, the arthroscopy-typed OCT, which can intraarticularly diagnose osteoarthritic cartilage, was developed as an in vivo cross-sectional imaging modality and was applied to a porcine knee joint. In addition, ex vivo animal experiments were also carried out to apply D-OCSA to the prepared rabbit's OA cartilage caused by amputation of knee ACL. As a result, it was confirmed that the constructed system could intraarticularly provide morphologic diagnosis of cartilage, e.g. tide mark. D-OCSA showed superior increase in attenuation of compressive strain rate only for early OA cartilage during relaxation test, which can be seen that there is a loss of visco-elastic properties as compared to normal cartilage. In conclusions, the proposed arthroscopic-typed D-OCSA system could be effective to assessments of the early OA as "Micro Mechanical Biopsy".

#### Fundamental Study on Ultrasonic Detection of Uncured Region in GFRP Plates

Akihiro WADA, Tomohiro YAMASAKI, Eiji KITAGAWA and Hiroshi ITO

Journal of the Japan Society for Composite Materials, 43(3), pp.112-119(2017)

Ultrasonic waves are applied to detection of uncured regions in glass-fiber reinforced plastic (GFRP) plates. Polymer-based composites play an increasingly important role in the field of civil engineering because of their high specific stiffness, strength, and excellent corrosion resistance. For example, GFRP pipes are used to rehabilitate aged sewerage pipes. Uncured GFRP tubes are inserted in the aged pipes, and are then inflated and cured with steam blowing to create close-fit pipes. In this cured-in-place pipe (CIPP) method, an uncured region may be left in the GFRP pipe, so the constructed pipe must be inspected to ensure the integrity of the reinforcement. In this study, for detection of such an uncured region in GFRP structures, the effect of resin cure

on ultrasonic propagation characteristics is investigated experimentally. Through-thickness and in-plane ultrasonic measurements are conducted, and their sensitivities to resin cure are compared. In addition to wave attenuation and velocity, several AU parameters are evaluated from the power spectrum of a broadband signal. It is found that the A2 parameter, which represents the centroid of the power spectrum, has a good correlation with the mechanical properties of GFRP plates, and is expected to improve the detectability of uncured regions.

#### Development of a Bridge Inspection Robot Capable of Traveling on Splicing Parts

#### Yogo TAKADA, Satoshi ITO, and Naoto IMAJO

#### Inventions, Vol. 2, No. 3, 22 (2017), DOI:10.3390/inventions2030022.

Several infrastructures, such as bridges and tunnels, require periodic inspection and repair to prevent collapse. There is a strong demand for practical bridge inspection robots to reduce the cost and time associated with the inspection of bridges by an inspector. Bridge inspection robots are expected to pass through obstacles such as bolted splice part and right-angled routes. The aim of this study involved developing a bridge inspection robot that can travel on a right-angle path as well as splicing parts. A two-wheel-drive robot was developed and equipped with two rimless wheels as driving wheels. A neodymium magnet was provided at the tip of each spoke. Non-driving wheels were attached at the rear as a rotatable caster. The robot can turn on the spot to avoid the bolt on the splicing part. Experiments were conducted to check the performance of the robot. The results confirmed that the robot passed through the internal right-angle paths in a laboratory and in an actual environment that corresponds to a box girder of a bridge. It is extremely difficult to manually control a robot on the splicing part. Therefore, a camera and an LED (light emitting diode) were attached to autonomously control the robot. The results indicate that the newly developed robot could run through the splicing part without hitting the nuts.

#### X-ray Stress Measurement of the Cylindrical Surface by the cos a Method

Taizo OGURI (Technology Research Institute of Osaka Prefecture), Tsutomu TANAKA (Technology Research Institute of Osaka Prefecture), Toshiyuki OKANO (Okano Blast Co. Ltd.), Kazuo MURATA (Okano Blast Co. Ltd.), Hiroshi KAWAKAMI, and Yoshihiro SATO

Journal of the Society of Materials Science, Japan, Vol. 66, No. 7, pp. 488-494 (2017) (in Japanese)

The investigation was made on the phenomena observed in the X-ray stress measurement on a curved surface by the cos  $\alpha$  method. Numerical analysis was performed simulating the cos  $\alpha$  method for the circumferential stress and the axial stress on a cylindrical surface. The X-ray residual stress measurements by the cos  $\alpha$  method and the sin<sup>2</sup>  $\psi$  method were carried out respectively for the blasted surface of round steel bars with various diameters. It was found that the debye ring turned oval and the slope of cos  $\alpha$  diagram decreased as the ratio of the X-ray beam size to the bar diameter increased, i.e. the magnitude of the measured stress was smaller than that of actual one. These tendencies were remarkable in the circumferential stress measurement. With respect to the relation between the X-ray beam size and the measured value of stress, the difference between the cos  $\alpha$  method and the sin<sup>2</sup>  $\psi$  ethod was found to be small. The measurement error due to a cylindrical surface was negligible when the X-ray beam size was less than 1/3 of the diameter.

### Estimation of Residual Stress Distribution under Shot-Peened Surface by Using Theory of Thermal Stress Analysis

Toshiyuki OKANO (Okano Blast Co. Ltd.), Kazuo MURATA (Okano Blast Co. Ltd.), Taizo OGURI (Technology Research Institute of Osaka Prefecture), Tsutomu TANAKA (Technology Research Institute of Osaka Prefecture), Hiroshi KAWAKAMI, and Yoshihiro SATO

Journal of the Society of Materials Science, Japan, Vol. 66, No. 7, pp. 508-514 (2017) (in Japanese)

In the shot peening process, the residual stress on the shot-peened surface and its distribution under the surface are important evaluation items for the high value-added surface creation. In this paper, it was proposed that the residual stress distribution under the shot-peened surface for a thin plate was non-destructively estimated from

the measured value of residual stress on the surface and that of the arc height, by applying the theory of linear thermal stress analysis for a thin plate. The analyzed residual stress profile showed good agreement with that of the experimental results obtained from the surface removal by electro-polishing. From the results of analysis, it was found that the depth of compressive residual stress (the depth which changes from the compressive stress to the tensile stress), the residual stress at the depth of the inherent strain and the residual stress on the opposite surface to the shot-peened surface characterizing the profile of residual stress distribution had a relationship with the ratio of a thickness of plate to an inherent strain depth.

#### Effects of Wipe Cleaning with Detergents on Antibacterial Activities of Copper Surface

#### Pengyuan WANG, Hiroshi KAWAKAMI, and Yoshihiro SATO

Journal of Japan Institute of Copper, Vol. 56, No. 1, pp. 323-328 (2017) (in Japanese)

In this study, effects of surface contamination by an oily substance and wipe cleaning using detergents on antibacterial activities of copper were investigated. Sample used was oxygen free copper (OFC) (> 99.96 %). Triolein was employed as a model surface contaminant. Detergents used for wiping were hypochlorite (NaOCl aq.) and ethanol (EtOH). Distilled water (D.W.) was also used as a detergent for wiping. The test surfaces of coupon specimens were firstly contaminated with triolein and then subjected to wiping using a sterile wipe loaded with one of the detergents. The specimens were also subjected to the wet-dry cycles, i.e. the specimens subjected to the cycle of being wetted with the detergents for about 15 s and being left in an atmosphere for 24 hours. Antibacterial tests were carried out according to the film contact method designated in JIS Z 2801, except that the time length of film contact was set to 30 min. The strain used in the antibacterial tests was E. coli (NBRC 3972). Antibacterial activities of the specimens were reduced by surface contamination with triolein. The reduced antibacterial activities were reactivated by the application of wipe cleaning using the detergents. The wiping with a dry sterile wipe also reactivated the reduced antibacterial activities. The surfaces of the specimens corroded when the specimens were subjected to the wet-dry cycle for several times. The specimens treated with NaOCl aq. showed severe decrease in the antibacterial activities followed by the specimens treated with D.W., and the amount of decrease in the antibacterial activities of the EtOH treated specimens was small. For the specimens left in an atmosphere for the same period of time as the wet-dry cycles, the antibacterial activities did not change significantly from that of specimens with clean surface. Such results indicate that the wiping using the detergents is presumably not adequate for copper and the wiping with a dry sterile wipe is a preferred method for copper to reactivate the antibacterial activities reduced by surface contamination by oily substances.

#### Investigation of the Quality of Autoclaved Composite Plates through Working Process

Norimichi NANAMI, Toshikazu UCHIDA, Yosuke WATANABE, Katsuyuki HARA, Koji KURODA, Hiroyuki HAMADA, Akihiko GOTO and Hayato NAKATANI

*Proc. JSME/ASME 2017 6th International Conference on Materials and Processing (ICMP2017)*, Los Angeles, CA, USA, June 4-8, Paper ID: ICMP2017-4334 (2017).

Carbon fiber reinforced polymer (CFRP) products are utilized in the aerospace industry to provide high specific stiffness/strength. It is necessary to assure of the quality of CFRP products such as strength and stiffness. Defects in the products are caused by the skill of the working people, leading to the unexpected damage and failure of the products. Herein, we investigate the influence of the worked surface quality to the open hole tensile strength and interlaminar shear strength of CFRP plates. The results revealed that the quality of the machined surface of the plate in the hole making process altered its tensile strength. However, a further testing method to estimate the interlaminar shear strength of the plate is required to understand the influence of its surface quality in working process to its interlaminar shear strength.

#### Thermal Treatment and Microstructure Observation for Japanese Sewing Scissors made by the "Sohizukuri" Forging Process

Hayato NAKATANI, Yasuko KITAJIMA, Takuya SUGIMOTO, Akihiko GOTO and Hiroyuki HAMADA *Proc. JSME/ASME 2017 6th International Conference on Materials and Processing (ICMP2017)*, Los Angeles, CA, USA, June 4-8, Paper ID: ICMP2017-4357 (2017).

The metallic structure observations and hardness measurement are carried out for the so-hizukuri scissors to show its uniformly sized martensitic structure and much higher hardness compared to standard quenched steel in the steel part of the blade. These facts are related to the craftsman's action during quenching process. Coating the blades with a kind of clay and shaking the heated blades in cooling water can result in uniform cooling for whole blade. Pressing the blades against the inner wall of the water vessel during the cooling and annealing by utilizing remaining heat can be correspond to press quench and marquench, respectively as often employed in forging technique of today. The forging by hammering should introduce the residual compressive stress and refinement of crystal grains that lead to the excellent sharpness of the scissors.

### Shortening in Resin Impregnation Time of VaRTM Process and Interlaminar Toughening for GFRP by inserting Polyamide Mesh

#### Hayato NAKATANI, Yosuke HANDA and Katsuhiko OSAKA

*Proc. JSME/ASME 2017 6th International Conference on Materials and Processing (ICMP2017)*, Los Angeles, CA, USA, June 4-8, Paper ID: ICMP2017-4371 (2017).

During vacuum assisted resin transfer molding (VaRTM) process a distribution medium which is incorporated on fiber preform as a surface layer is used to shorten impregnation time of resin. In this study the distribution medium is replaced by thermoplastic polyamide meshes and is inserted between fiber fabrics rather than placed on the surface. The mesh is expected to improve not only the resin flow but also interlaminar toughness in the composite laminate by remaining in it after the VaRTM process. Multipoint measurements for resin arrivals in GFRP (Glass fiber fabrics / epoxy composites) during VaRTM process are carried out by using embedded fiber optic sensors. It is confirmed that the polyamide mesh inserted in the fiber preform increased the flow rate during the impregnation of resin, and that thicker polyamide mesh resulted in higher flow rate. This fact is related to experimentally obtained permeability of the polyamide mesh with different thicknesses. Numerical simulation based on CV/FEM approach also represents both the flow front of resin where the resin preferentially proceeds in the polyamide mesh and flow rate at each measurement point. End notched flexure (ENF) tests using specimens which have bonded doubler plates of CFRP to both top and bottom surfaces are carried out. The crack length can be predicted by a simple beam theory for bonded doubler plates during the ENF testing. It is found that interlaminar fracture toughness  $G_{UC}$  is improved by inserting the thinner and finer polyamide mesh due to the complexity of the crack path. From these results it is shown that improvements in both resin flow and interlaminar fracture toughness can be achieved by inserting the polyamide mesh.

#### Comparison of Worker's Skill during Vacuum-assisted Resin Transfer Molding using Motion Analysis

Yasunari KURATANI, Kentaro HASE, Tomoe KAWAZU, Aya MIKI, Norimich NANAMI, Hayato NAKATANI and Hiroyuki HAMADA

Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future, Proc. AHFE 2017 International Conference on Human Aspects of Advanced Manufacturing, Los Angeles, CA, USA, July 17-21, pp.398-406 (2017).

In the field of carbon fiber reinforced polymer (CFRP), it is difficult to find the optimal molding conditions, since the Vacuum-assisted Resin Transfer Molding(VaRTM) requires a process which makes fiber-base materials fit into a three-dimensional shape, by applying pressure and heat simultaneously. In this study, three subjects with a varying number of years' of experience produced a VaRTM molding, with the objective of identifying the factors that contribute to the accuracy in molding conditions. The study showed that the process was dependent on the ability of the worker and experience. Herein, the researchers analyzed the behavior of experts and develop a standard procedure in order to help beginners training and to contribute to the composites CFRP industry process learning procedures.

### Characteristics of Cutting Performance for Japanese Sewing Scissors Made by the "So-hizukuri" Forging Process

#### Yasuko KITAJIMA, Hayato NAKATANI, Akihiko GOTO and Hiroyuki HAMADA

Advances in Physical Ergonomics and Human Factors, Proc. AHFE 2017 International Conference on Physical Ergonomics and Human Factors, Los Angeles, CA, USA, July 17-21, pp.466-478 (2017).

Scissors are commonly known as a tool that has been used since long ago. The X-shaped scissors currently commonly used in Japan date back to 160 years ago when Admiral Perry arrived in Uraga. Since that time Yakichi Yoshida, known as the originator of Japanese scissors, has made many reforms leading scissors to their present shape. His method is called "So-hizukuri", and today there is a very small number of artisans left who have inherited the Sohizukuri method. In previous research our research group investigated why sewing scissors made with the So-hizukuri method have a sharp cutting edge. The results showed that the surface of So-hizukuri method scissors blades have a curved surface with a difference of about 0-150 µm applied. It was suggested that the curved surface being applied causes the cutting power of the scissors to be focused onto the point where the two blades overlap when cutting cloth, leading to a sharp cutting edge. We also confirmed that when the two blades overlap the parts of the other blades are separated. In this research, we intend to extract characteristics of the So-hizukuri scissors with sharp cutting edges which were not clarified in the previous research. We had a tailor who is a specialist in handling scissors use new So-hizukuri sewing scissors and So-hizukuri sewing scissors which have been used for more than 20 years and which were both made by the same scissors artisan, and examined what effect this had on the operations of the person handling the scissors when cutting cloth. We had the person cut the same cloth under the same conditions using the same method, and recorded the process with a high-speed camera for analysis. The results showed a clear difference in the movements of the tailor when handling the So-hizukuri scissors and the cheap scissors, but no significant difference between the new Sohizukuri scissors and the So-hizukuri scissors which had been used for more than 20 years. We considered the reasons for this difference including an interview with the tailor, which we will report here.

#### Eye Movement Analysis of Japanese Sewing Scissors Craftsman

Yasuko KITAJIMA, Hayato NAKATANI, Yoichiro OGURA, Akihiko GOTO, Hiroyuki HAMADA and Norimichi NANAMI

Advances in Physical Ergonomics and Human Factors, Proc. AHFE 2017 International Conference on Physical Ergonomics and Human Factors, Los Angeles, CA, USA, July 17-21, pp.479-490 (2017).

The purpose of this study is to elucidate the skill of a blacksmith who has an ability to produce a pair of scissors whose two blades accurately comes across in the length, width and angle of each blade, even though they were produced separately. The processing method this scissor artisan employs is known as "So-hizukuri" (total forging process). The elucidation was conducted through observing the line of sight of the artisan using an eye movement analysis camera during his forging process. There are four main stages in the So-hizukuri process, and each stage involves several steps. In this study, we asked the scissor artisan to wear an eye movement analysis camera while engaging with the "Namatogi" (grinding before quenching) step in the "rough finishing before quenching" stage, which is the second in the four main stages, and observed his eye movements. We viewed the video recorded by the eye camera, and studied which parts of the blades he focused on, and the amount of time he focused on each part, when the artisan was comparing the two blades by laying one blade on top of the other. As a result, it was clarified that the artisan works on each of the left and the right blade alternately and gradually at every step toward the final stage, as the left and right blades of the scissors come across accurately when the scissors are completed. At any point in the process, he did not focus on forging one blade intensively, use a measuring instrument to measure the length of the blades, or use one of the blades as a standard to match the other blade.

#### Applying Copper-Ball Dissolution for Prolonging Life of Electroless Copper Plating Solution

### H. KANEMOTO, T. KAWAMURA, T. ITABASHI, T.MIYAZAKI and Y. KANEKO

Trans. Japan Inst. Electronics Packing, Vol.9, pp.1-10 (2016).

Under the goal of prolonging lifetime of an electroless-copper-plating solution, a new method for supplying  $Cu^{2+}$  ions to the solution, copper-ball dissolution method was developed. The effect of the developed method was examined by comparing with conventional methods: CuO-particle dissolution method and CuSO<sub>4</sub>-supply method. Studies on copper ball dissolution reaction clarified that Cu2+ ion could be supplied to the plating solution by dissolving copper ball in the oxygen-supplied solution. Compared with CuSO4-supply method, copper-ball dissolution method prevents salts from being accumulated in the solution, which can potentially double the lifetime of the solution, similar to CuO-particle dissolution method. The films obtained by copper-ball dissolution method contain fewer impurities than those of deposited by CuO-particle dissolution. As a result, the mechanical properties of the deposited film and the reliability of through-hole connection are improved. It is concluded that copper-ball dissolution method is an effective method for prolonging the lifetime of an electroless copper-plating solution, leading to reduction in environmental loads.

#### EBSD Analysis of Local Lattice Rotation below Fracture Surface

#### Y. KANEKO, C. YONEDA and M. UCHIDA

Proceeding of 14th International Conference on Fracture, (2017), in USB memory.

Microstructures developing below fatigue fracture surface were investigated by local EBSD analysis of small planes. A fatigue crack growth test was conducted in a center-cracked tension specimen of polycrystalline copper. After the crack growth test, various positions in the fracture surface were milled by the FIB technique to obtain small flat planes normal to loading direction. The flat planes were analyzed with the EBSD system. To estimate the lattice rotation quantitatively, lattice rotation angles were calculated from the numerical data collected by the EBSD analyses. The lattice rotation angle was defined as misorientation angle between a point of interest and a reference point, which is a center of an analyzed grain. In the present study, the lattice rotation was calculated along a certain line lying in the milled plane. It is found that the lattice rotation increased with increasing  $\Box K_{\rm I}$  value, in the milled planes existing at central sites of specimen thickness.

#### Implementation of an Extended Flory-Rehner Model with Two Scaling Exponents and Basic Analysis

#### Shoji SHIMIZU, Dai OKUMURA, Makoto UCHIDA, and Hiro TANAKA

*Journal of the Japan Society for Computational Methods in Engineering*, Vol. 16, pp.37-42 (2016) (in Japanese). In this study, we perform finite element implementation of a free energy function extended by introducing two scaling exponents into the Flory-Rehner model for swollen elastomers. This extended model is implemented into the finite element package Abaqus using the user-defined material subroutine UHYPER. To verify this implementation, the stress-stretch responses of elastomers at equilibrium swelling under uniaxial tension are simulated and compared with analytical predictions. The aid of artificial damping is needed to capture a rapid decrease in stress caused by swelling-induced strain softening. Effects of artificial damping on automatic incrementation analysis are discussed.

#### Evaluation of Fields of Stress and Strain of Pure Copper during Uniaxial Tensile Test using Digital Image Correlation Method and Finite Element Method

#### Makoto UCHIDA, Towa UENO, Takahiro ABE and Yoshihisa KANEKO

Proc. the 11th International Symposium on Advanced Science and Technology in Experimental Mechanics, Paper No. 56, 5pages (2016)

In order to predict the non-uniform deformation behavior of engineering materials, evaluation and modeling of the strain field are very important. Recently, accurate and contactless measurement of strain field can be performed using the optical measurement method such as digital image correlation (DIC) method. Evaluation of the stress field is also required to model the non-uniform deformation behavior of the material. In this study, fields of stress and strain are evaluated by coupling the DIC and FEM. Local strain can be decomposed into

elastic and inelastic parts by introducing the stress equilibrium around the displacement measurement points. Then, local stress tensor can be obtained by introducing the elastic strain components into generalized Hooke's law. Large deformation theory based on the update Lagrange method is also introduced to evaluate local true stress and true strain tensors for large strain range. Fields of stress and strain for pure copper specimens were evaluated during tensile tests of two different-shape specimens, Specimens NU and U. The cross section of Specimen NU continuously changes while it is constant for Specimen U. Local true stress–true strain relation basically located around the global value, and the relation for Specimens NU and U are almost similar. These results indicated that the proposed methods could evaluate local stress and strain properly.

#### Computational Simulation of Scale-Dependent Non-Uniform Deformation Behavior of Polymer Foam

Makoto UCHIDA, Keita SUZUKI and Yoshihisa KANEKO

Key Eng. Mater., Vol. 725, pp 456-461 (2016).

Polymer foam is widely used in the engineering field because of various functions such as lightweight, shock absorbing, insulation and so on. However, the strength of the material dramatically decreases with the increase in the volume fraction of the pore. In the present study, a micro- to macroscopic deformation behavior of polymer foam is modeled using the rate-form second-order homogenization method. To model the microscopic structure consisting of the pore and polymer wall, a hexagonal shape periodic structure was used, and the molecular chain network theory was used to represent an elastic-viscoplastic deformation behavior of the polymer wall. The bending resistance, in other words, resistance to the strain gradient clearly depended on comparative size difference between microscopic and macroscopic structures. For smaller pore model, the strain distribution was point symmetry, and those for different specimen sizes were almost same. On the other hand, in larger pore model, strain field was not symmetry, and the magnitude of the asymmetry was emphasized for small specimen. Large difference in the macroscopic strain through the unit cell induced the asymmetry to larger pore model, and it caused size-dependent bending resistance of the low density polyethylene foam.

#### Numerical Analysis of Evaluation of Local Wall Thinning on the Inner Surface of Pipe by the Direct-Current Potential Difference Method

#### Naoya TADA, Manabu NOHARA and Makoto UCHIDA

J. Soc. Mater. Sci, Jpn, Vol. 66, pp. 158-165 (2017) (in Japanese).

Local wall thinning is one of serious problems in aged power generating and chemical plants. As the thinning grows inside the pipes, it is difficult to detect and evaluate it from the outer surface of pipe. In this study, an evaluation method of semi-ellipsoidal local wall thinning on the inner surface of pipe by the direct-current potential difference method (DC-PDM) was proposed, and the related numerical analyses were carried out. At first, very fast electric field analysis method, i.e., defect-current modification method (DCMM), was extended to the local wall thinning with semi-ellipsoid shape on the inner surface of pipe, and the solution was validated by comparing with that obtained by the finite element method (FEM). Then, the geometry of the local wall thinning was evaluated by the proposed method based on the distribution of potential difference on the outer surface of pipe obtained by FEM. The evaluated results were successful, and it was found that the DC-PDM is applicable to the evaluation of local wall thinning.

## Evaluation of Nonuniform Deformation during Plastic Deformation of Polypropylene-Cu Mesh Composite

#### Makoto UCHIDA, Daichi KAWAMOTO and Yoshihisa KANEKO

J. Jpn Soc. Technol. Plast., Vol. 58, pp.145-150 (2017.2) (in Japanese).

To improve the plastic instability of a thermoplastic polymer composite under cold forming, a copper mesh was filled into the polypropylene (PP). PP-Cu mesh composite plate specimens with the Cu mesh inclined in various directions were formed by the compression molding of the PP pellet and Cu mesh. First, the tensile behavior of Cu meshes with the angles of  $0/90^{\circ}$ ,  $15/75^{\circ}$ ,  $30/60^{\circ}$  and  $45^{\circ}$  to the tensile direction was examined. The

maximum stress decreased gradually with increasing Cu mesh angle to the tensile direction because the Cu wires rotated in the tensile direction. The anisotropic response was also confirmed for the PP-Cu mesh composite, and the anisotropy was emphasized for composites with the higher volume fractions of the Cu mesh. The decrease in the nominal stress, which is often seen in the tensile deformation of the thermoplastic polymer, almost disappeared for the composite specimen with the Cu mesh at the angle of 45° to the tensile direction. Also, the deformation concentration in the specimen was effectively suppressed by reducing the deformation resistance in the early stage of deformation and by increasing the strain hardening after yielding.

### Quantitative Evaluation of the Development of Stress and Strain Fields using Digital Image Correlation and Finite Element Methods

#### Makoto UCHIDA, Towa UENO, Takahiro ABE and Yoshihisa KANEKO

#### Advanced Experimental Mechanics, Vol. 2, pp.76-81 (2017.8).

In order to predict the nonuniform deformation behavior of engineering materials, both the evaluation and modeling of the strain field are very important. Recently, accurate and contactless measurement of the strain field was performed using digital image correlation (DIC). Evaluation of the stress field is also required to model the nonuniform deformation behavior of the material. In this study, the stress and strain fields are evaluated by coupling the DIC and the finite element methods (FEM). The local strain can be decomposed into elastic and inelastic parts, based on the stress equilibrium around the displacement-measurement points. The local stress tensor can then be obtained by introducing the elastic strain components into a generalized Hooke's law. The large deformation theory, based on the updated Lagrange method, is also introduced to evaluate the local true stress and true strain tensors for large strain range. The stress and strain fields for pure copper specimens that had two different shapes, namely, specimens NU and U, were evaluated during tensile tests. The cross-section of specimen NU continually changes whereas it is constant for specimen U. Furthermore, two specimens with different crystal grain size were used to investigate the effect of the microscopic heterogeneity. The local true stress-true strain relationship spanned regions in the proximity of the global response, while the relationship for specimens NU and U were almost similar. The effect of the microscopic heterogeneity on the macroscopic nonuniform deformation was investigated using the evaluated stress and strain fields. In larger-grain specimens, the evaluated stress gradient was lower than that estimated using the strain gradient since the hardening rate spatially distributed owing to the microscopic heterogeneity.

#### Plastic Flow of Glassy Epoxy Network

#### Shin'ya YOSHIOKA, Yasuhito ITAMI and Akira KAWAI

#### *J. Soc. Mat Sci, Jpn*, Vol.66, pp.1-6 (2017). (in Japanese)

Steady plastic flow in specimens of tightly cross-linked glassy epoxy network was analyzed as a rate process to discuss the mechanism of nonlinear viscoelastic behavior of glassy network polymers under large deformation. Specimens were uniaxially stretched at temperatures below the glass transition temperature with various strain rates. True stress  $\sigma$  and birefringence in the specimen were recorded during the deformation as functions of nominal strain  $\varepsilon_n$ . The glassy stress  $\sigma_G$  was extracted from the  $\sigma$ - $\varepsilon_n$  relations by means of modified stress-optical rule (MSOR). The obtained  $\sigma_G$ - $\varepsilon_n$  relations had a steady flow region, which was observed as an almost constant stress state in the post-yield strain range. The flow stress in this region was analyzed by using the Eyring equation in a special way proposed by Nanzai. The analysis gave an experimental relation between the activation enthalpy  $\Delta H$  and the activation entropy  $\Delta S$ , which agreed fairly well with that derived from WLF equation for the linear viscoelastic relaxation of the glass into liquid-like, highly non-equilibrium structure in the glassy network polymer under large deformation. Independently of the presence of crosslinked molecular structures, the essential mechanism of nonlinear viscoelasticity of glassy polymers is found to be strain-induced structural change.

#### **Stress-Strain Behavior of Glassy Epoxy Network Subjected to A Stepwise Change of Tensile Rate** Shin'ya YOSHIOKA and Shun KATO

Nihon Reoroji Gakkaishi (J. Soc. Rheol., Jpn), Vol.45, pp.79-82 (2017). (in Japanese)

Stress-strain relations of a cured epoxy network subjected to uniaxial stretching during which the tensile rate changed stepwise were observed at a temperature below the glass transition. When the tensile rate was increased or decreased to a prearranged identical value, the stress-strain curves after the tensile rate change finally coincided with each other in the post-yield strain-hardening region, after showing transient variations. This behavior was observed independently of the amount of strain where the strain rate changed. Thus, the stress-strain relation in the strain-hardening region at a given strain rate did not depend on preceding strain rate history. Since the strain-hardening behavior in this system is ascribable to an increase of the rubbery stress originated from the chain orientation, the strain-hardening behavior independent of strain rate history means that the intensity of glassy stress, which is another stress component of glassy polymers, is uniquely determined only by the strain rate at the moment. Thus, the glassy stress in the strain range well beyond the yield point proved to be a steady flow stress in the network polymer.

#### **Electronics and Informatics**

#### **Applied Physics and Electronics**

#### Impacts of Annealing on Interfaces of Al foil/Si Junctions by Using Surface Activated Bonding

Katsuya FURUNA, Jianbo LIANG, Moeko MATSUBARA (Toyo Aluminum K. K.), Marwan DHAMRIN (Toyo Aluminum K. K.), Yositaka NISHIO (Toyo Aluminum K. K.) and Naoteru SHIGEKAWA

*Extended Abstracts of the 2017 International Conference on Solid State Devices and Materials, Sendai, 2017,* H-4-01 pp. 387-388 (2017)

We investigated impacts of annealing on Al foil/Si (100) junctions that were fabricated by using surface activated bonding. By performing X-ray photoelectron spectroscopy analyses as well as scanning electron microscope/energy dispersive X-ray spectrometry observations, we found that Al was diffused into the Si substrate and Si and Al reacted across the bonding interfaces when the junctions were annealed at temperatures higher than 800 °C.

#### Al-foil-based Low-loss Coplanar Waveguides Directly Bonded to Sapphire Substrates

Keita MATSUURA, Jianbo LIANG, Koichi MAEZAWA (University of Toyama) and Naoteru SHIGEKAWA *Extended Abstracts of the 2017 International Conference on Solid State Devices and Materials, Sendai, 2017*, J-7-03 pp. 495-496 (2017)

We successfully fabricate coplanar waveguides (CPWs) composed of 17  $\mu$ m Al foils on sapphire sub-strates by surface activated bonding (SAB). We demon-strate that transmission and line loss are improved by us-ing Al foils in comparison with CPWs composed of evap-orated Al films. The obtained results imply that CPWs with better performances are realized by using SAB.

#### Aluminum Foil/Si Direct Bonding as Prototypes of Ultra-Thick Metal Contacts in Devices

Jianbo LIANG, Katsuya FURUNA, Moeko MATSUBARA (Toyo Aluminum K. K.), Marwan DHAMRIN (Toyo Aluminum K. K.), Yositaka NISHIO (Toyo Aluminum K. K.) and Naoteru SHIGEKAWA

ECS J. Solid State Sci. Technol. 6(9) P626 [7 pages] (2017)

We bonded aluminum (Al) foils to Si substrates to fabricate Al/p-Si, Al/n-Si, Al/p+-Si, and Al/n+-Si junctions by surface activated bonding (SAB) method and investigated the effects of the annealing process on the electrical properties of the junctions by measuring their current - voltage (*I-V*) characteristics. It was found that the leakage current of the reverse bias voltage in the bonded Al/n-Si junctions significantly decreased and the interface resistance of the bonded Al/p-Si junctions dramatically decreased with the annealing temperature. The smallest interface resistances of the bonded Al/p+-Si and Al/n+-Si junctions were obtained to be 0.021 and 0.032  $\_\cdot$  cm2, after annealing at 300 and 400 °C, respectively. We demonstrated the fabrication of Al foil mesa-structures and micro wiring with complex structures on Si substrates. The sheet resistance of the bonded micro wiring was found to be more than two orders of magnitude lower than that of the evaporated micro wiring. In addition, Al foil mesa structures revealed a good thermal stability at the annealing temperature lower than 600 °C. These results indicated that the fabrication of the thick metal electrode in devices could be realized by SAB.

### Room Temperature Direct Bonding of Single Crystal Diamond and Si Substrates for the Combination of Diamond Devices with Si LSI

Jianbo LIANG, Satoshi Masuya (Univ. of Saga), Makoto Kasu (Univ. of Saga), Manikant Singh (Univ. of Bristol), Michael J. Uren (Univ. of Bristol), Martin Kuball (Univ. of Bristol) and Naoteru SHIGEKAWA Extended Abstracts of 12<sup>th</sup> Topical Workshop on Heterostructure Miccroelectronics (TWHM 2017), pp.71-72 (2017)

#### Formation of Contacts with High Thermal Tolerance by Using Si/GaN Junctions

Jianbo LIANG, Takuya NISHIMURA, Moeko MATSUBARA (Toyo Aluminum K. K.), Marwan DHAMRIN (Toyo Aluminum K. K.), Yositaka NISHIO (Toyo Aluminum K. K.) and Naoteru SHIGEKAWA *Extended Abstracts of 12<sup>th</sup> International Conference on Nitride Semiconductors (ICNS'12), Strasbourg*, C01.44 (2017)

### Plane-view Transmission Electron Microscopy of Si/GaAs Interfaces Fabricated by Surface-activated Bonding at Room Temperature

Yutaka OHNO (Univ. of Tohoku), Hideto YOSHIDA (Univ. of Osaka), Seiji TAKEDA (Univ. of Osaka), Liang JIANBO and Naoteru SHIGEKAWA

Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D), pp.4 (2017)

Si/GaAs interfaces fabricated by surface-activated bonding at room temperature were examined by plane-view transmission electron microscopy. It was hypothesized that the interface resistance would be originated from surface defects on the Si and GaAs substrates introduced during the bonding process.

### Transport Characteristics of Optically-Excited and Electrically-Injected Minority Electrons across p-Si/n-SiC Hetero-Interfaces

Naoteru SHIGEKAWA, Sae SHIMIZU, Jianbo LIANG, Masato SHINGO (Univ. of Fukui), Kenji SHIOJIMA (Univ. of Fukui) and Manabu ARAI (New Japan Radio Co. Ltd.)

Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D), p.26 (2017)

We report on the photoresponse of *p*-Si/*n*-SiC heterojunctions and the electrical characteristics of SiC/Si heterojunction bipolar transistors (HBTs), both of which are fabricated by bonding SiC and Si layers. We find that in the photoresponse measurements the square root of the quantum yield almost linearly depends on the photon energy and the absorption edge (1.2 V) is close to the bandgap of Si (1.12 eV), which implies that the achieved signal is attributed to the minority electrons optically excited in the *p*-Si layer and collected in the *n*-SiC layer across the hetero-interfaces. The characteristics of the SiC/Si HBTs reveal the common-base current gain  $\alpha$  of  $\approx$  0.9 for the base-collector bias voltage of 0 V at room temperature. These results indicate that SiC/Si hetero-interfaces are applicable for novel minority-carrier-based semiconductor devices.

#### Electrical Conduction of Si/ITO/Si Junctions Fabricated by Surface Activated Bonding

Jianbo LIANG, Tomoki OGAWA, Kenji ARAKI (Toyota Technological Institute), Takefumi KAMIOKA (Toyota Technological Institute) and Naoteru SHIGEKAWA

*Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D)*, pp.51 (2017)

The electrical properties of n-Si/ITO/n-Si, n-Si/ITO/p-Si, and p-Si/ITO/n-Si junctions fabricated by surface activated bonding (SAB) were investigated. The current-voltage (*I-V*) characteristics of n-Si/ITO/n-Si, n-Si/ITO/p-Si, and p-Si/ITO/n-Si junctions showed excellent linearity. The interface resistance of n-Si/ITO/p-Si junctions was found to be 0.0249  $\Omega \cdot cm^2$ , which is the smallest value observed in all the samples.

### Impacts of Bonding-layer Resistance of Si Bottom Cells on Interface Resistance in InGaP/GaAs/Si Hybrid Triple-junction Cells

Naoteru SHIGEKAWA and Jianbo LIANG

Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D), pp.52 (2017)

We fabricate InGaP/GaAs/Si hybrid triple-junction (3J) cells with different sheet resistances of bonding layers in Si bottom cells. We estimate resistances across the p-GaAs/n-Si bonding interfaces of the respective 3J cells by measuring the potentials of the bonding layers. We find that the interface resistances are higher in 3J cells with the bonding layers of Si bottom cells with higher sheet resistances.

#### Electrical Properties of Al-Foil/4H-SiC Schottky Junctions Fabricated by Surface-Activated Bonding

Sho MORITA, Jianbo LIANG, Moeko MATSUBARA (Toyo Aluminum K. K.), Marwan DHAMRIN (Toyo Aluminum K. K.), Yositaka NISHIO (Toyo Aluminum K. K.) and Naoteru SHIGEKAWA

Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D), pp.68 (2017)

17-µm Al-foil/n-4H-SiC Schottky junctions with the foils as contacts are fabricated in order to investigate the impacts of annealing on their electrical characteristics. By measuring their current-voltage and capacitance-voltage characteristics, the ideality factor and Schottky barrier height (SBH) are estimated to be 1.31 and 1.37 eV for junctions after annealing at 673 K, respectively.

#### Analysis of the Influence of Interface Charges on the Electrical Characteristics of GaAs/GaN Junctions Syoji YAMAJO, Jianbo LIANG and Naoteru SHIGEKAWA

*Extended Abstracts of 2017 IEEE International Workshop on Low Temperature Bonding for 3D Integration (LTB-3D)*, pp.77 (2017)

Electrical properties of p+-GaAs/n-GaN and n+-GaAs/n-GaN, heterojunctions fabricated by using surface-activated bonding (SAB) are investigated. The measured C-V characteristics of p+-GaAs/n-GaN and n+-GaAs/n-GaN junctions are in quantitative agreement with modeled ones obtained for the interface states density and the conduction-band discontinuity of  $1.5 \times 1014$  cm-2 eV-1 and 0.63 eV, respectively.

### Surface-activated Bonding of III-V Compound Semiconductors and Si for Fabricating Hybrid Tandem Solar Cells

#### Naoteru SHIGEKAWA and Jianbo LIANG

*Extended Abstracts of 2017 International Conference on Electronics Packaging (ICEP 2017) proc.* pp. 229-231 (2017)

The possibility of the surface-activated bonding (SAB) technologies for fabricating III-V-on-Si hybrid tandem solar cells is discussed. Although the electrical conduction across the bonding interfaces is influenced by the interface states introduced during the surface-activation process, their impacts are likely to be lowered by combining more heavily-doped bonding layers and the annealing process after the bonding. InGaP/GaAs/Si hybrid triple-junction cells are successfully fabricated by bonding III-V heterostructres for InGaP/GaAs double-junction cells and Si cell structures. This means that the bonding interfaces have an enough tolerance against the possible stress during the conventional device process sequence and that the SAB is promising as a practical substitute for the conventional semiconductor growth technologies in fabricating III-V-on-Si tandem cells.

#### Realization of Direct Bonding of Single Crystal Diamond and Si Substrates

Jianbo LIANG, Satoshi Masuya (Univ. of Saga), Makoto Kasu (Univ. of Saga) and Naoteru SHIGEKAWA *Appl. Phys. Lett.* 110, 111603 [4 pages] (2017)

Diamond/Si junctions have been achieved by surface activated bonding (SAB) method without any chemical and heating treatments. Bonded interfaces were obtained that were free from voids and mechanical cracks. Observations by using transmission electron microscopy indicated that an amorphous layer with a thickness of ~ 20 nm across the bonded interface was formed, no structural defects were observed at the interface. The amorphous layer of the diamond side was confirmed to be the mixture of  $sp^2$  and  $sp^3$  carbons by electron energy loss spectroscopy analyzation. The  $sp^3/(sp^2 + sp^3)$  ratio estimated from the X-ray photoemission spectra decreased from 53.8 % to 27.5 %, while the relative intensity of  $sp^2$  increased from 26.8 % 72.5 % after the irradiation of Ar fast beam which should be predominantly attributable to the diamond-graphite conversion.

#### Research on Output Signal of Piezoelectric Lead Zirconate Titanate Detector Using Monte Carlo Method

Seiji TAKECHI, Tomoaki MITSUHASHI, Yoshinori MIURA, Takashi MIYACHI (Chiba Institute of Technology), Masanori KOBAYASHI (Chiba Institute of Technology), Osamu OKUDAIRA (Chiba Institute of Technology), Hiromi SHIBATA (Osaka University), Masayuki FUJII (Famscience), Nagaya OKADA (Honda Electronics), Takeshi MURAKAMI (NIRS) and Yukio UCHIHORI (NIRS)

*Nuclear Instruments and Methods in Physics Research A*, Vol. 858, pp. 69-72 (2017)

The response of a radiation detector fabricated from piezoelectric lead zirconate titanate (PZT) was studied. The response signal due to a single 400 MeV/n xenon (Xe) ion was assumed to have a simple form that was composed of two variables, the amplitude and time constant. These variables were estimated by comparing two output waveforms obtained from a computer simulation and an experiment on Xe beam irradiation. Their values appeared to be dependent on the beam intensity.

### Reaction Mechanisms of Methylene-blue Degradation in Three-dimensionally Integrated Micro-solution Plasma

Tatsuru SHIRAFUJI, Yodai ISHIDA, Ayano NOMURA, Yui HAYASHI and Motonobu GOTO

Jpn. J. Appl. Phys., Vol. 56, 06HF02 (6 pages) (2017)

We have performed matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF) mass spectrometry (MS) on methylene-blue aqueous solutions treated with three-dimensionally integrated micro-solution plasma, in which we have acquired the time evolution of mass spectra as a function of treatment time. The time evolution of mass spectral peak intensities for major detected species has clearly indicated that the parent methylene-blue molecules are degraded through consecutive reactions. The primary reaction is the oxidation of the parent molecules. The oxidized species still have two benzene rings in the parent molecules. The secondary reactions are the separation of the oxidized species and the formation of compounds with one benzene ring. We have also performed the numerical fitting of the time evolution of the mass spectral peak intensities, the results of which have indicated that we must assume additional primary reactions before the primary oxidation for better

agreement with experimental results. DOI: 10.7567/JJAP.56.06HF02

#### **Diagnostics of Air-plasma-treated Water Using Fluorescent Reagents**

Kentaro NISHIMOTO, Shin-ichi IMAI and Tatsuru SHIRAFUJI

*The 34th Symposium on Plasma Processing / The 29th Symposium on Plasma Science for Materials, Jan. 16-18, 2017, Hokkaido University, Sapporo, Hokkaido, Japan,* P2-9 (2 pages) (2016)

We have applied fluorescence spectroscopy for detecting peroxynitrite, which may be generated in the water in contact with air plasma. As the fluorescent reagents, we have used aminopheyl fluorescein (APF) and hydroxyphenyl fluorescein (HPF). We have verified that irradiation of 490 nm-light on the aqueous solution with peroxynitrite causes fluorescence around the wavelength of 515 nm. With increasing the treatment time, however, fluorescence intensity of APF-mixed and HPF-mixed water have shown opposite tendency. These results indicate that plasma-treated water contains some interference species which cause the same fluorescence around 515 nm. We have discussed possibility of contribution of  $H_2O_2$  and HNO<sub>3</sub> as the interference species.

### Effects of Ambient Gases on Atomic Oxygen Flux from an Atmospheric Pressure Plasma Jet on a Flowing Medium

#### Tatsuru SHIRAFUJI

*The 34th Symposium on Plasma Processing / The 29th Symposium on Plasma Science for Materials, Jan. 16-18, 2017, Hokkaido University, Sapporo, Hokkaido, Japan,* P1-1 (2 pages) (2016)

We have performed numerical simulation of an atmospheric pressure plasma jet (APPJ) of  $O_2/N_2$  gas mixture on a flowing medium. Atomic oxygen flux from the atomic oxygen flux from the APPJ on flowing medium (1 m/s) in air ambient becomes 10% of that from the APPJ on a static medium. The first cause of this reduction in atomic oxygen flux is increase in the effective path length from the APPJ nozzle to the target medium surface, which is inevitable. The second cause is the fact that ambient air slip into the gap between the APPJ and medium due to a gas drag effect of the medium surface, which is controllable. By changing ambient gas from air to nitrogen, we can recover atomic oxygen flux from 10% to 30%.

#### **Recognition of Single Japanese Sounds using sEMG Signals and Membership Functions**

Hiroki MURAKAMI, Masafumi MURAJI and Tatsuru SHIRAFUJI

*IEEJ Transactions on Electronics, Information and Systems*, Vol.136, No.12, pp.1821-1826 (2016)

We report a method for recognizing single Japanese sounds including a consonant using surface electromyography (sEMG) signals and membership functions. We focused on six features of the waveforms of four muscles (a total of 24 indexes) and examined the consistency between the sEMG signals and the distribution of each index regarded as membership functions. We also introduced  $\pi$ -type membership functions and confirmed an improvement in the recognition rate (average recognition rate 62.3%, recognition of a series of Japanese syllables 99.1%) by varying the parameter values. These methods allow greater recognition of single Japanese sounds by users.

#### Cavity Effect on a Biexciton in a CuCl Microcavity

Yasuyoshi MITSUMORI, Shimpei MATSUURA, Shoichi UCHIYAMA, Keiichi EDAMATSU, and Masaaki NAKAYAMA

#### Physical Review B Vol. 94, 115308 (5 pages) (2016)

We studied the population and coherence dynamics of a biexciton in a planar CuCl microcavity. We developed a time-resolved two-photon polarization spectroscopy technique, by which we extracted the population dynamics of the biexciton even when the biexciton was spectrally overlapped with the lower cavity polariton. The observed lifetime of the cavity biexciton in the weak-coupling regime was much shorter than that of a bare CuCl thin film without a cavity, which directly demonstrates cavity enhancement of the radiative decay rate of the biexciton. The cavity enhancement originates from the hybridization of the unbound two-cavity-polariton state to the biexciton wave function by the biexciton-cavity coupling. By comparing the population and coherence decay curves of the biexciton, we found that the coherence of the cavity biexciton was limited by the radiative population decay. DOI: 10.1103/PhysRevB.94.115308

#### Observation of Diffusive and Dispersive Profiles of the Nonequilibrium Polariton-Condensate Dispersion Relation in a CuBr Microcavity

Masaaki NAKAYAMA and Masafumi UEDA *Physical Review B* Vol. 95, 125315 (7 pages) (2017) We have investigated the dispersion relation of polariton condensates in a CuBr microcavity with the use of angle-resolved photoluminescence (PL) spectroscopy at 77 K. The polariton condensation was clearly confirmed by the thresholdlike changes in the PL intensity, energy, and bandwidth of the lower polariton at a zero in-plane wave-vector k = 0 as a function of excitation power density. A blueshifted flat dispersion of the PL energy suddenly appeared at the condensation threshold in a small k region accompanied by the dispersion of the noncondensate PL as a background. With increasing excitation power density from the threshold, the intensity of the noncondensate PL became negligible. As a result, we found a dispersive profile of the dispersion relation of the condensate in a large k region in addition to the flat dispersion corresponding to the diffusive profile. The total dispersion relation of the condensate was explained quantitatively by a theoretical model for nonequilibrium condensation.

DOI: 10.1103/PhysRevB.95.125315

#### Initial Process of Photoluminescence Dynamics of Self-Trapped Excitons in a β-Ga<sub>2</sub>O<sub>3</sub> Single Crystal

Suguru YAMAOKA, Yoshiaki FURUKAWA and Masaaki NAKAYAMA

Physical Review B Vol. 95, 094304 (5 pages) (2017)

We investigate the photoluminescence (PL) dynamics of self-trapped excitons (STEs) in a  $\beta$ -Ga<sub>2</sub>O<sub>3</sub> single crystal from the viewpoint of the transition process from the free exciton to the STE. We succeed in measuring the PL rise time (~24 ps) at 8 K corresponding to the tunneling time through the barrier between the free exciton and STE states in the adiabatic potential. From the analysis of the PL rise time of the STE based on perturbation theory for the tunneling time considering exciton-phonon interactions, we obtain the following results. Acoustic phonons near the Brillouin zone center contribute to the tunneling process. This suggests that the wave function of the STE is still spatially extended at the final state in the tunneling process. Furthermore, we investigate temperature dependence of the PL rise time of the STE. It is found that the PL rise time decreases with increasing temperature. The PL rise times in the temperature range from 8 to 100 K can be quantitatively explained by an adiabatic theory for the tunneling process. Consequently, the self-trapping process is dominated by the tunneling process at low temperatures.

DOI: 10.1103/PhysRevB.95.094304

#### Polariton-Condensation Effects on Photoluminescence Dynamics in a CuBr Microcavity

Masaaki NAKAYAMA, Katsuya MURAKAMI and Yoshiaki FURUKAWA

Journal of Luminescence, Vol. 191, pp. 68-72 (2017)

Temporal profiles of photoluminescence (PL) from the cavity polariton at the ground state in a CuBr microcavity at 10 K have been investigated from the viewpoint of the cavity-polariton condensation. We measured angle-resolved reflectance spectra to characterize the cavity-polariton dispersions, cavity- photon dispersion, and quality factor from which the intrinsic cavity-polariton lifetime was estimated. The threshold-like changes of the PL intensity, band width, and energy of the lower polariton as a function of excitation power are consistent with previously reported experimental results for the cavity-polariton condensation. It was found that the PL rise and decay times are markedly decreased by the cavity-polariton condensation, which can be attributed to the appearance of the bosonic final state stimulation and intrinsic lifetime of polaritons in the relaxation and decay processes, respectively.

DOI: 10.1016/j.jlumin.2017.02.045

#### Longitudinal Optical Phonon-Plasmon Coupled Mode in Undoped GaAs/*n*-Type GaAs Epitaxial Structures Observed by Raman Scattering and Terahertz Time-Domain Spectroscopic Measurements: Difference in Observed Modes and Initial Polarization Effects

Hideo TAKEUCHI, Takahiro SUMIOKA and Masaaki NAKAYAMA

IEEE Transaction on Terahertz Science and Technology, Vol. 7, pp. 124-130 (2017)

We investigated longitudinal optical (LO) phonon-plasmon coupled (LOPC) mode in undoped GaAs/*n*-type GaAs epitaxial structures using Raman scattering and terahertz time-domain spectroscopic measurements. In the Raman measurement, the LOPC mode, the frequency of which is determined by the doped electron density in the *n*-type layer, was observed in addition to the LO phonon in the undoped layer. Contrastingly, in terahertz time-domain measurements, the frequency of the observed coherent LOPC mode is dominated by a photogenerated electron density: frequency-tunable LOPC mode. This indicates that the LOPC mode is generated in the undoped layer. Thus, the probing mechanisms for the LOPC mode are different in the Raman and terahertz time-domain measurements. The built-in electric field exists in the undoped layer. This field enlarges the initial polarization of the LO phonon and, as a result, enables to observe the coherent LOPC mode generated in the undoped layer with the use of the terahertz time-domain spectroscopy.
# Effects of Photogenerated Carrier Scattering on the Decay Process of Coherent Longitudinal Optical Phonons in an Undoped GaAs/*n*-type GaAs Epitaxial Structure Investigated by Terahertz Time-Domain Spectroscopy

Hideo TAKEUCHI, Takahiro SUMIOKA and Masaaki NAKAYAMA

Journal of Vacuum Science & Technology A Vol.35, 04D104 (6 pages) (2017)

The authors investigated the scattering effect of photogenerated carriers on the decay of the coherent longitudinal optical (LO) phonons in an undoped GaAs/*n*-type GaAs epitaxial structure using a terahertz time-domain spectroscopic technique. The terahertz wave from the coherent LO phonon was observed together with those emitted both by the ultrafast photocurrent and by the coherent LO-phonon-plasmon coupled (LOPC) mode. The simultaneous observation of the coherent LO phonon and coherent LOPC mode originates from the fact that the photogenerated carrier density laterally distributes around the surface of the undoped GaAs layer owing the Gaussian profile of the pump beam. The authors found that the terahertz wave from the coherent LO phonon lives up to 5.0 ps, whereas those from the coherent LOPC mode and ultrafast photocurrent disappear within 1.0 ps. The decay time of the coherent LO phonon monotonically decreases with an increase in the pump power. This finding indicates that the dephasing of the terahertz wave from the coherent LO phonon is dominated by the photogenerated carrier scattering in the time range shorter than 1.0 ps in which photogenerated carriers remain. DOI: 10.1116/1.4983637

## Controls of Electronic Structures and Phonon Dynamics in Quantum Dot Superlattice by Manipulating Interior Nano Space

### I-Ya CHANG, DaeGwi KIM and Hyeon-Deuk KIM

ACS Appl. Mater. Interfaces Vol. 8, pp. 18321-18327 (2016)

Quantum dot (QD) superlattice, a periodically ordered array structure of QDs, is expected to provide novel photo-optical functions owing to resonant couplings between adjacent QDs. Here, we computationally demonstrated that electronic structures and phonon dynamics of QD superlattice can be effectively and selectively controlled by manipulating its interior nano space where quantum resonance between neighboring ODs appears rather than by changing component OD size, shape, compositions, etc. A simple H-passivated Si OD was examined to constitute one-, two- and three-dimensional QD superlattice, and thermally fluctuating band energies and phonon modes were simulated by finite-temperature ab initio molecular dynamics (MD) simulations. The QD superlattice exhibited decrease of the band-gap energy enhanced by thermal modulations and also selective extraction of charge carriers out of the component QD, indicating its advantage as a promising platform to be implemented in solar cells. Our dynamical phonon analyses based on the ab initio MD simulations revealed that THz-frequency phonon modes were created by inter-QD crystalline lattice formed in the QD superlattice, which can contribute to thermoelectric conversion of low energy and will be useful for direct observation of the dimension-dependent superlattice. Further, we found that crystalline and ligand-originated phonon modes inside each component QD can be independently controlled by asymmetry of the superlattice and by restriction of the interior nano space, respectively. Taking into account the thermal effects at the finite temperature, we proposed guiding principles for designing efficient and space-saving QD superlattice to develop functional photovoltaic and thermoelectric devices.

DOI: 10.1021/acsami.6b03219

## Synthesis of Type-I CdTe Core and Type-II CdTe/CdS Core/Shell Quantum Dots by a Hydrothermal Method and Their Optical Properties

Taichi WATANABE, Kohji TAKAHASHI, Kunio SHIMURA, Hang-Beom BU, Hyeon-Deuk KIM and DaeGwi KIM

Bull. Chem. Soc. Jpn. Vol.90, pp. 52-58 (2017)

CdTe and CdTe/CdS quantum dots (QDs) weresynthesized via hydrothermal method in one-step processes just by controlling a reaction time. A gradual thermal decomposition of thiol ligand N-acetyl-L-cysteine results in formation of a CdS shell on a CdTe core. The experimental results of X-ray diffraction and energy dispersive X-ray spectroscopy indicated that growth of the CdS shell started in a longer reaction time than 30 minutes and that the thickness of the CdS shell increased with increasing the reaction time. The CdTe/CdS QD exhibited a longer photoluminescence-decay time than the CdTe core QD due to the type-II band alignment, and the decay time in the CdTe/CdS QDs increased with an increase in the reaction time. The increase in the decay time in the CdTe/CdS QDs was qualitatively reproduced by a decrease in an overlap integral of electron and hole wave functions caused by an increase of the CdS shell thickness.

#### DOI:10.1246/bcsj.20160299

## Microwave-Assisted Hydrothermal Synthesis of Highly Luminescent ZnSe-Based Quantum Dots with a Quantum Yield Higher than 90%

Yong-Shin LEE, Kaoru, NAKANO, Hang-Beom BU and DaeGwi KIM

Appl. Phys. Express Vol. 10, 065001 (4 pages) (2017)

Highly luminescent ZnSe-based quantum dots (QDs) were synthesized by a microwave-assisted hydrothermal method. The characteristics of the ZnSe precursor solution strongly influenced the photoluminescence (PL) quantum yields (QYs) of the QDs. The PL QY of ZnSe-core QDs synthesized under the optimum conditions reached 60%. Furthermore, the PL QY further increased to higher than 90% when a ZnS shell was applied to prepare ZnSe/ZnS-core/shell QDs.

DOI:10.7567/APEX.10.065001

### Influence of Carrier Localization at the Core/Shell Interface on the Temperature Dependence of the Stokes Shift and the Photoluminescence Decay Time in CdTe/CdS type-II Quantum Dots

Taichi WATANABE, Kohji TAKAHASHI, Kunio SHIMURA and DaeGwi KIM

*Phys. Rev. B* Vol. 96, 035305 (7 pages) (2017)

We have systematically investigated the temperature dependence of absorption, photoluminescence (PL), and PL decay profiles in CdTe-core and CdTe/CdS type-II quantum dots (QDs). In CdTe/CdS QDs, Stokes shifts and PL decay time become larger with an increase in temperature above 120 K, while those in CdTe-core QDs are almost independent of temperature. The unusual temperature dependence of Stokes shifts and PL decay time in CdTe/CdS QDs is understood by considering carrier localization at the core/shell interface at low temperatures and thermal-energy-assisted detrapping from localized-exciton to type-II-exciton states at higher temperatures. Furthermore, a phenomenological rate equation model is developed to explain the experimentally observed temperature-dependent PL decay time.

doi: 10.1103/PhysRevB.96.035305

## Control of Multiple Exciton Generation and Electron-Phonon Coupling by Interior Nano Space in Hyper-Structured Quantum Dot Superlattice"

I-Ya CHANG, DaeGwi KIM and Hyeon-Deuk KIM

ACS Appl. Mater. Interfaces, in press

Possibility of precisely manipulating interior nano space, which can be adjusted by ligand attaching down to subnanometer regime, in hyper-structured quantum dot superlattice (QDSL) induces a new kind of collective resonant couplings among QDs and opens new opportunities for developing advanced optoelectric and photovoltaic devices. Here, we report the first real-time dynamics simulations of the multiple exciton generation (MEG) in one-, two- and three-dimensional (1D, 2D, and 3D) hyper-structured H-passivated Si QDSL accounting for thermally fluctuating band energies and phonon dynamics obtained by finite-temperature ab initio molecular dynamics simulations. We computationally demonstrated that the MEG was significantly accelerated especially in the 3D QDSL compared to the 1D and 2D QDSL. The MEG acceleration in the 3D QDSL became almost 1.9 times in comparison with the isolated QD case. The dimension-dependent MEG acceleration was attributed not only to the static density of states but also to the dynamical electron-phonon couplings depending on the dimension-dependent modifications originated from the short range quantum resonance among component QDs and were intrinsic to the hyper-structured QDSL. We propose that photoexcited dynamics including the MEG process can be effectively controlled by only manipulating the interior nano space of the hyper-structured QDSL without changing component QD size, shape, compositions, ligand, etc.

### Electric and Information Engineering

### Portrait and Landscape Mode Convertible Stereoscopic Display Using Parallax Barrier

Yusuke MINAMI, Goro HAMAGISHI, Kayo YOSHIMOTO and Hideya TAKAHASHI

*Proc. IS&T Int. Symp. Electronic Imaging 2017 Stereoscopic Display and Applications XXVIII,* San Francisco, Jan. 31, pp.106-112 (2017)

We propose a tablet type stereoscopic display. It features moire free and low crosstalk ratio. The proposed system consists of parallax barriers, a tablet type liquid crystal display (LCD) and stereo cameras. A tablet type display has two display modes, portrait and landscape. It is necessary to realize same viewing distance both portrait and landscape modes. Therefore, it is difficult to observe high quality stereoscopic image by using tablet type display. In proposed system, the same parallax barriers are used both portrait and landscape modes. Therefore, viewing distance of the system is constant regardless of whether the LCD is portrait or landscape. We constructed the prototype system to verify the effectiveness of the proposed system. We used 15.6 inch 4K display as an LCD for tablet. By realizing new stereoscopic image arrangement that was different from between in portrait and landscape modes, we can see stereoscopic images with the slanted barriers with the same specifications. We confirmed that viewing distance is constantly 207.375 mm and moire patterns are not generated on its image. Additionally, max crosstalk ratio is 6.56 % at portrait mode and 14.00 % at landscape mode.

### Analysis of Retinal Images for Retinal Projection Type Super Multi-view 3D Head-mounted Display

Takashi EMOTO, Tadayuki KONDA, Kayo YOSHIMOTO and Hideya TAKAHASHI

*Proc. IS&T Int. Symp. Electronic Imaging 2017 Stereoscopic Display and Applications XXVIII,* San Francisco, Feb. 1, pp.188-193 (2017)

In the augmented reality technology, what a viewer sees needs to be augmented by 3D information in accordance with the real object. Thus, we have previously proposed a retinal projection type super multiview HMD which provides a viewer with natural 3D images. However, the proposed HMD has two problems. One is whether the blurred retinal image of the real 3D object is equal to the superimposed parallax images of the virtual 3D image. The other one is the restricted depth range of 3D images. When the parallax difference is large and corresponding pixels of parallax images do not overlap each other, we cannot use the superimposed parallax images instead of the blurred image. In this paper, we theoretically consider above problems and verify the effectiveness of the super multi-view HMD. By simulation the light intensity distributions of retinal images, we confirmed that the superimposed parallax images was equal to the blurred image. Moreover, from the range of the suitable parallax difference, we verified the depth range of the 3D image by the proposed HMD was more than 113 mm in front of the pupil.

## Evaluation of Endoscopic Entire 3D Image Acquisition of the Digestive Tract Using a Stereo Endoscope

Kayo YOSHIMOTO, Kenji WATABE (Osaka University), Tetsuji FUJINAGA (Osaka University), Hideki IIJIMA (Osaka University), Masahiko TSUJII (Osaka University), Hideya TAKAHASHI, Tetsuo TAKEHARA (Osaka University) and Kenji YAMADA (Osaka University)

*Proc.SPIE Advanced Biomedical and Clinical Diagnostic and Surgical Guidance Systems XV*, San Francisco, Feb. 14, Vol.10054, CD-ROM (2017).

Because the view angle of the endoscope is narrow, it is difficult to get the whole image of the digestive tract at once. If there are more than two lesions in the digestive tract, it is hard to understand the 3D positional relationship among the lesions. Virtual endoscopy using CT is a present standard method to get the whole view of the digestive tract. Because the virtual endoscopy is designed to detect the irregularity of the surface, it cannot detect lesions that lack irregularity including early cancer. In this study, we propose a method of endoscopic entire 3D image acquisition of the digestive tract using a stereo endoscope. The method is as follows: 1) capture sequential images of the digestive tract by moving the endoscope by image analysis, 4) reconstitute the entire image of the digestive tract by combining the 3D surface pattern. To confirm the validity of this method, we experimented with a straight tube inside of which circles were allocated at equal distance of 20 mm. We captured sequential images and the reconstituted image of the tube revealed that the distance between each circle was  $20.2 \pm 0.3$  mm (n=7). The results suggest that this method of endoscopic entire 3D image acquisition may help us understand 3D positional relationship among the lesions such as early esophageal cancer that cannot be detected by virtual endoscopy using CT.

### A Novel Approach on Infant Facial Pain Classification using Multi Stage Classifier and Geometrical-Textural Features Combination

Yosi Kristian (ITS), Hideya Takahashi, I Ketut Eddy Purnama (ITS), Kayo Yoshimoto, Esther Irawati Setiawan (ITS), Elizeus Hanindito (ITS) and Mauridhi Hery Purnomo (ITS)

IAENG International Journal of Computer Science, vol.44, no.1, pp.112-121 (2017).

Infants are unable to communicate pain, they cry to express their pain. In this paper we describe the most effective feature for infant facial pain classification. The image dataset was classified by medical doctors and nurses based on cortisol hormone difference and FLACC (Face, Legs, Activity, Cry, Consolability) measurement. In this paper we try a number of features based on Action Unit (AU) for infant facial pain classification and discover that the best features are combination between geometrical and textural features. We trained our own Active Shape Model (ASM) and extracted the geometrical features based on landmark points found by our ASM. The textural features are extracted using Local Binary Patterns (LBP) from multiple facial patches. We also experiment with two stage pain classification preceded by a cry detection system, and concluded that this scenario combined with geometrical and textural feature produce a very high F1 score for infant facial pain classification.

### A Fundamental Study on Vessel Depth Estimation Based on Refocusing Using Light Field Imaging

Kayo YOSHIMOTO, Hideya TAKAHASHI and Kenji YAMADA (Osaka University)

International Journal of Applied Biomedical Engineering, vol.9, no.1, pp.1-6 (2016).

Venipuncture is a medical practice which is ordinarily performed in hospital. However, it is a difficult procedure as the occurrence of many failure of the puncture and sometimes medical accidents such as nerve damage and blood vessel damage are reported. This is caused by the difficulty of visually identification of the blood vessel. Although the depth information of the blood vessel is also important, the existing system in clinical practice can visualize vessels only by two dimensional images. In this paper, to estimate the three dimensional position of the blood vessel, we propose the system based on refocusing using light field imaging. This method can obtain cross-sectional information of blood vessel emphasized using near infrared light at each depth. We finally confirm the validity of the proposed method by using blood vessel simulated object and human finger.

## Aerial Volumetric Image Display Based on Retroreflective Imaging and Optical Scanning with a Slanted Rotating Mirror

Daisuke MIYAZAKI, Rina TAMAKI and Takaaki MUKAI

The 23rd International Display Workshops, Fukuoka, Dec. 7-9, 3DSA7 - 1 (2016)

Imaging based on retroreflection can provide aerial image formation with a wide view angle and lowdistortion in spite of high numerical aperture. A floating volumetric display technology based on retroreflection with a dihedral corner reflector array and optical scanning with a slanted rotating mirror are described.

#### **Floating Three-Dimensional Display with a Lenticular Sheet and a Dihedral Corner Reflector Array** Yuma TOKUBO, Daisuke MIYAZAKI and Takaaki MUKAI

Information Photonics 2017, Yokohama, April 19, IP-21PM-1-6 (2017)

In a conventional autostereoscopic display with a lenticular sheet, blurring of a three-dimensional (3D) image increases as the depth distance of the 3D image from the display increases. In addition, the 3D image position changes depending on observing position. In this report, we propose an aerial 3D display combined multiview dispay with a lenticular sheet and floating image formation with a dihedral corner reflector array. This method can form a 3D image at a fixed position in the air with the simple composition. By combining a motion sensor for human hands, the interaction between an aerial image and a user is allowed, and an intuitive interface can be achieved.

### Pulsed Power Network with Power Sources and Consumers Operated on Exhibition Table

Hisayoshi SUGIYAMA

## 2017 14th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, USA, Jan. 8, pp.571-572 (2017)

A mini-scaled pulsed power network operation is demonstrated. This scheme of smart grid was proposed in my previous papers and the basic operation was already demonstrated. In this exhibition, an advanced performance of the pulsed power network is demonstrated where electric pulses are autonomously transmitted among users according to current demands of consumers through pre-reserved transmission paths. Reliability of the decentralized control is also demonstrated against power router failures.

### Influence of Packetized Electric Power Transmission on Radio Wave Environment

### Hisayoshi SUGIYAMA

## 2017 IEEE International Conference on Consumer Electronics - Taiwan (ICCE-TW), Taipei, Taiwan, June 12, pp.195-196 (2017)

Influence of packetized electric power transmission on radio wave environment is investigated. In contrast to conventional power transmission with continuous electric current of low frequency sine wave, packetized power transmission may affect surrounding field with high frequency radio noises. In this paper, based on the analysis of electric field strength around a power line, the radio noises generated by various packetized power transmissions are evaluated. Pulse trains in synchronized frame structure of pulsed power network is adopted as the power packet signals. As the results, though the total of generated radio power exceeds that of conventional power transmissions, peak strength of electric field rather falls behind the conventional one.

### Localized Pulsed Power Network for Distributed Generations and Consumers

### Hisayoshi SUGIYAMA

2017 EMN Europe Meetings of Smart Grid Technology, Barcelona, Spein, Sep. 11, (2017)

As one of the upcoming smart grids, pulsed power network is proposed to distribute electric power effectively over the consumers. In this scheme, time axis is equally divided into frames synchronized over the network, and each frame is subdivided into N power slots. Power transmission is decomposed into a series of electric pulses at specified power slots in successive frames. These power slots are pre-reserved throughout the power transmission path by associated nodes with decentralized algorithm. Intermediate power routers directly relays the power transmission without additional relay loss. This scheme of pulsed power network has affinity with distributed generations and high reliability based on decentralized system control. With this scheme, localized power network can be established where consumers are supplied power only by distributed generations. This localized power network is applicable to communities remote from bulk power generations and to isolated areas such as large ships or space stations.

This paper introduces the scheme of pulsed power network and proposes a system operation procedure for the localized systems. The proposed procedure satisfies the inherent requirements of the power network. First, the establish of a new power transmission path is triggered by a consumer demand occurring. Second, the consumer can receive power from multiple generations simultaneously. Overview of the proposed procedure and simulation results are described.

### **Pulsed Power Network with Inherent Operating Procedure and Multiple Relaying of Power Routers** Hisayoshi SUGIYAMA, Mami CHATANI, Ryousuke SIMIZU and Kenji YASUI

### 2017 IEEE Global Conference on Consumer Electronics (GCCE), Nagoya, Japan, Oct. 24, (2017)

Pulsed power network is one of the alternatives of smart grid systems. This scheme is applicable especially to localized power grid where only distributed generations supply power to consumers. In this demonstration, a miniature model of the localized pulsed power network is constructed and performed with two distributed generations, four consumers, and eight power routers. This model is operated with inherent procedure for effective power distribution over consumers and with multiple relaying of power routers for enhanced power transmission capacity.

# Power Transmission Procedure for Localized Pulsed Power Network with Distributed Generations and Consumers

Hisayoshi SUGIYAMA 2017 IEEE Global Conference on Consumer Electronics (GCCE), Nagoya, Japan, Oct. 24, (2017) A power transmission procedure is proposed for localized pulsed power networks that consist of distributed generations and consumers. The pulsed power network has affinity with distributed generations and high reliability based on decentralized system control. With this scheme, power networks can be operated where consumers are supplied power by distributed generations only. With the proposed procedure, as the inherent requirements of the power networks, the establish of a new power transmission path is triggered by a consumer demand occurring, and the consumer can receive power from multiple generations simultaneously. Simulations confirm the system performance.

### Photocatalytic Water Oxidation by Persulphate with a Ca<sup>2+</sup> Ion-Incorporated Polymeric Cobalt Cyanide Complex Affording O<sub>2</sub> with 200% Quantum Efficiency

Yusuke YAMADA, Kohei OYAMA, Tomoyoshi SUENOBU and Shunichi FUKUZUMI

Chem. Commun., Vol. 53, pp. 3418-3421 (2017)

Incorporation of a small amount of  $Ca^{2+}$  ions into a polymeric cobalt cyanide complex to form  $Ca_x[Co^{II}(H_2O)_2]_{1.5-x}[Co^{III}(CN)_6]$  resulted in a significant enhancement of activity for photocatalytic water oxidation in a buffer solution (pH 7.0) containing  $[Ru(bpy)_3]^{2+}$  (bpy = 2,2'-bipyridine) as a photocatalyst and Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> as an electron acceptor to achieve a quantum efficiency of 200%.

### Dual Function Photocatalysis of Cyano-Bridged Heteronuclear Metal Complexes for Water Oxidation and Two-Electron Reduction of Dioxygen to Produce Hydrogen Peroxide as a Solar Fuel

Yusuke ARATANI, Tomoyoshi SUENOBU, Kei OHKUBO, Yusuke YAMADA and Shunichi FUKUZUMI *Chem. Commun.*, Vol. 53, pp. 3473-3476 (2017)

The photocatalytic production of hydrogen peroxide from water and dioxygen under visible light irradiation was made possible by using polymeric cyano-bridged heteronuclear metal complexes ( $M^{II}[Ru^{II}(CN)_4(bpy)]$ ;  $M^{II} = Ni^{II}$ , Fe<sup>II</sup> and Mn<sup>II</sup>), where the photocatalytic two-electron reduction of O<sub>2</sub> and water oxidation were catalysed by the Ru and  $M^{II}$  moieties, respectively.

### Heterogeneous Catalase-Like Activity of Gold(I)–Cobalt(III) Metallosupramolecular Ionic Crystals

Mihoko YAMADA, Nobuhito YOSHINARI, Naoto KUWAMURA, Toru SAITO, Satoshi OKADA, Sai P. MADDALA, Koji HARANO, Eiichi NAKAMURA, Kohei YAMAGAMI, Keisuke YAMANAKA, Akira SEKIYAMA, Tomoyoshi SUENOBU, Yusuke YAMADA and Takumi KONNO

Chem. Sci., Vol. 8, pp. 2671-2676 (2017)

Unique heterogeneous catalase-like activity was observed for metallosupramolecular ionic crystals  $[Au_4^{I}Co_2^{III}(dppe)_2(D-pen)_4]X_n$  ([1]X<sub>n</sub>; dppe: 1,2-bis(diphenylphosphino)ethane; D-pen: D-penicillaminate; X<sub>n</sub>: (Cl<sup>-</sup>)<sub>2</sub>, (ClO<sub>4</sub><sup>-</sup>)<sub>2</sub>, (NO<sub>3</sub><sup>-</sup>)<sub>2</sub> or SO<sub>4</sub><sup>2-</sup>) consisting of Au<sub>4</sub><sup>I</sup>Co<sub>111</sub><sup>III</sup><sub>2</sub> complex cations, [1]<sup>2+</sup>, and inorganic anions, X or X<sub>2</sub>. Treatment of the ionic crystals with an aqueous H<sub>2</sub>O<sub>2</sub> solution led to considerable O<sub>2</sub> evolution with a high turnover frequency of 1.4 x 10<sup>5</sup> h<sup>-1</sup> for the heterogeneous cobalt complexes, which was dependent on their size and shape as well as the arrangement of cationic and anionic species. These dependencies were rationalized by the presence of cobalt(II) centers on the crystal surface and their efficient exposure on the (111) plane rather than the (100) plane based on morphological and theoretical studies.

## Synthesis of CuPd Alloy Nanoparticles with High Efficacy for Aqueous Phase Catalytic Reduction of Nitroaromatics and Hexavalent Chromium

Himadri SAIKIA, Biraj J. BOTRAH, Yusuke YAMADA and Pankaj BHARALI

J. Colloid Interface Sci., Vol. 486, pp. 46-57 (2017)

We report a surfactant-free, economically feasible chemical route to synthesize bimetallic CuPd alloy nanoparticles under hydrothermal conditions. The structural and morphological characterizations of the nanoparticles are carried out by XRD, SEM/EDX, TEM, XPS and BET surface area analysis. The synthetic strategy comprises of 9:1 molar composition of  $Cu^{2+}$  and  $Pd^{2+}$  salt in the aqueous solution. The size of the nanoparticles is found within 3-4 nm with very notable specific surface area of 298 m<sup>2</sup>g<sup>-1</sup>. The synthesized nanoparticles exhibit excellent catalytic performance towards the aqueous phase reduction of 4-nitrophenol and 4-nitroaniline in the presence of NaBH<sub>4</sub> as a reducing agent and the conversion of toxic Cr(VI) to less toxic Cr(III) at room temperature. The bimetallic CuPd alloy nanoparticles are found to be catalytically more active and exhibit good recyclability corresponding to the monometallic Cu and Pd.

#### **Utilization of Polymeric Cyano-Bridged Metal Complexes as Heterogeneous Catalysts** Yusuke YAMADA

Bull. Jpn. Soc. Coord. Chem., Vol. 68, pp. 16-28 (2016) (in Japanese)

Recent reports on utilization of polymeric cyano-bridged metal complexes, which have reticular structures utilizing  $M^{C}$ -CN- $M^{N}$  coordination networks, as heterogeneous catalysts have been reviewed. Among the

complexes, the most widely investigated ones contain zinc ions at  $M^N$  sites acting as Lewis acid, where polymerization of epoxide such as propylene oxide, esterification of fatty acids, and hydrolysis of glycerides are catalyzed. Another class of complexes containing redox active transition metals such as iron (II), cobalt (II) and copper (II) at  $M^N$  sites, catalyze oxidation and reduction reactions. Some complexes thermally oxidize benzene and styrene to phenol and styrene oxide with hydrogen peroxide, respectively. Additionally, some complexes can also photocatalyze Fenton reaction to decompose organic dyes with hydrogen peroxide, benzene oxidation to phenol with molecular oxygen, and water oxidation to evolve dioxygen together with a photosensitizer. All the complexes allow the improvements to achieve highly active catalysts based on atomic insights with various manners.

## Efficient Photocatalytic Production of Hydrogen Peroxide from Water and Dioxygen with Bismuth Vanadate and Cobalt(II) Chlorin Complex

Kentaro MASE, Masaki YONEDA, Yusuke YAMADA and Shunichi FUKUZUMI

ACS Energy Lett., Vol. 1, pp. 913-919 (2016)

Efficient photocatalytic production of  $H_2O_2$  as a promising solar fuel from  $H_2O$  and  $O_2$  in water has been achieved by the combination of bismuth vanadate (BiVO<sub>4</sub>) as a durable photocatalyst with a narrow band gap for the water oxidation and a cobalt chlorin complex (Co<sup>II</sup>(Ch)) as a selective electrocatalyst for the two-electron reduction of  $O_2$  in a two-compartment photoelectrochemical cell separated by a Nafion membrane under simulated solar light illumination. The concentration of  $H_2O_2$  produced in the reaction solution of the cathode cell reached as high as 61 mM, when surface- modified BiVO<sub>4</sub> with iron(III) oxide(hydroxide) (FeO(OH)) and Co<sup>II</sup>(Ch) were employed as a water oxidation catalyst in the photoanode and as an  $O_2$  reduction catalyst in the cathode, respectively. The highest solar energy conversion efficiency was determined to be 6.6% under simulated solar illumination adjusted to 0.05 sun after 1 h of photocatalytic reaction (0.89% under 1 sun illumination). The conversion of chemical energy into electric energy was conducted using  $H_2O_2$  produced by photocatalytic reaction by an  $H_2O_2$  fuel cell, where open-circuit potential and maximum power density were recorded as 0.79 V and 2.0 mW cm<sup>-2</sup>, respectively.

### Hydrogen Peroxide Used as a Solar Fuel in One-Compartment Fuel Cells

Shunichi FUKUZUMI and Yusuke YAMADA

*ChemElectroChem*, Vol. 3, pp. 1978-1989 (2016)

Clean and highly efficient production of solar fuels as well as effective methods to store solar fuels have long been sought to solve global energy and environmental issues. Among solar fuels such as gaseous hydrogen and carbon monoxide, aqueous hydrogen peroxide  $(H_2O_2)$  is an ideal chemical for energy storage, because endothermic  $H_2O_2$  decomposition produces only water and oxygen. In addition,  $H_2O_2$  can be transported in plastic containers with a high energy density.  $H_2O_2$  can be converted into electricity by using  $H_2O_2$  fuel cells without a membrane and composed of an anode and a cathode, and they can selectively catalyze  $H_2O_2$ oxidation or reduction. The one-compartment structure without a membrane is more promising to develop low-costing fuel cells than a two-compartment structure with expensive membranes. This article provides a focused review of recent developments and future perspectives of  $H_2O_2$  fuel cells without membranes, combined with  $H_2O_2$  production from seawater and dioxygen in the air by utilizing solar energy.

## An Effective Preparation Method of Composite Photocatalysts for Hydrogen Evolution Using an Organic Photosensitizer and Metal Particles Assembled on Alumina-Silica

Yusuke YAMADA, Hideyuki TADOKORO and Shunichi FUKUZUMI

Catal. Today, Vol. 278, pp. 303-311 (2016)

Composite catalysts for photocatalytic hydrogen (H<sub>2</sub>) evolution were prepared by loading an organic electron donor–acceptor linked dyad [2-phenyl-4-(1-naphthyl)quinolinium ion, QuPh<sup>+</sup>–NA] as an organic photosensitizer and Pt or Cu particles as H<sub>2</sub>-evolution catalysts on alumina-silica. The composite catalysts loading Pt particles were prepared by two different methods; first, Pt particles were deposited by reduction of  $PtCl_6^{2^-}$  owing to photocatalysis of QuPh<sup>+</sup>–NA supported on alumina-silica (PD method), and second, alumina-silica was impregnated with the  $PtCl_6^{2^-}$  and calcined, and then QuPh<sup>+</sup>–NA was loaded on the Pt/alumina-silica by a cation exchange method (IMP method). When a composite catalyst was prepared by the IMP method, a high Pt-loading amount of 4.2 wt% was necessary to achieve the highest H<sub>2</sub>-evolution rate of 0.27 mol h<sup>-1</sup>. On the other hand, a composite catalyst prepared by the PD method exhibited three

times faster H<sub>2</sub> evolution (0.83 mol h<sup>-1</sup>) even though the loading amount of Pt was as low as 0.4 wt%. The activity of composite catalysts prepared by the PD method highly depends on the electric charges of precursors for Pt particles. A composite catalyst prepared with positively charged Pt(NH<sub>3</sub>)<sub>4</sub><sup>2+</sup> as a precursor of Pt particles exhibited low catalytic activity with the H<sub>2</sub>-evolution rate of 0.10 mol h<sup>-1</sup>, which is significantly lower than the rate (0.27 mol h<sup>-1</sup>) for the composite catalysts employing Cu particles as an H<sub>2</sub>-evolution catalyst, because the Cu precursors of metal particles and negatively charged surfaces of alumina-silica should be taken into account to construct efficient H<sub>2</sub>-evolution catalysts.

### **Development and Evaluation of Full Field Type EDXRF Imaging Instrument**

Yuki TAKIMOTO, Masaki YAMANASHI, Francesco Paolo ROMANO and Kouichi TSUJI

*Adv. X-Ray. Chem. Anal., Japan*, Vol. 48, pp. 159-168 (2017) (in Japanese)

Energy dispersive X-ray fluorescence (EDXRF) is a nondestructive method for simultaneously analyzing multi elemental composition. To obtain a 2D elemental image, scanning type XRF imaging with a micro X-ray beam has been applied. In this case, the spatial resolution is very high. However, the drawback of this method is a long measurement time if a measurement area is large. In contrast, a full field type imaging technique is expected to obtain a large elemental image in a short time. Then, EDXRF imaging instrument with an X-ray CCD camera was evaluated as one of the tools to obtain information about elemental distribution of a specimen. This work describes the performance of the present EDXRF imaging instrument regarding such as spatial resolution and limit of detection. Finally, XRF images of practical samples were tried to be obtained.

### Application of Principal Component Analysis for Improvement of X-Ray Fluorescence Images Obtained by Polycapillary-Based Micro-XRF Technique

Shota AIDA, Tsuyoshi MATSUNO, Takeshi HASEGAWA and Kouichi TSUJI

Nucl. Instrum. Methods Phys. Res., Sect. B, Vol. 402, pp. 267-273 (2017)

Micro X-ray fluorescence (micro-XRF) analysis is repeated as a means of producing elemental maps. In some cases, however, the XRF images of trace elements that are obtained are not clear due to high background intensity. To solve this problem, we applied principal component analysis (PCA) to XRF spectra. We focused on improving the quality of XRF images by applying PCA. XRF images of the dried residue of standard solution on the glass substrate were taken. The XRF intensities for the dried residue were analyzed before and after PCA. Standard deviations of XRF intensities in the PCA-filtered images were improved, leading to clear contrast of the images. This improvement of the XRF images was effective in cases where the XRF intensity was weak.

## In-Situ Observation of Corrosion Process of Steel Sheet in a Solution by Confocal Micro XRF Technique

Ryohei HOSOMI, Jigi CHIN, Takashi DOI, Koji AKIOKA and Kouichi TSUJI

Bunseki Kagaku, Vol. 66, pp. 713-718 (2017) (in Japanese)

X-ray fluorescence (XRF) analysis is the technique which can carry out element analysis with non-destructive and non-contact. In our laboratory, a confocal micro-XRF method has been developed. This instrument can detect X-ray fluorescence which appeared in specific micro space by attaching the polycapillary X-ray lens to the X-ray tube and the detector. In this paper, we applied this technique for in-situ observation of corrosion process of steel sheet in a solution. In our research, we made up the sample cell for in-situ observation at solid-liquid interfaces. The steel sheet was immersed in water solution in the sample cell. As a result, coating blister occurred on the surface of the steel sheet. The corrosion process of the steel sheet could be observed by acquiring the elemental mapping images near the solid -liquid interface.

### X-Ray Fluorescence Imaging

Kouichi TSUJI

In *Introduction to Analytical Techniques for Iron and Steel Part III*, The Iron and Steel Institute of Japan, pp. 113-119 (2017) (in Japanese)

A non-destructive elemental imaging is important for environmental, forensic, and material sciences. To

obtain XRF elemental images, two approaches have been studied; scanning and projection types. Advantages and drawbacks of both techniques are discussed. In the scanning XRF technique, production of micro X-ray beam is important. A polycapillary optics is useful for this purpose, especially in the laboratory. XRF analysis is performed as the sample stage is moved to the fixed micro X-ray beam, leading to XRF elemental mapping. By applying confocal setup, 3D elemental analysis is also possible. The drawback of the scanning type XRF imaging would be a long acquisition time, although elemental images with high spatial resolution are obtained. A projection type XRF imaging has also been studied. WD-XRF imaging spectrometer was developed by using WDS spectrometer, a straight polycapillary optics, and X-ray CCD camera. The advantage of WD-XRS is a high energy-resolution, approximately 40 eV. Rapid elemental imaging is achieved in a short time less than 1 s by using highly sensitive 2D X-ray detector.

### Perspective of Analytical Chemistry Applied to Various Fields

Kouichi TSUJI

*Perspective and topics of 77<sup>th</sup> discussion on analytical chemistry*, The Japan Society for Analytical Chemistry p. 2 (2017) (in Japanese)

### X-Ray Technology

### Kouichi TSUJI

In Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons, Inc., total pages 36, in press (2017)

Analytical X-ray instruments are used to characterize materials in several ways. There are analytical instruments that can produce images of the internal structure of objects that are opaque to visible light. There are instruments used to determine chemical composition of an object, the crystalline phases of solids, and the complete atomic and molecular structure of a single crystal. The determination of particle size, structural information for fivers and polymers and the study of stress, texture, and thin films are applications that are growing in importance and can be examined with X-ray instruments. This article gives information on the characterization, generation, and properties of X-rays, and principles of X-ray diffraction. Small molecule and macromolecule single-crystal structure determinations are discussed. These techniques are compared with powder diffraction. X-ray reflectometers, position sensitive detectors, and area detectors are some of the special instruments designed to measure properties of the new and exotic materials being manufactured. Details on X-ray fluorescence spectrometry and X-ray radiography are also given.

## Photocatalytic Reduction of $CO_2$ by Pt-Loaded $TiO_2$ in the Mixture of Sub- and Supercritical Water and $CO_2$

Noritsugu KOMETANI, Shoutarou HIRATA and Masaaki CHIKADA

J. Supercrit. Fluids, Vol. 120, pp. 443-447 (2017)

Photocatalytic reduction of  $CO_2$  by Pt-loaded TiO<sub>2</sub> in the mixture of  $CO_2$  and water has been examined as a function of temperature and pressure up to 400 °C and 30 MPa. The abrupt increase in the yields of CO, CH<sub>4</sub>, HCOOH and HCHO was observed as temperature was elevated from 300 to 400 °C at a constant pressure of 30 MPa. This is attributed to the formation of uniform single phase mixture of water and CO<sub>2</sub> under supercritical condition, leading to the enhanced efficiency of CO<sub>2</sub> reduction. In contrast, the yield of H<sub>2</sub> produced by water reduction showed a monotonous increase with temperature because of the thermal acceleration of photocatalytic reaction. It is suggested that the control of the phase state of reaction medium has a key role in the determination of conversion efficiency for the photocatalytic reduction of CO<sub>2</sub> with water.

## Catalytic Enantioselective Aza-Diels-Alder Reactions of Unactivated Acyclic 1,3-Dienes with Aryl-, Alkenyl-, and Alkyl-Substituted Imines

Yasuo HATANAKA, Shuuto NANTAKU, Yuhki NISHIMURA, Tomoyuki OTSUKA and Tohru SEKIKAWA

Chem. Commun., Vol. 53, pp. 8996-8999 (2017)

Catalytic enantioselective aza-Diels-Alder reaction of unactivated acyclic dienes with aryl-, alkenyl-, and alkyl-substituted imines is described. With 5-10 mol % loadings of new Brønsted acid catalyst, the aza-Diels-Alder reaction of unactivated acyclic dienes proceeded to give the corresponding aza-Diels-Alder

adducts in high yields (up to 98%) with excellent enantioselectivity (up to 98% ee). Preliminary DFT calculations suggest that the reaction proceeds through a chiral ion pair intermediate.

## Effect of Solvents on the Crystal Formation of Poly(vinylidene fluoride) Film Prepared by a Spin-coating Process

Takashi NISHIYAMA, Takayuki SUMIHARA, Eriko SATO and Hideo HORIBE

*Polym. J.*, Vol. 49, pp. 319-325 (2017)

The effect on the solvent evaporation rate and solvent type on the crystal formation of poly(vinylidene fluoride) (PVDF) prepared by spin-coating was evaluated over time. In the much-solvent-remaining state, the crystalline phase of PVDF changed in the order of  $\alpha$ ,  $\gamma$  and  $\beta$  with the increasing dipole moment of the In the almost-all-solvent-evaporated state. the crystalline solvent. structure of PVDF/hexamethylphosphoramide with a higher dipole moment was dominantly dependent on the evaporation rate and varied in the order of  $\beta$ ,  $\gamma$  and  $\alpha$  with the increasing solvent evaporation rate. However, PVDF/triethyl phosphate, having a lower dipole moment, always formed the  $\alpha$  phase, regardless of the evaporation rate. The PVDF a phase in the concentrated solution state is difficult to transform into the  $\beta$  and y phases because the potential energy of each PVDF crystalline phase in the spin-coating method is strongly affected by both the polymer-solvent electrostatic interactions and the evaporation conditions. From the results of the crystal transition behavior, it was experimentally supported that the potential energy of the PVDF crystalline structure increases in the order of  $\alpha$ ,  $\gamma$  and  $\beta$ .

### Decomposition Processes of Photoresist Polymers by H Atoms Produced on Hot Wire Surfaces

Hironobu UMEMOTO, Teruto KATO, Masayuki TAKIGUCHI, Seiji TAKAGI and Hideo HORIBE *Thin Solid Films*, Vol. 635, pp. 27-31 (2017)

Mass spectrometry was used to identify the decomposition products of two typical photoresist polymers, Novolak and polymethylmethacrylate, by H atoms produced on hot wire surfaces. The production of  $CH_4$ and CO was confirmed for both polymers. Other possible products are  $C_3H_8$ ,  $C_4H_{10}$  or  $C_4H_8$ , and some esters such as  $CH_3COOC_2H_5$ . The production of  $CO_2$ ,  $C_2H_4$ ,  $C_2H_6$ , alcohols, and aromatics are minor. The possible decomposition mechanisms are discussed on the basis of density functional calculations of the energetics.

### Pressure Dependence of Photoresist Removal Rate Using Hydrogen Radicals

Masashi YAMAMOTO, Tomohiro SHIROI, Shiro NAGAOKA, Tomokazu SHIKAMA, Hironobu UMEMOTO, Keisuke OHDAIRA, Seiji TAKAGI, Takashi NISHIYAMA and Hideo HORIBE *J. Photopolym. Sci. Tech.*, Vol. 30, pp. 297-301 (2017)

Photoresists play a key role in lithography processes for the fabrication of electronic devices, but must be removed after processing. The removal method using hydrogen radicals, which are produced on a tungsten hot-wire catalyst, is effective to resolve some environmental and industrial problems in usual methods. However, the removal rate is enhanced just by decreasing Hydrogen pressure but the rate limitations not clarified in present study, we examined the removal rate dependence on the pressure and revealed that the upper limitation of the enhancement is achieved at 0.50 Pa was 8.3 times higher than that at 20 Pa when the surface temperature was  $250 \,^{\circ}C$ .

### Degradation of Hydrophilic Polymers in Aqueous Solution by Using Ozone Microbubble

Takashi NISHIYAMA, Kohei MATSUURA, Eriko SATO, Noritsugu KOMETANI and Hideo HORIBE

J. Photopolym. Sci. Tech., Vol. 30, pp. 285-289 (2017)

Polyethylene grycol (PEG) in aqueous solution was decomposed by treating  $O_3$  microbubbles and  $O_3$  water. The molecular weight of PEG treated with  $O_3$  microbubbles became lower, and the PEG degradation was enhanced in alkaline condition. PEG in aqueous solution was efficiently decomposed by reactive oxygen species generated by  $O_3$  decomposition, and  $O_3$  microbubbles promoted the  $O_3$  decomposition in the interface of  $O_3$  gas and surrounding water in which OH anion localized. PEG in aqueous solution was decomposed to inorganic oxygen by advanced oxidation process (AOP) of  $O_3$  microbubbles and  $H_2O_2$ , and the reduction rate of total organic carbon (TOC) was over 70%.

### Dissolution Promotion Effect of Addition of Low Molecular Compounds to Positive Tone Chemically Amplified Photoresist System

### Kazuma TAKAMORI, Takashi NISHIYAMA, Eriko SATO and Hideo HORIBE

J. Photopolym. Sci. Tech., Vol. 30, pp. 281-284 (2017)

Three-component chemically amplified photoresists which are consisted of a base resin, a photo acid generator and a dissolution inhibitor are promising because the high sensitivity and the high resolution can be satisfied at the same time. We studied about the dissolution promotion effect of hydroquinone (HQ) in the exposed area. HQ is a model compound of the photo induced product of the dissolution inhibitor. We disclosed that HQ depressed a glass transition temperature  $(T_g)$  of the base resin and the sensitivity was improved by enhancing the dissolution rate in the exposed area. It is expected that the dissolution rate was promoted when the post exposure bake temperature exceeded  $T_{\rm g}$  because the acid diffuse more easily.

### Analysis of Resist Removal Phenomenon Using Laser Irradiation

Tomosumi KAMIMURA, Hirouki KURAMAE, Takayuki YAMASHIRO, Kosuke NUNO, Yuji UMEDA, Shingo TSUJIMOTO, Ryosuke NAKAMURA, Takashi NISHIYAMA and Hideo HORIBE

J. Photopolym. Sci. Tech., Vol. 30, pp. 291-295 (2017)

Resist removal phenomenon with laser irradiation was analyzed by using a finite element (FE) method. Laser irradiation in the water can improve the resist removal effect as compared with that of normal atmosphere irradiation. A two-dimensional (2-D) micro-FE model was constructed based on the boundary surface between the Si wafer, resist and water during laser radiation. In the normal atmosphere, any effective stress did not occur along the x-axis direction in the resist. In contrast, for the laser irradiation in the water, large stress in the resist is thought to improve the resist removal efficiency.

### Photoresist Removal Using H Radicals Generated by Iridium Hot-Wire Catalyst

Masashi YAMAMOTO, Shiro NAGAOKA, Hironobu UMEMOTO, Keisuke OHDAIRA, Takashi NISHIYAMA and Hideo HORIBE

Int. J. Polym. Sci., Vol. 2017, 2983042 (5 pages) (2017)

We examined an environmentally friendly photoresist removal method using H radicals produced by decomposing hydrogen on a hor iridium catalyst. We examined the relationship between photoresist removal rate and its surface temperature using thin film interference and the removal properties using H radicals produced by the Ir catalyst. Decomposition behavior at polymer surface by radicals may be analyzed in further detail from the aspect of kinetics. Additionally, we investigated the oxygen addition effects on the removal rate. The photoresist removal rate increased with the oxygen additive amount and then decreased more gradually than in the case of using W filament. The increasing behavior was similar but there was a large difference between W and Ir catalyst in the decreasing behavior.

### Dismantlable Adhesion Properties of Reactive Acrylic Copolymers Resulting from Cross-linking and **Gas Evolution**

Eriko SATO, Shusei, IKI Keisuke YAMANISHI, Hideo HORIBE and Akikazu MATSUMOTO J. Adhes., Vol. 93, pp. 811-822 (2017)

The acrylic copolymers involving 2-hydroxyethyl acrylate (HEA) and tert-butyl acrylate (tBA) units as reactive units behave as pressure-sensitive adhesive type dismantlable adhesive materials. In order to clarify the individual role of HEA and tBA units on dismantlability, the 180° peel behavior after the dismantling treatment, i.e., heating in the presence of given amount of acid catalysts, was systematically investigated using the acrylic copolymers involving different amounts of the reactive units. It was revealed that transesterification of HEA units resulted in an increase in the cohesive force and modulus due to an increase in the molecular weight and cross-linking. Deprotection of tBA units, i.e., transformation of tBA to acrylic acid (AA) unit with isobutene evolution, promoted cross-linking by the esterification of AA units and tended to reduce a cohesive force by forming voids in the adhesive layer due to the evolution of isobutene gas. Interfacial failure in the peel tests corresponded with a high degree of cross-linking and increased modulus of the adhesive. Conversely, cohesive failure was associated with reduced cohesive strength of the adhesive layer and a low peel strength.

### Coumarin-containing Polymers as Thermo- and Photo-responsive Polymers: Copolymerization with Solvophilic or Solvophobic Comonomers to Control Themoresponsive Behavior

Eriko SATO, Ryota NAKANISI, Takashi NISHIYAMA and Hideo HORIBE

### Chem. Lett., Vol. 46, pp. 108-110 (2017)

The lower critical solution temperature of thermo- and photo-responsive polymers, which involve coumarin units having functions for the dual-responsivity in chloroform, was controlled by the copolymerization. The cloud points of the copolymers of 7-methacryloyloxycoumarin with methacrylic acid and methyl methacrylate as solvophobic and solvophilic comonomers, respectively, were tuned below room temperature to nearly the boiling point of chloroform. The photodimerization of the coumarin units in the copolymer resulted in a decrease of the cloud points, i.e., photoresponsivity.

### Photocuring of Radically Polymerizable Hyperbranched Polymers Having Degradable Linkages

Eriko SATO, Yoji YAMASHITA, Takashi NISHIYAMA and Hideo HORIBE

J. Photopolym. Sci. Technol., Vol. 30, pp. 241-246 (2017)

Hyperbranched polymers having a number of reductive disulfide bonds and radically reactive vinyl groups were synthesized by the bulk radical homopolymerization of bis(2-methacryloyloxyethyl)disulfide (disulfide based dimethacrylate, DSDMA) as a divinyl monomer in the presence of methyl 2-(bromomethyl)acrylate as an addition-fragmentation chain transfer agent. The resulting hyperbranched polymers (HB-DSDMAs) were photocured by irradiated at 365 nm in the presence of 2,2-dimethoxy-2-phenylacetophenone as a photo radical initiator. The photocured HB-DSDMA exhibited high transparency in the visible region and good solvent resistance for various organic solvents. Reduction of the disulfide groups smoothly proceeded in the presence of tributylphosphine as a reductant, and the cured HB-DSDMAs were completely solubilized. HB-DSDMAs were also photocured by irradiation at 254 nm due to the homolysis of the disulfide groups with subsequent initiation of the radical polymerization.

## Control of Adhesive Strength of Acrylate Polymers Containing 1-Isobutoxyethyl and Isobornyl Esters in Response to Dual Stimuli for Dismantlable Adhesion

Yusuke FUKAMOTO, Eriko SATO, Haruyuki OKAMURA, Hideo HORIBE and Akikazu MATSUMOTO *Appl. Adhes. Sci.*, Vol. 5, 6 (11 pages) (2017)

Background: To develop an adhesion system satisfying both constant adhesion strength during use and quick debonding ability during a dismantling process.

Methods: Adhesive properties were investigated for the random and block copolymers consisting of 1-isobutoxyethyl acrylate (iBEA), 2-ethylhexyl acrylate (2EHA), and 2-hydroxyethyl acrylate (HEA) as the dismantlable pressure-sensitive adhesives in the presence of a photoacid generator in response to dual external stimuli of photoirradiation and post baking.

Results: The use of LED combined with a new photoacid generator SIN-11 was enable us to achieve a rapid dismantling process during UV irradiation within several minutes. The protection of the ester alkyl group in the iBEA repeating unit to give an acrylic acid unit was suppressed by the introduction of isobornyl acrylate (IBoA) as the additional unit into the copolymer of iBEA, 2EHA, and HEA. While IBoA-containing block copolymer showed a constant adhesive strength during photoirradiation as the single external stimulus, deprotection was immediately induced by the subsequent heating, leading to a significant decrease in the adhesive strength.

Conclusion: The copolymer including the iBEA and IBoA units was revealed to function as the highly sensitive adhesive materials for dual-locked dismantlable adhesion.

## Thermal Degradation Behavior of Polymers Containing a *tert*-Butoxycarbonyl Group in the Side Chain and Application to Dismantlable Adhesion Materials

Fumiya SUZUKI, Eriko SATO and Akikazu MATSUMOTO

J. Adhes. Soc. Jpn., Vol. 53, pp. 4-9 (2017) (in Japanese)

In this study, we carried out the thermolysis of poly[p-(tert-butoxycarbonyloxy)styrene] (PBSt) prepared by radical polymerization and investigated the reaction mechanism for the formation of poly(p-hydroxystyrene) accompanying the elimination of isobutene and carbon dioxide from the *tert*-butoxycarbonyl (Boc) group in the side chain. We also discussed the reaction conditions for the quantitative transformation of the protected functional groups in the side chain of the polymer. The adhesion of aluminum plates using a copolymer of p-(tert-butoxycarbonyloxy)styrene and glycidyl methacrylate(P(BSt-co-GMA)) with a diamine cross-linker was carried out. The lap shear test revealed that high adhesion strength was observed for the thermally cured specimen at 100 °C for 4 h, and that the strength drastically decreased after heating at 150 °C for 1 h, due to

the decomposition of the Boc group in the copolymer.

### **Synthesis of Functional Hyperbranched Polymers by Radical Polymerization of Divinyl Monomers** Eriko SATO

In *Kinosei Monoma No Erabikata, Tsukaikata Jireishu*, Technical Information Institute, pp. 69-74 (508 pages in total) (2017) (in Japanese)

### **Precise Synthesis of Reactive Polymers and Their Application to Interfacial Functional Materials** Eriko SATO

The 97th CSJ Annual Meeting, CSJ Award Lecture for Outstanding Young Women Chemists, Keio University, March 16<sup>th</sup>, 2017, Abstracts, 1 A2-34 (2 pages)

### **Synthesis of Well-defined Reactive Polymers and Their Application to Advanced Adhesive Materials** Eriko SATO

The 63th Annual Kobe Polymer Research Symposium, *Kansai Branch of the Society of Polymer Science, Japan,* Award Lecture for Young Scientist, Kobe, July 14th, 2017, Abstracts, pp. 12-13 (in Japanese)

### **Precise Synthesis of Reactive Polymers and Their Application to Interfacial Functional Materials** Eriko SATO

International Union of Materials Research Societies-The 15<sup>th</sup> International Conference on Advanced Materials, Invited Lecture, Kyoto, August 28th, 2017, Abstracts, B4-I28-003 (1 page)

## Optical Properties and Solvatofluorochromism of Fluorene Derivatives Bearing S,S-Dioxidized Thiophene

Tatsumoto NAKAHAMA, Daichi KITAGAWA, Hikaru SOTOME, Shoji ITO, Hiroshi MIYASAKA and Seiya KOBATAKE

Photochem. Photobiol. Sci., Vol. 15, pp. 1254-1263 (2016)

Fluorene derivatives having phenylthiophene (FPT) or benzothiophene (FBT), and their *S*,*S*-dioxidized compounds (FPTO<sub>2</sub>, FPTO<sub>4</sub>, FBTO<sub>2</sub> and FBTO<sub>4</sub>) were prepared by oxidation of the thiophene rings in FPT and FBT with *m*-chloroperoxybenzoic acid. FPT and FBT exhibited similar optical properties for absorption maximum wavelength, fluorescence maximum wavelength and fluorescence quantum yield. However, the absorption and fluorescence spectra of FPTO<sub>2</sub> were largely shifted toward longer wavelength in comparison with those of FPT, and their fluorescence spectra and the fluorescence quantum yield of FBTO<sub>2</sub> and FBTO<sub>4</sub> were similar to those of FBT. Moreover, FPTO<sub>2</sub> and FBTO<sub>2</sub> showed large solvatofluorochromism. Such solvent dependent properties are ascribed to the charge-transfer character of the molecules.

### Polymorphs of a Diarylethene That Exhibits Strong Emission and Direct Visualization of Polymorphic Phase Transition Process by Fluorescence Color Change

Daichi KITAGAWA, Tatsumoto NAKAHAMA, Katsuya MUTOH, Yoichi KOBAYASHI, Jiro ABE, Hikaru SOTOME, Shoji ITO, Hiroshi MIYASAKA and Seiya KOBATAKE

Dyes Pigm., Vol. 139, pp. 233-238 (2017)

Luminescent solid-state materials with high fluorescence quantum yield have attracted much attention in application to organic optoelectronics. In the course of study of photochromic diarylethene crystals, it was found that two polymorphic forms of a diarylethene are obtained by recrystallization from acetone and n-hexane solutions. Both polymorphic crystals exhibited strong emission whose fluorescence quantum yield (> 0.5) is much higher than that in n-hexane solution (0.017). Furthermore, the thermodynamic solid-state polymorphic phase transition was found and the process was directly visualized by a fluorescence color change.

## Solvent Effect of Fluorescence On/Off Switching of Diarylethene Linked to Excited-State Intramolecular Proton Transfer Fluorophore

Tatsumoto NAKAHAMA, Takayoshi MUKAIYAMA, Daichi KITAGAWA and Seiya KOBATAKE

### Res. Chem. Intermed., Vol. 43, pp. 5321-5336 (2017)

Efficient fluorescence on/off switching of a dyad consisting of a photochromic diarylethene and a fluorescence dye based on excited state intramolecular proton transfer (ESIPT) was designed and demonstrated. Diarylethenes linked to (2-(2-methoxy-5-methylphenyl)benzothiazol-6-yl)and (2-(2-hydroxy-5-methylphenyl)benzothiazol-6-yl)-9,9-dioctylfluorene moieties (1a and 2a, respectively) exhibited fluorescence on/off switching upon alternating irradiation with ultraviolet and visible light in various solvents. The fluorescence on/off contrast of 2a was found to be higher than that of 1a in *n*-hexane because the overlap integral between the absorption spectrum of the diarylethene closed-ring form and the fluorescence spectrum of 2a is larger than that of 1a. Diarylethene 2a exhibited green fluorescence with large Stokes shift in *n*-hexane, which is ascribed to the ESIPT process from the enol form to the keto form. In contrast, the fluorescence of 2a in N.N-dimethylsulfoxide (DMSO) was mainly observed as blue fluorescence from enol form, while diarylethene **1a** exhibited blue fluorescence in *n*-hexane and DMSO. The fluorescence on/off contrast of 2a in n-hexane was higher than that in DMSO because of the difference in the spectral overlaps in *n*-hexane and DMSO.

### Fluorescence On/Off Switching in Polymers Bearing Diarylethene and Fluorene in Their Side Chains

Tatsumoto NAKAHAMA, Daichi KITAGAWA, Hikaru SOTOME, Shoji ITO, Hiroshi MIYASAKA and Seiya KOBATAKE

### J. Phys. Chem. C, Vol. 121, pp. 6272-6281 (2017)

A diarylethene-fluorene dyad connected by an ester bond (DE-FL) and random and alternating copolymers with diarylethene and fluorene moieties in their side chains (poly(DE1<sub>x</sub>-co-FL1<sub>y</sub>) and poly(DE1-alt-FL2)) were synthesized, and their fluorescence on/off switching properties were investigated. All compounds exhibited reversible photochromism and fluorescence on/off switching in a solution upon alternating irradiation with ultraviolet and visible light. Although the fluorescence intensity of DE-FL linearly decreased with increasing photocyclization conversion of the diarylethene, the fluorescence intensity of poly(DE1<sub>x</sub>-co-FL1<sub>y</sub>) at the same molar fraction of diarylethene/fluorene significantly decreased with photocyclization conversion. Moreover, the fluorescence intensity of the polymers in the photostationary state was much lower than that of DE-FL. These results indicate that the fluorescence on/off switching properties of the polymers were improved by introducing diarylethene and fluorene moieties into their side chains. Moreover, it was revealed that the monomer sequences and the molar fractions of the diarylethene and fluorene moieties into their side chains. Moreover, it fluorescence on/off switching properties of the diarylethene and fluorene moieties into their side chains. Moreover, it was revealed that the monomer sequences and the molar fractions of the diarylethene and fluorene moieties into their side chains. Moreover, it was revealed that the monomer sequences of the copolymers.

## Thiophene-*S*,*S*-Dioxidized Diarylethenes for Light-Starting Irreversible Thermosensors That Can Detect a Rise in Heat at Low Temperature

Daichi KITAGAWA, Koki TANAKA and Seiya KOBATAKE

J. Mater. Chem. C, Vol. 5, pp. 6210-6215 (2017)

Diarylethenes having trimethylsilyl and triethylsilyl groups at the reactive positions and their *S*,*S*-dioxidized diarylethenes were synthesized and their optical and thermal properties were investigated. Upon irradiation with ultraviolet light, the diarylethenes and thiophene-*S*,*S*-dioxidized diarylethenes underwent photochromic reactions from the colorless open-ring isomer to the colored closed-ring isomer. The photogenerated closed-ring isomers were found to undergo thermal bleaching reactions to produce colorless byproducts. In particular, the thiophene-*S*,*S*-dioxidized diarylethene having a triethylsilyl group at the reactive positions underwent the thermal bleaching reaction even at -40 °C. Such materials could be used as light-starting irreversible thermosensors that can detect a rise in heat at low temperature.

## Wavelength-Selective and High-Contrast Multicolour Fluorescence Photoswitching in a Mixture of Photochromic Nanoparticles

Sanae ISHIDA, Tuyoshi FUKAMINATO, Daichi KITAGAWA, Seiya KOBATAKE, Sunnam KIM, Tomonari OGATA and Seiji KURIHARA

Chem. Commun., Vol. 53, pp. 8268-8271 (2017)

Wavelength-selective and high-contrast multicolor fluorescence photoswitching between white-, orange-, cyan-, and dark-colors was successfully demonstrated in a mixture of two distinguishable emission colored photochromic nanoparticles composed of different pairs of a photoswitching unit and a fluorescence unit.

## Efficient Cycloreversion Reaction of a Diarylethene Derivative in Higher Excited States Attained by Off-Resonant Simultaneous Two-Photon Absorption

Hikaru SOTOME, Tatsuhiro NAGASAKA, Kanako UNE, Chiaki OKUI, Yukihide ISHIBASHI, Kenji KAMADA, Seiya KOBATAKE, Masahiro IRIE and Hiroshi MIYASAKA

J. Phys. Chem. Lett., Vol. 8, pp. 3272-3276 (2017)

Off-resonant excitation of the closed-ring isomer of a photochromic diarylethene derivative at 730 nm induced the efficient cycloreversion reaction with a yield of ~20%, while the reaction yield was only 2% under one-photon excitation at 365 nm. Excitation wavelength dependence of the one-photon cycloreversion reaction yield under steady-state irradiation in a wide wavelength range showed that the specific electronic state leading to the large cycloreversion reaction yield, which is originally forbidden in the optical transition but partially allowed owing to the low symmetry of the molecule, is spectrally overlapped with the electronic state accessible by the allowed one-photon optical transition in the UV region. Femtosecond transient absorption spectroscopy also revealed that the off-resonant two-photon excitation preferentially pumped the molecule into the specific state, leading to the 10-fold enhancement of the cycloreversion reaction.

### Synthesis and Optical Properties of Fluorescent Switchable Silica Nanoparticles Covered with Copolymers Consisting of Diarylethene and Fluorene Derivatives

Katsuya SHIMIZU and Seiya KOBATAKE

ChemistrySelect, Vol. 2, pp. 5445-5452 (2017)

Silica nanoparticles covered with random copolymers consisting of diarylethene monomer (DE) and fluorene monomer (FL) (SNP-poly(DE-*co*-FL)) were designed and synthesized by reversible addition-fragmentation chain transfer (RAFT) copolymerization of DE and FL initiated from a RAFT agent immobilized on the surface of silica nanoparticle. SNP-poly(DE-*co*-FL) and silica-free polymer (poly(DE-*co*-FL)), which are soluble in tetrahydrofuran, underwent reversible photoisomerization of DE moieties upon alternating irradiation with ultraviolet and visible light. They exhibited fluorescence ON/OFF switching between fluorescence on state of FL in the open-ring form of DE and fluorescence OFF state by an efficient Förster/fluorescence resonance energy transfer from the excited FL not only in the same polymer chain but also in the surrounding polymer chains to the closed-ring form of DE. Diarylethene-fluorene dyad (DE-FL) was synthesized to compare with fluorescence ON/OFF switching efficiencies of SNP-poly(DE-*co*-FL) and poly(DE-*co*-FL). The closed-ring isomers of DE in DE-FL, poly(DE-*co*-FL), and SNP-poly(DE-*co*-FL) were found to quench fluorescence of 0.78, 6.3, and 15.6 FL moieties, respectively. Thus, fluorescence switching efficiency of SNP-poly(DE-*co*-FL) was 2.5 times higher than poly(DE-*co*-FL) and 20 times higher than DE-FL. Furthermore, the closed-ring isomer of DE in SNP-poly(DE-*co*-FL) was found to quench 6.3 FL moieties in the same polymer chain and 9.3 FL moieties in four polymer chains in the neighborhood.

### Dependence of Photoinduced Bending Behavior of Diarylethene Crystals on Ultraviolet Irradiation Power

Akira HIRANO, Takuya HASHIMOTO, Daichi KITAGAWA, Kenji KONO and Seiya KOBATAKE *Cryst. Growth Des.*, Vol. 17, pp. 4819-4825 (2017)

The photoinduced bending behavior of diarylethene crystals upon irradiation with various ultraviolet (UV) light intensities was investigated. The bending velocity of the photoinduced bending crystals was estimated from the curvature of the bending crystal. The initial velocity of curvature change ( $V_{init}$ ) increased in proportion to the power of the incident UV light even when the crystal thickness was different, which suggests that the local strain caused by photoisomerization makes a cumulative contribution to the bending behavior. Moreover, for all UV light intensities, the relationship between  $V_{init}$  and the crystal thickness was well explained by the easily handled Timoshenko bimetal model. This result provides a validated method for the quantitative evaluation of the photoinduced bending velocity in various molecular crystals.

### Mechanical Behavior of Molecular Crystals Induced by Combination of Photochromic Reaction and Reversible Single-Crystal-to-Single-Crystal PhaseTransition

Daichi KITAGAWA, Kaito KAWASAKI, Rika TANAKA and Seiya KOBATAKE

Chem. Mater., Vol. 29, pp. 7524-7532 (2017)

A unique mechanical behavior of a molecular crystal induced by combination of a photochromic reaction and a reversible single-crystal-to-single-crystal (SCSC) phase transition is reported herein. A crystal of a diarylethene having octyl group at both sides was found to undergo a reversible thermodynamic SCSC phase transition accompanying a change in crystal length, which was clarified by DSC measurement, X-ray crystallographic analysis, and direct microscopic observation of the crystal length. Furthermore, upon irradiation with ultraviolet light, the diarylethene crystal exhibited an unusual photomechanical behavior. The mechanism of the behavior was proposed based on photoisomerization of the diarylethene from the open-ring isomer to the closed-ring isomer and a reversible thermodynamic SCSC phase transition, which was well-supported by thermal bending behavior of a photoirradiated crystal.

## Restricted Diffusion and Spatial Distribution Measurement of Guest Molecules in Polymer Thin Films as Revealed by Three-Dimensional Single-Molecule Tracking

Shoji ITO, Kengo HIRATSUKA, Yuhei TAGA, Satoshi TAKEI, Daichi KITAGAWA, Seiya KOBATAKE and Hiroshi MIYASAKA

J. Spectrosc. Soc. Jpn., Vol. 65, pp. 255-257 (2016) (in Japanese)

Restricted diffusion and spatial distribution measurement of guest dyes in thin film of poly(2-hydroxyethyl acrylate) on glass substrates have been introduced in Japanese.

### **Introduction of Our Laboratory**

Seiya KOBATAKE

*Newsletter, The Technical Association of Photopolymers, Japan*, Vol. 78, pp. 3-4 (2017) (in Japanese) Recent research topics in our laboratory has been introduced in Japanese.

### Photoresponsive Molecular Crystals for Light-Driven Micromachines

Daichi KITAGAWA and Seiya KOBATAKE

Photochemistry, Vol. 48, pp. 54-59 (2017) (in Japanese)

Various types of photomechanical motion have drawn much attention because there is a potential to create photomechanical actuators from molecular-scale to macro-scale. To construct photoactuators, it is necessary to utilize a molecular assembly with a small free volume. Photochromic compounds undergo photoreversible isomerization between the original colorless isomer and the photogenerated colored isomer upon alternating irradiation with UV and visible light. Among many known photochromic compounds, diarylethenes undergo photochromic reactions even in the crystalline phase. The present review introduces recent development in study of photomechanical crystals including crystal shape changes, bending velocity, dependence of the bending behavior on irradiation wavelength, the behavior in mixed crystal, new types of photomechanical motion, and applications. These photomechanical behaviors are based on geometrical structure changes in the crystalline phase, and can be applied to macro-sized light-driven actuators.

### Unusual Photoinduced Bending Behavior of Photochromic Diarylethene Crystals

Seiya KOBATAKE, Daichi KITAGAWA, Rika TANAKA and Kaito KAWASAKI

8th International Symposium on Photochromism (ISOP 2016), Oral Presentation, O-5, East China University of Science and Technology, Shanghai, China, November 4-7 (2016)

The unusual photoinduced bending behavior of photochromic diarylethene crystals has been presented in English.

### **Photoinduced Rapid and Explosive Fragmentation of Diarylethene Crystals Having Urethane Bonding** Daichi KITAGAWA, Tomohiro OKUYAMA, Rika TANAKA and Seiya KOBATAKE

8th International Symposium on Photochromism (ISOP 2016), Poster Presentation, P-4, East China University of Science and Technology, Shanghai, China, November 4-7 (2016)

The photoinduced rapid and explosive fragmentation of diarylethene crystals having urethane bonding has been presented in English.

### The Effect of Monomer Sequence for the Fluorescence On/Off Switching Properties in Polymers Bearing Diarylethene and Fluorene in Side Chains

Tatsumoto NAKAHAMA, Daichi KITAGAWA, Hikaru SOTOME, Syoji ITO, Hiroshi MIYASAKA and Seiya KOBATAKE

8th International Symposium on Photochromism (ISOP 2016), Poster Presentation, P-28, East China

University of Science and Technology, Shanghai, China, November 4-7 (2016)

The effect of monomer sequence for the fluorescence ON/OFF switching properties in polymers bearing diarylethene and fluorene in the side chain has been presented in English.

### Synthesis and Characterization of Fluorescence Switchable Silica Nanoparticle Covered with Copolymers Consisting of Diarylethene and Fluorene Derivatives

Katsuya SHIMIZU and Seiya KOBATAKE

8th International Symposium on Photochromism (ISOP 2016), Poster Presentation, P-79, East China University of Science and Technology, Shanghai, China, November 4-7 (2016)

Synthesis and characterization of fluorescence switchable silica nanoparticle covered with copolymers consisting of diarylethene and fluorene derivatives have been presented in English.

# Organic Crystalline Materials Accompanying Coloration, Bending, and Twisting upon Photoirradiation

### Seiya KOBATAKE

6th CSJ Chemistry Festa 2016, the Chemical Society of Japan, Invited Lecture, C2-02, Tower Funabori, November 14-16 (2016) (in Japanese)

Photochromism, photomechanical bending, and novel photomechanical behavior of diarylethene crystals have been presented in Japanese.

### Photomechanical Behavior of Photochromic Diarylethene Single Crystals

Daichi KITAGAWA and Seiya KOBATAKE

Symposium on Soft Robots: Mechanical Materials, Invited Lecture, Nishiwaseda Campus, Waseda University, May 27 (2017) (in Japanese)

Photomechanical behavior of diarylethene crystals has been presented in Japanese. The crystalline materials showing the photoreversible shape change are useful for application to photoactuators.

### Photoinduced Electron Transfer from Aromatic Amino Acids to the Excited Isoalloxazine in Single Mutated Flavin Mononucleotide Binding Proteins: Effect of the Dimer Formation on the Rate and the Electrostatic Energy Inside the Proteins

Nadtanet NUNTHABOOT, Kiattisak LUGSANANGARM, Arthit NUEANGAUDOM, Somsak PIANWANIT, Sirirat KOKPOL, Fumio TANAKA, Seiji TANIGUCHI, Haik CHOSROWJAN, Takeshi NAKANISHI and Masaya KITAMURA

Comput. Theor. Chem., Vol. 1108, pp. 1-9 (2017)

Conformational changes in the single mutated flavin mononucleotide binding proteins (FBP), E13K (Glu13 of wild type FBP is replaced by Lys), E13R (Glu13 replaced by Arg), E13T (Glu13 replaced by Thr) and E13Q (Glu13 replaced by Gln) upon dimer formations were studied through the phenomena of photoinduced electron transfer (ET) from tryptophan 32 (Trp32) and tryptophan 106 (Trp106) to the excited isoalloxazine (Iso\*). The ET rates were obtained with atomic coordinates of the proteins determined by a method of molecular dynamics simulation (MDS) and an ET theory using the reported experimental fluorescence decays of the FBPs. The value of the net electrostatic energy (NetES) between the photo-products and ionic groups inside the proteins increased in magnitude upon the dimer formation in every mutated FBP. Dependencies in the logarithmic ET rate (In Rate) on the donor-acceptor distances (Rc) could not be approximated with simple linear nor parabolic functions in most ET donors, which are ascribed to the relatively greater values of the NetES in the dimers compared to the energy terms of the standard free energy gap (SFEG), solvent reorganization energy (SROE) and the electrostatic energy between the photo-products (ESDA) in total free energy gap (GT) in the ET rates. The NetES vs Rc relations displayed two distinct groups in Trp32KB, Trp32QA and Trp32QB. The ln Rate vs Rc relations in these donors displayed different behaviors between the two groups.

### Localized Solvent Effects on the Crystal Habit of tert-Butoxycarbonyl-L-asparagine (BocASN)

Masaru HIRANO, Koichi IGARASHI and Hiroshi OOSHIMA

J. Chem. Eng. Jpn., Vol. 50, pp. 207-212 (2016)

Solvent selection is one of the most important factors for the control of crystal habits. However, this

relationship is poorly understood. The aim of this study was to determine the solvent selectivity to obtain a desired crystal habit using *tert*-butoxycarbonyl-L-asparagine (BocASN) as a model compound. The [110], [100], and [001] faces were dominant for the BocASN crystals obtained from acetone and ethanol. However, the [011], [100], and [001] faces were dominant for those obtained from methanol. The interactions between the solvent molecules and the functional groups exposed on the crystal surface were examined. The solvent-surface interactions on each surface of the BocASN crystal were dependent on the type of solvent. The different solvent-surface interactions along the a-, b-, and c-axes affected the growth rate and aspect ratio of the crystal. The analysis of the solvent-surface interactions is useful to predict the crystal habit.

## Cooling Crystallization Using a mL-Scale Continuous Crystallizer Equipped with a High Speed Agitator for Production of Uniform Small Crystals

### Koichi IGARASHI and Hiroshi OOSHIMA

### J. Chem. Eng. Jpn., Vol. 49, pp. 805-808 (2016)

A mL-scale continuous crystallizer has been newly developed to produce small crystals with a narrow size distribution. The crystallizer is composed of a stainless-steel mixing vessel with an inner working volume of 7.9 mL and a high-speed agitator that can agitate the crystallization solution up to 24,000 rpm. In previous work, the crystallizer was used for the drowning-out crystallization of glycine and L-alanine. The crystals obtained with the novel crystallizer were small and uniform in size, comparing with those obtained with a conventional beaker-scale semi-batch and continuous MSMPR type crystallizers. In this study, the cooling crystallization of l-alanine was attempted using the mL-scale crystallizer. The undersaturated hot solution of L-alanine and the water-immiscible coolant liquid was introduced into the crystallizer and were intensely agitated. The solution was dispersed as small droplets into the coolant liquid and rapidly cooled. The crystals obtained by the mL-scale cooling crystallizer are small and uniform in size as well as the drowning-out crystallization.

## Water Solubilization of Fullerene Derivatives by $\beta$ -(1,3-1,6)-D-Glucan and Their Photodynamic Activities toward Macrophages

Atsushi IKEDA, Tatsuya IIZUKA, Naotake MAEKUBO, Kazuyuki NOBUSAWA, Kouta SUGIKAWA, Kazuya KOUMOTO, Toshio SUZUKI, Takeshi NAGASAKI and Motofusa AKIYAMA *Chem. Asian J.*, Vol. 12, pp. 1069-1074 (2017)

Anionic and neutral fullerene derivatives were dissolved in water by using  $\beta$ -(1,3-1,6)-D-glucan ( $\beta$ -1,3-glucan) as a solubilizing agent. In the water-solubilized complexes, the concentrations of fullerene derivatives were  $\approx 0.30$  mm and the average particle sizes were  $\approx 90$  nm. The  $\beta$ -1,3-glucan-complexed fullerene derivative with a carboxylic acid was found to have higher photodynamic activity toward macrophages under visible-light irradiation ( $\lambda$ >610 nm) than other  $\beta$ -1,3-glucan-complexed fullerene derivatives. This result suggests that carboxylic acid moieties in the complex enhance the binding affinity with  $\beta$ -1,3-glucan receptors on the surface of macrophages when the  $\beta$ -1,3-glucan is recognized. In contrast, all  $\beta$ -1,3-glucan-complexed fullerene derivatives showed no photodynamic activity toward HeLa cells under the same conditions.

## Formation of β-(1,3-1,6)-D-Glucan-Complexed [70]Fullerene and its Photodynamic Activity towards Macrophages

Atsushi IKEDA, Motofusa AKIYAMA, Kouta SUGIKAWA, Kazuya KOUMOTO, Yuta KAGOSHIMA, Jiawei LI, Toshio SUZUKI and Takeshi NAGASAKI

Org. Biomol. Chem., Vol. 15, pp. 1990-1997 (2017)

[70]Fullerene was dissolved in water by complexation with  $\beta$ -1,3-glucan using a mechanochemical high-speed vibration milling apparatus. The photodynamic activity of  $\beta$ -1,3-glucan-complexed C70 was highly dependent on the expression level of dectin-1 on the cell surfaces of macrophages. The photodynamic activity increased as a result of a synergistic effect between  $\beta$ -1,3-glucan-complexed 1'-acetoxychavicol acetate and the C70 complex.

# Photoresponsive Gene Delivery System: Photoregulation of Intracellular Trafficking Using Photoresponsive Liposome

Takeshi NAGASAKI and Tsutomu HAMADA

### *Rev. Laser Eng.*, Vol. 45, in press (in Japanese)

Since light as a stimulus can be controlled both temporally and spatially, photo-irradiation improves both the endosomal escape of exogenous DNA and DNA release from the complexes with carriers. When a photo-responsive cationic lipid formed a cell-sized giant vesicle, we observed the photo-isomerization effect of azobenzene on its shape change. Photoswitching the membrane line tension induced reversible transitions between a closed sphere and an opened disk with a bilayer pore. In a transfection experiment using a photoresponsive cationic lipid, UV irradiation improved the transfection efficiency. After the lipoplexes passed through the plasma membrane by endocytosis, *trans* to *cis* isomerization of azobenzene moiety destabilized the vesicle membrane, thus accelerating not only the membrane fusion of the photo-responsive lipid vesicles but also the endosomal escape of the exogenous DNA.

## Displaying a Recombinant Protein on Flocs Self-Produced by *Escherichia coli* through Fused Expression with Elongation Factor Ts

Yoshihiro OJIMA, Shota NUNOGAMI, Masayuki AZUMA and Masahito TAYA

*Enzyme Microb. Technol.*, in press (DOI:10.1016/j.enzmictec.2017.08.010)

The utility of engineering flocculation is wildly recognized in applied and environmental microbiology. We previously reported self-produced flocculation of *Escherichia coli* cells by overexpressing the native *bcsB* gene that encodes a component of the cellulose synthesis pathway. Further experiments clarified that the spontaneous *E. coli* flocs were proteinous, and elongation factor Ts (Tsf) was the main component. In this study, we demonstrated successful expression of a fusion protein consisting of Tsf and green fluorescence protein (GFP) on *E. coli* flocs. Interestingly, the percentage of Tsf-GFP in total floc protein reached approximately 15% (w/w). The proposed design of a fusion protein with Tsf enables displaying a recombinant target protein on the floc structure.

## Quantitative Evaluation of Recombinant Protein Packaged into Outer Membrane Vesicles of *Escherichia coli* Cells

Yoshihiro OJIMA, Kyota YAMAGUCHI and Masahito TAYA

Biotechnol. Prog., in press (DOI:10.1002/btpr.2536)

Outer membrane vesicles (OMVs) are spherical bilayered proteolipids released from the cell surfaces of bacteria, which have gained traction in the biotechnology fields. Bacterial cellular machinery can be genetically engineered to produce and package heterologous enzymes into OMVs, producing nanocarriers and nanoparticle catalysts. However, the productivity or efficiency of packaging the target protein into OMVs has not been quantitatively evaluated. In this study, we packaged green fluorescence protein (GFP) into the OMVs of *Escherichia coli* through N-terminal fused expression to outer membrane protein W (OmpW). The OMV productivity and amount of OmpW-GFP packaged in the OMVs were quantitatively compared between two hypervesiculating mutant strains  $\Delta nlpI$  and  $\Delta degP$ . Both strains increased the OMV production, but the  $\Delta nlpI$  strain additionally enhanced the packaging of OmpW-GFP into OMVs. It was further confirmed that Spr, a peptidoglycan endopeptidase, plays an important role in the enhanced packaging of OmpW-GFP released in the OMV fraction of both mutants was determined in terms of the OMV productivity and the packaging efficiency of OmpW-GFP into OMVs.

### Design and Fabrication of Devices for Investigating Cell-Sheet Stretch

Yang LIU, Yoshihiro OJIMA, Masanobu HORIE, Eiji NAGAMORI and Hideaki FUJITA *PioChin L* in pross (DOI:10.1007/s12206.017.1201.1)

*BioChip J.*, in press (DOI:10.1007/s13206-017-1301-1)

Recently, many efforts have been made to investigate the cell stretch response through focal adhesions, which are usually utilized by cells cultured on elastic materials. However, not all stretch sensing is mediated through focal adhesions but from cell-cell contacts such as adherence junctions. To unveil the details of the stretch-sensing mechanism through cell-cell contacts, we developed a cell-sheet extension device for visualizing dynamic changes of individual living cells induced by external mechanical stretch. A cell-sheet is an ideal observation object, as it can be comprised merely of cells without any mechanical influences from external matrices while maintaining normal cell-cell adhesions as in the in vivo situation. Two microfluidic extension devices were designed and fabricated using a silicone elastomer, which were capable of extending a cell-sheet made from Caco-2 cells up to 1.3- and 1.5-fold from its original state. Based on the obtained

results, we expected that such cell-sheet extension systems can be useful tools for understanding the mechanisms of cellular stretch sensing through cell-cell contacts in living cells.

## Flocculation of Real Sewage Sludge Using Poly- $\gamma$ -glutamic Acid Produced by *Bacillus* sp. Isolated from Soil

## Tao LIU, Kyouhei YAMASHITA, Yoshihiro FUKUMOTO, Taro TACHIBANA and Masayuki AZUMA *J. Chem. Eng. Jpn.*, Vol. 50, pp. 201-206 (2017)

In order to promote farmland utilization of the sewage sludge, a flocculant suitable for the agriculture application is required. In general an inorganic flocculant such as aluminium sulfate has been used at a large sewage disposal plant. However there is concern that aluminium is accumulated when it is returned to farmland, and therefore a biodegradable flocculant instead of the inorganic flocculant is required. To obtain biodegradable flocculants produced by microorganisms, microorganisms were isolated from soils and sewage sludges, and flocculation activity of those culture broths was evaluated. Here real sewage sludge was used for the evaluation because practical use was regarded as important. As a result the strains, V13 and RK14, were selected, and those were identified as Bacillus megaterium and Bacillus licheniformis, respectively. It was also found that the flocculations were caused by poly- $\gamma$ -glutamic acid ( $\gamma$ -PGA).  $\gamma$ -PGA from RK14 cells had considerably high molecular weight compared with the commercial  $\gamma$ -PGA, and the enantiomeric composition was different from that of PGA from other B. licheniformis. In order to obtain mutants with high  $\gamma$ -PGA productivity, RK14 cells were treated with ethyl methanesulfonate, and a mutant (RK14-46) was selected. The culture medium suitable for  $\gamma$ -PGA production by RK14-46 cells was totally different from that by RK-14 cells. The  $\gamma$ -PGA production reached to 21.1 g/L when RK14-46 cells were cultured in the optimum semi-synthetic medium at 30°C for 2 days. Besides, the combination of  $\gamma$ -PGA obtained from RK14-46 cells and chitosan, a cationic flocculant, was very effective for flocculation of real sewage sludge.

### Identification and Characterization of D-Succinylase, and a Proposed Enzymatic Method for D-Amino Acid Synthesis

Yosuke SUMIDA, Sachio IWAI, Yoshiaki NISHIYA, Shinya KUMAGAI, Toshihide YAMADA and Masayuki AZUMA

Adv. Synth. Catal., Vol. 358, pp. 2041-2046 (2016)

Chiral amino acids are important intermediates for the pharmaceutical industry. We have developed a novel one-pot enzymatic method for D-amino acid synthesis by the dynamic kinetic resolution of *N*-succinyl-DL-amino acids using D-succinylase (DSA) and *N*-succinylamino acid racemase (NSAR, EC 4.2.1.113). The DSA from Cupriavidus sp. P4-10-C, which hydrolyzes *N*-succinyl-D-amino acids enantioselectively to their corresponding damino acids, was identified for the first time by screening soil microorganisms. Subsequently, the DSA gene was cloned and overexpressed in *Escherichia coli*. DSA was shown to comprise two subunits with molecular masses of 26 kDa and 60 kDa. Additionally, the NSAR gene from *Geobacillus stearothermphilus* NCA1503, which racemizes *N*-succinylamino acids, was also cloned and overexpressed in *E. coli*. The highly purified DSA and NSAR prepared from each recombinant *E. coli* were characterized and used for D-amino acid synthesis. A one-pot enzymatic method converted 100 mM *N*-succinyl-DL-phenylalanine to D-phenylalanine in 91.1% conversion with 86.7% *ee*. This novel enzymatic method may be useful for the industrial production of many d-amino acids.

### ARHGEF10 Directs the Localization of Rab8 to Rab6-Positive Executive Vesicles

Satoshi SHIBATA, Tsubasa KAWANAI, Takayuki HARA, Asuka YAMAMOTO, Taro CHAYA, Yasunori TOKUHARA, Chinami TSUJI, Manabu SAKAI, Taro TACHIBANA and Shinobu INAGAKI *J. Cell Sci.*, Vol. 129, pp. 3620-3634 (2016)

The function of ARHGEF10, a known guanine nucleotide exchange factor (GEF) for RhoA with proposed roles in various diseases, is poorly understood. To understand the precise function of this protein, we raised a monoclonal antibody against ARHGEF10 and determined its localization in HeLa cells. ARHGEF10 was found to localize to vesicles containing Rab6 (of which there are three isoforms, Rab6a, Rab6b and Rab6c), Rab8 (of which there are two isoforms, Rab8a and Rab8b), and/or the secretion marker neuropeptide Y (NPY)-Venus in a Rab6-dependent manner. These vesicles were known to originate from the Golgi and contain secreted or membrane proteins. Ectopic expression of an N-terminal-truncated ARHGEF10 mutant

led to the generation of large vesicle-like structures containing both Rab6 and Rab8. Additionally, small interfering (si)RNA-mediated knockdown of ARHGEF10 impaired the localization of Rab8 to these exocytotic vesicles. Furthermore, the invasiveness of MDA-MB231 cells was markedly decreased by knockdown of ARHGEF10, as well as of Rab8. From these results, we propose that ARHGEF10 acts in exocytosis and tumor invasion in a Rab8-dependent manner.

### Testis-Specific Histone Variant H3t Gene Is Essential for Entry into Spermatogenesis

Jun UEDA, Akihito HARADA, Takashi URAHAMA, Shinichi MACHIDA, Kazumitsu MAEHARA, Masashi HADA, Yoshinori MAKINO, Jumpei NOGAMI, Naoki HORIKOSHI, Akihisa OSAKABE, Hiroyuki TAGUCHI, Hiroki TANAKA, Hiroaki TACHIWANA, Tatsuma YAO, Minami YAMADA, Takashi IWAMOTO, Ayako ISOTANI, Masahito IKAWA, Taro TACHIBANA, Yuki OKADA, Hiroshi KIMURA, Yasuyuki OHKAWA, Hitoshi KURUMIZAKA and Kazuo YAMAGATA

*Cell Rep.*, Vol. 18, pp. 593-600 (2017)

Cellular differentiation is associated with dynamic chromatin remodeling in establishing a cell-type-specific epigenomic landscape. Here. we find that mouse testis-specific and replication-dependent histone H3 variant H3t is essential for very early stages of spermatogenesis. H3tgene deficiency leads to azoospermia because of the loss of haploid germ cells. When differentiating spermatogonia emerge in normal spermatogenesis, H3t appears and replaces the canonical H3 proteins. Structural and biochemical analyses reveal that H3t-containing nucleosomes are more flexible than the canonical nucleosomes. Thus, by incorporating H3t into the genome during spermatogonial differentiation, male germ cells are able to enter meiosis and beyond.

### Application of Monoclonal Antibodies Against Mouse Dermokine

Kiyoshi HIGASHI, Cai-Xia WANG, Chikako YOKOYAMA, Keita YAMADA, Koichi SAITO and Taro TACHIBANA

Monoclon Antib Immunodiagn Immunother., Vol. 36, pp. 15-19 (2017)

Dermokine is most highly expressed proteins differentiating one of the in keratinocytes. Mouse dermokine has been reported to be encoded by 22 exons, and its expression leads to three transcripts,  $\beta$ ,  $\gamma$ , and  $\alpha$ , which are transcribed from two different transcriptional start sites. The  $\alpha$ isoform represents the carboxyl-terminal domain of the  $\beta$  isoform, whereas the  $\gamma$  isoform lacks this domain. To reveal the distributions and expression levels of each isoform in mice, we generated rat monoclonal antibodies against dermokine- $\beta/\gamma$  and dermokine- $\beta/\alpha$ . In immunofluorescence studies, the expression levels of dermokine in the cytosol of the cultured mouse keratinocytes were significantly elevated by high levels of extracellular calcium. In Western blot analyses, the expression levels of dermokine-β and dermokine- $\alpha$  were increased in the presence of high calcium. Finally, we developed a monoclonal antibody-based sensitive sandwich enzyme-linked immunosorbent assay (ELISA) and showed that the secreted dermokine- $\beta$  into the culture medium from mouse keratinocytes was significantly increased in a manner dependent on the extracellular calcium concentration. These dermokine-specific antibodies have allowed us to gain new insights into the role of each dermokine isoform in cutaneous homeostasis.

## Septin 9\_i2 Is Downregulated in Tumors, Impairs Cancer Cell Migration and Alters Subnuclear Actin Filaments

Pascal VERDIER-PINARD, Danièle SALAUN, Habib BOUGUENINA, Shun SHIMADA, Matthieu POPHILLAT, Stéphane AUDEBERT, Emilie AGAVNIAN, Sergiu COSLET, Emmanuelle CHARAFE-JAUFFRET, Taro TACHIBANA and Ali BADACHE

Sci. Rep., Vol. 7, 44976 (18 pages) (2017)

Functions of septin cytoskeletal polymers in tumorigenesis are still poorly defined. Their role in the regulation of cytokinesis and cell migrationwere proposed to contribute to cancer associated aneuploidy and metastasis. Overexpression of Septin 9 (Sept9) promotes migration of cancer cell lines. SEPT9 mRNA and protein expression is increased in breast tumors compared to normal and peritumoral tissues and amplification of SEPT9 gene was positively correlated with breast tumor progression. However, the existence of multiple isoforms of Sept9 is a confounding factor in the analysis of Sept9 functions. In the present study, we analyze the protein expression of Sept9\_i2, an uncharacterized isoform, in breast cancer cell lines and tumors and describe its specific impact on cancer cell migration and Sept9

cytoskeletal distribution. Collectively, our results showed that, contrary to Sept9\_i1, Sept9\_i2 did not support cancer cell migration, and induced a loss of subnuclear actin filaments. These effects were dependent on Sept9\_i2 specific N-terminal sequence. Sept9\_i2 was strongly down-regulated in breast tumors compared to normal mammary tissues. Thus our data indicate that Sept9\_i2 is a negative regulator of breast tumorigenesis. We propose that Sept9 tumorigenic properties depend on the balance between Sept9\_i1 and Sept9\_i2 expression levels.

### Crystal Structure and Characterization of Novel Human Histone H3 Variants, H3.6, H3.7, and H3.8

Hiroyuki TAGUCHI, Yan XIE, Naoki HORIKOSHI, Kazumitsu MAEHARA, Akihito HARADA, Jumpei NOGAMI, Koichi SATO, Yasuhiro ARIMURA, Akihisa OSAKABE, Tomoya KUJIRAI, Takeshi IWASAKI, Yuichiro SEMBA, Taro TACHIBANA, Hiroshi KIMURA, Yasuyuki OHKAWA and Hitoshi KURUMIZAKA

### *Biochemistry*, Vol. 56, pp. 2184-2196 (2017)

Non-allelic histone variants are considered as epigenetic factors that regulate genomic DNA functions in eukarvotic chromosomes. In this study, we identified three new human histone H3 variants (named H3.6, H3.7, and H3.8), which were previously annotated as pseudogenes. H3.6 and H3.8 conserve the H3.3-specific amino acid residues, but H3.7 shares the specific amino acid residues with H3.1. We successfully reconstituted the nucleosome containing H3.6 in vitro and determined its crystal structure. In the H3.6 nucleosome, the H3.6-specific Val62 residue hydrophobically contacts the cognate H4 molecule, but its contact area is smaller than that of the corresponding H3.3 Ile62 residue. The thermal stability assay revealed that the H3.6 nucleosome is substantially unstable, as compared to the H3.3 nucleosome. Interestingly, mutational analysis demonstrated that the H3.6 Val62 residue is fully responsible for the H3.6 nucleosome instability, probably because of the weakened hydrophobic interaction with H4. We also reconstituted the nucleosome containing H3.8, but its thermal stability was quite low. In contrast, purified H3.7 failed to form nucleosomes in vitro. The identification and characterization of these novel human histone H3 variants provide important new insights into understanding the epigenetic regulation of the human genome.

### Urban Engineering

### Architecture and Building Engineering

### Comparison Study of Elasto Plastic Behavior on Static and Dynamic Responses

Yoshiya TANIGUCHI, Tomoya MATSUI and Susumu YOSHINAKA

Proc. of the IASS Annual Symposium 2016 "Spatial Structures in the 21st Century", Tokyo Japan, Sep 29-30, ID1129

In this paper, the relationships between static load-carrying capacity and seismic resistant capacity are focused on, that is, the comparison study is carried out about elasto plastic behavior of both responses. The purpose is to establish an evaluation method of allowable maximum earthquake acceleration, which may bring a structure into an ultimate state. The both elasto plastic behavior is analyzed for single layer lattice domes under vertical loading, which is a static vertical uniform load and a vertical seismic motion. The relationships between equivalent velocity of static absorbed energy and vertical deformations are focused on as a static elasto plastic behavior. The other relationships is the maximum earthquake input acceleration and the equivalent velocity of strain energy of domes as a dynamic elasto plastic behavior. Consequently, the change of slopes between the elastic and plastic ranges is concerned with each other.

### Effect of Joints Eccentricity of Web Members on Load-carrying Capacity for Parallel Chord Truss Beams

Ryosuke TAKAOKA, Yoshiya TANIGUCHI and Susumu YOSHINAKA

Proc. of the IASS Annual Symposium 2016 "Spatial Structures in the 21st Century", Tokyo Japan, Sep 29-30, ID1232

It is well known that, to prevent flexural moments in truss members, they should be connected without joint eccentricity. Joints should be strong enough to transmit axial forces. Various industrialized joints have been developed for use in steel structures. We have studied a new jointing system for timber lattice structures. In designing timber structures, most designers wish to conceal steel jointing systems. Simpler jointing systems could be devised if some joint eccentricity were allowable. This study considers the effect of joint eccentricity on the load bearing capacity of parallel chord truss beams. A numerical study was carried out with the parameter of web member eccentricity to demonstrate the lowering of buckling loads and peak loads.

## Experimental Study on New Jointing System for Timber Lattice Structures by Direct Contact of Member Cross Sections in the Fiber Direction

Hitoshi OKUYAMA, Yoshiya TANIGUCHI and Yuki TANIGUCHI

Proc. of the IASS Annual Symposium 2016 "Spatial Structures in the 21st Century", Tokyo Japan, Sep 29-30, ID1255

It may be important to use timbers from thinning, to maintain forest in a good condition. The timbers from thinning are usually irregular goods because of their shorter length or smaller cross section. Lattice structures have been often adopted in overcoming this disadvantage. Former timber lattice structures may mostly stand on the technology of industrial steel truss systems. In this paper, a new concept is introduced in the transmission of member axial forces. The compressive member axial forces are directly delivered by the contact of cross sections, that is, timbers are mutually contacted through cross sections. The other tensile and shear forces are mainly delivered by steel plates hidden in timbers with drift pins. This basic technology itself is not innovative, however, it may be sufficient to abandon the conventional manner in realizing timber lattice structures with a screw jointing system.

### Settings of Tuning Ratios of Tuned Mass Dampers with Initial Displacement

Susumu YOSHINAKA, Keita KOZURU and Yoshiya TANIGUCHI

Journal of Structural and Construction Engineering (Transactions of AIJ), AIJ, 738, pp. 1177-1187, (2017) (in Japanese)

In order to control the transient response more effectively, we propose TMDs (Tuned mass dampers) with initial displacement. In our previous study, we formulated the equation for initial conditions to release initial TMD displacement. By using this equation, the structural response of the first mode with the lowest modal damping is eliminated on a two-degrees-of-freedom model. In this paper, we study the effect of the settings of TMDs tuning ratios on the control performance. And we study the causes focusing on the interrelationship between a main mass and two TMDs on the complex plane and the TMD power flow.

## Uncertainties in the Estimation of Local Peak Pressures on Low-Rise Buildings by Using the Gumbel Distribution Fitting Approach

Eri GAVANSKI, Kurt R. GURLEY (Univ. of Florida) and Gregory A. KOPP (Univ. of Western Ontario) *J. of Struct. Eng.*, 142(11), pp.1-14 (2016)

The lack of a standard accepted method to estimate local peak pressure coefficients from wind tunnel data can lead to inconsistent definitions and interpretations, particularly since cost and time constraints associated with wind tunnel tests of low-rise buildings necessitate that relatively short (equivalent full-scale) test durations be used. This paper focuses on a Gumbel distribution fitting method widely used in practice. Since the sources of uncertainty on estimated peaks include the use of short duration records (in practice) and the assumption that the observed peaks from wind tunnel pressure data are Gumbel distributed, this is quantified in detail in terms of the parameters determining the required minimum record length. It is shown that 15 observed peaks can lead to local peak pressure estimates with adequate precision for many design scenarios. However, the conversion of peak coefficients from a short duration to those of a longer duration requires an increase in the number of observed peaks to maintain precision.

### Fragility Assessment of Roof-to-Wall Connection Failures for Wood-Frame Houses in High Winds

Eri GAVANSKI and Gregory A. KOPP (Univ. of Western Ontario)

ASCE-AME J. of Risk Uncertainty Eng. Syst., Part A; Civ. Eng., 3(4): 04017013 (2017)

The Enhanced-Fujita Scale (EF-scale) is used to identify tornado intensity. It uses several Damage Indicators (DIs), each of which has descriptions of the Degrees-of-Damage (DOD) along with associated wind speeds. Recent research has indicated that for wood-frame, one- and two-family houses, differences in the structural details result in significant variations in the wind speeds estimated to cause specific levels of damage, particularly with respect to the performance of roofs. This suggests that a single damage indicator for this class of structure may be inadequate. In order to examine this point in detail, the paper focuses on failures of the roof-to-wall-connections (RTWCs) in wood-frame houses, which are frequently damaged in tornadic wind events. Fragility analyses were conducted using an extensive wind-tunnel-based dataset for the determination of the statistics of wind loads and full-scale house test data for the toe-nailed RTWC resistances. The wind load data came from wind tunnel simulations of the atmospheric boundary layer, which, as discussed in the paper, are likely to provide upper-bound failure wind speeds for tornadoes. The results indicate that the roof shape and the capacity of RTWCs (i.e., number/type of connections) are the primary factors affecting the failure winds for houses with dominant openings. Recommendations for modifications to the EF-Scale to account for these are provided.

### Evaluation of Typhoon Induced Wind Risk on Japanese Residential Houses due to Climate Change

Eri GAVANSKI, Kazuyoshi NISHIJIMA (Univ. of Kyoto) and Takashi MARUYAMA (Univ. of Kyoto)

Proc. of  $6^{th}$  U.S.- Japan Workshop on Wind engineering –Windstorm hazard reduction of critical infrastructure-, Tokyo, May 12-16, (2016)

This paper presents a reliability-based vulnerability model for Japanese residential houses under typhoon wind loads. Although vulnerability models for residential house have been studies especially in US, such model has not been developed in Japan where the characteristics of residential houses such as employed cladding components is different from those in US. Our focus in the developing the vulnerability model is to consider the regional difference of residential houses in order to estimate their wind risk with more accuracy. Although there are many reginal characteristic of residential houses to be considered, the current study deals with only the difference in roof tile fastener wind resistance as a starting point. Furthermore, using the developed vulnerability model with the wind speeds estimated from the probabilistic typhoon model under present and future climates, the annual expected monetary consequence due to typhoon wind load is evaluated for several Japanese regions and its difference due to climate change is evaluated.

### Households's Air-Conditioners Evaluation and Use under Electricity Shortage after the Disaster in 2011 -Thermal Control Use during Summer in Apartment Houses in Osaka City

Xiaoyong LIN and Noriko UMEMIYA

### Transaction of AIJ, 81(727), pp.785-794, (2016) (in Japanese)

Electricity conservation was requested by government in the national interest after the earthquake that occurred in Tohoku on March 11. Electric utility in Kansai asked businesses and households to reduce summer electricity consumption by up to 10 percent and 9 percent was reduced in households in 2012. This study clarifies how the

electricity consumption was reduced by questionnaire survey of apartments in Osaka city. 1) Electricity charges were lower in 2011 by 23.0% in August. The cooling charge was lower by 43.3%. The mean setting temperature was 26.0°C in 2004 and 27.5°C in 2011. Subjective degree of air conditioner use did not differ. Difference of regression estimates of cooling charge for mean setting temperatures between 2004 and 2011 was similar to the difference of mean cooling charge between in 2004 and in 2011. 2) Satisfaction with AC and orientation to AC was higher and awareness of cooling cost was lower in 2011. Consciousness of the environment was not rather lower in 2011. Residents depended on AC more greatly in 2011. 3) No relation was found between evaluation of thermal environment indoors and cooling charge in 2011.

### Air-Conditioner Use Effects on Thermal Environment and Sleep Quality in Bedrooms during Summer -Analysis of University Students in Osaka

Noriko UMEMIYA, Yoshiki TACHIBANA, Tomohiro KOBAYASHI and Yusuke NAKAYAMA

Proceedings of 9th Windsor Conference, 7-4, pp.1-8, Windsor, UK, April 7-10, (2016)

Analyses of thermal environment, thermal control behaviors, thermal sensations, and sleep quality yielded the following results indicating air conditioner (AC) use effects on sleep quality in 11 bedrooms during three periods of summer. 1) Outside temperatures were higher on AC use days but room temperatures during sleep were kept almost identical (25.7°C). 2) Sleep quality as evaluated by the OSA score was higher on AC use days. However, it was hotter and less acceptable on AC use days, although thermal comfort was not different. 3) On AC non-use days, the relation between thermal comfort and thermal sensation was stronger. Thermally acceptable ranges were wider on non-use days. 4) Relation between the OSA score and the degree of sound sleep was weaker on AC use days. The OSA score was more strongly related to thermal acceptability on AC use days than non-use days. 5) Differences in sleep quality were smaller between AC use days and non-use days than between the surveyed periods. Lower sleep quality in mid-summer was caused not by AC, but by higher room temperatures.

### **Relation between Constitutions and Thermal Control Use during Summer**

Noriko UMEMIYA, Bing ZHANG and Tomohiro KOBAYASHI

Proceedings of the 5th International Conference on Human-Environment System, TC4-4, pp.1-8, Nagoya, Japan, Oct 29-Nov 2, (2016)

Relation between thermal control use in summer and respondents' constitutions such as heat and cold resistance, tendency of catching cold, and bad circulation were investigated by questionnaire surveys carried out for Osaka apartment dwellers. 1-a) Males reporting a strong constitution do not use air conditioners, set the highest temperatures, and open windows the most. 1-b) Females reporting weaker constitutions do not use fans. 1-c) Occupied younger females who are 'tolerant to heat' use air conditioners and fans the most. 1-d) Occupied younger males who are intolerant to heat use air conditioners, close windows the most, and set the lowest temperatures. 1-e) Occupied younger women with bad circulation do not use air conditioners much, but set the temperature high. 2) Females who are intolerant of heat report the highest costs for air conditioners, whereas females who report weaker constitutions also report the lowest costs. 3) Frequency of air conditioners use is related to heat tolerance and age. Younger respondents use air conditioners frequently.

#### Lighting Styles and Electric Charge in Apartments

Noriko UMEMIYA, Shuta TAKAYAMA, Tomohiro KOBAYASHI and Yuya KOBAYASHI

on the behaviours when local lighting was used. It was highest for relaxing and lowest for eating.

Proceedings of the 9th Conference of China, Japan and Korea, pp.139-142, Busan, Korea, Aug 18-19, (2016) Questionnaire survey of lighting use and electric bill was carried out for more than three hundred family type apartments in Osaka to compare electric energy consumption against daytime and night time lighting styles. Lighting use in daytime and nighttime, electric bill in natural ventilation season, and basic attributes of apartments, family rooms and respondents were asked. Results show the followings: 1) 74.5 % had more than two lighting devices in family rooms. Two were 50.5 % and dominant. But only 8-15 % used them for nighttime local lighting. 2) 49.7 % rarely used daytime artificial lighting, whether 14.6 % used daytime lighting during family rooms stay. Frequency of nighttime local lighting use was lower for behaviors of eating, reading and working. 3) Electric bill of 'rarely daytime lighting' apartments was 12.0 % lower than that of 'almost lighting during stay' apartments. 4) Electric bill of night time 'single lighting' apartments was lower than other night time lighting style apartments, if lighting was used during stay. This tendency was true regardless of the stay duration. On the other hand, electric bill on night time 'single lighting' apartments was the highest, if daytime lighting was rarely used and if stay duration was shorter. 5) If daytime lighting was rarely used and if stay duration was longer, electric bill depended

### Urban Design and Engineering

## Autonomous Cane and Verbal Map Describing Vast Space for Improving Visually-impaired People's Daily Mobility

Yumie SAWADA, Takashi UCHIDA and Yukinori SAMIZO Japan Society of Traffic Engineers, Papers on Traffic Engineering, No. 36, pp. 139-144 (2016) (in Japanese)

## An Empirical Study on Verbal Map Guidelines for Visually-impaired People Navigation considering Daily Mobility Needs

### Mei TAKAHASHI and Takashi UCHIDA

*Journal of Japan Society of Civil Engineers, Ser. D3,* Vol.72, No.5, pp.I\_1085-I\_1094 (2016) (in Japanese) Unlike sighted people, visually-impaired people cannot use a high performance pedestrian navigation system. The purpose of this study is to revise verbal map guidelines that show rules for describing features in a town to enhance everyday mobility. Therefore, this study figures out feature information visually-impaired people use in everyday life.

This study presents a review of earlier studies and related studies, and make a speech augmented reality (AR) application. Then, two kinds of field experiments are conducted. The first experiment is a monitor experiment and has visually-impaired people use a smartphone which implemented a speech AR application in everyday life. The second experiment is a site experiment and has them use a pedestrian navigation system and walk in a course we set according to it. Finally, from the hearing result of those experiments, verbal map guidelines are revised.

### Study on the Effect that the Relationship and Evaluation for the Community Bus Gives Support Awareness to Business

### Yusuke KURASHIMA and Takashi UCHIDA

Journal of Japan Society of Civil Engineers, Ser. D3, Vol.72, No.5, pp.I\_721-I\_729 (2016) (in Japanese)

For the purpose of the acquisition of the new user and the increase in user, various use promotion measures are carried out by the community bus. Today, the measure for the purpose of bringing up attachment and support awareness for the bus is worked on. In such situation, it is that following two are important. First, evaluate a measure transversely and clarify the difference of the evaluation. Next, clarify about the relationship with the actual situation of the use and the evaluation and the attachment and support awareness to a bus.

In this study, we took up community bus "Taco-bass" of Akashi-shi, Hyogo as an example. We clarified the influence that the relation with the community bus such as the evaluation for various use promotion measures or the use of the bus, or the situation of the movement limitation, gave to support awareness, and showed consideration for the breeding of the support awareness.

## Causal Analyses of Attitudes of Residents along the Medium and Small Size River for the Posterior Evaluation of the Nature-Friendly Environment and the Water Amenity

### Yasumasa FUKUSHIMA and Takashi UCHIDA

Journal of Japan Society of Civil Engineers, Ser. D3, Vol.72, No.5, pp.I\_241-I\_249 (2016) (in Japanese)

In recent years the development of the urban river has been focusing on efforts for the environment and the water amenity besides the flood control and the water utilization. In the waterfront development the stakeholders/agents such as local governments, inhabitants, planners, and bodies concerned are mutually involved, in some cases however, the residents along the river have failed to value and then water amenity has made little progress.

This paper takes a case of the waterfront development of the small size river in an emerging built-up area. Going through several years after the project implementation, we take hold of the actual condition and the attitudes of residents by means of questionnaire survey to the inhabitants. This study performs respective analyses on the relationship between the factors towards the smooth implementation of the enterprise and the consensus formation and in urban riverside development considering development methods in order to promote the utilization with high evaluations from the inhabitants as concrete strategies.

### Questionnaire Survey of Riverfront Residents after Nature-oriented Water Amenity Development Project of a Minor River in a Built-up Area

### Yasumasa FUKUSHIMA and Takashi UCHIDA

Osaka City University, Memoirs of the Faculty of Engineering, Vol. 57, pp.11-25 (2016)

Recent municipal river development emphasizes environment and water amenity as well as flood control and water utilization. A waterfront development project involves multiple subjects such as a commissioning entity, riverfront residents, a planner, and agencies concerned. However, riverfront residents occasionally evaluate the project too little to encourage waterfront utilization. Therefore, examination based on a posterior situation is important for future improvement.

This study assesses waterside development in a minor river in an emerging built-up area. The actual conditions of and estimation of water amenity are comprehended using questionnaire survey of the riverfront residents at the project area several years after the completion. The analysis specifically examines their involvement in waterfront development. This study is expected to contribute fundamental data for examination and discussion of a development procedure highly appreciated by riverfront residents and effective for promotion of utilization, as concrete measures for smooth project performance and consensus building in the waterfront development of a municipal river.

### A Study on Bus Services to Support the Promotion of Additional Trips and Consumption by Accompanied Activity

Yusuke TAKAHASHI, Yasuo HINO and Takashi NISHIKAWA

Japan Society of Civil Engineers, Proceedings of Infrastructure Planning, No. 54, pp.1524-1529 (2016) (in Japanese)

The accompanied activities of elderly persons who should perform the key role of prosperity in the aging society may be making the increase of outside activities and additional trips and the consumption. Therefore, the suitable bus services must be investigated to promote the accompanied activities. In this study, the actual condition of the accompanied activities and the promotion effects of two types of bus services conducted in Kawachi-nagano city of Osaka Prefecture were investigated by two types of questionnaire surveys for general persons at the main rail station and bus passengers. As a result, some interesting findings came out of these surveys as followings. At first, in general, the accompanied activities made increasing the additional trips and consumption. And secondly, the introduced bus services made increasing the outside activities all the more. These results may provide the important information to investigate the more effective bus services to promote the prosperity in the aging society.

## A Study on Practice of Road Safety Education at School and Home by Using Instructor System for Bicycle

Yasuyuki TAKEDA, Yasuo HINO, Ryo NAKANISHI, Akira TOYOSHIMA and Tadashi SETOYAMA *Japan Society of Civil Engineers, Proceedings of Infrastructure Planning*, No. 54, pp.1903-1907 (2016) (in Japanese)

Recently, although the number of road accidents has been decreasing, the accident rate of the bicycle ride has been increasing. However, the gradual and continuous education at school for road safety may be not realized, because the almost of them must be depend on the police. Then, in this study, some questionnaire surveys for the road safety association of Osaka, some teachers and members of PTA were executed, in order to investigate the possibility of educating the responsible persons and coordinators between school and home, by using the instructor system for road safety for bicycle. As a result, an approach and processes to realize the intensive education at both school and home were proposed.

## Trial Implementation of Danish Cycling Game for Children in Japan and its Evaluation from a Developmental and Learning Perspective

Nagahiro YOSHIDA, Syuta HOSHIRO and Madoka YANO

*Japan Society of Civil Engineers, Proceedings of Infrastructure Planning*, No. 55, 2 pages (CD-ROM)(2017) (in Japanese)

## Issues of Children's Bicycle Safety Education: A Comparison of the Program between Different Organizers

Syuta HOSHIRO and Nagahiro YOSHIDA

*Japan Society of Civil Engineers, Proceedings of Infrastructure Planning*, No. 55, 6 pages (CD-ROM)(2017) (in Japanese)

### **Traffic-Conflict Analysis for the Installation of Bicycle Pavement Markings in Residential Roads** Takuma EDA and Nagahiro YOSHIDA

Japan Society of Civil Engineers, Proceedings of Infrastructure Planning, No. 55, 3 pages (CD-ROM)(2017) (in Japanese)

### A Study on Identifying Barriers and Potential Opportunities of Adaptive Cycles for People with Travel Difficulties

Takuya KONISHI and Nagahiro YOSHIDA

Japan Society of Civil Engineers, Proceedings of the annual meeting in Kansai, 2 pages (CD-ROM) (2017) (in Japanese)

### An Analysis on Motorcycle Driving Behavior of High School and University Students in Phnom Penh, the Kingdom of Cambodia

Toshiki KOYANAGI, Nagahiro YOSHIDA and Yuto KITAMURA

Japan Society of Traffic Engineers, Proceedings of the 37th annual conference(research paper), pp.701-704, (2017) (in Japanese)

In recent years, the motorcycle is widely used in developing countries so serious traffic accidents involving motorcycles have increased in some countries. Especially in Cambodia, the number of casualties in traffic accidents has increased about approximately 2.5 times during 2005-2014 as a serious social problem. Under these situations, JICA tried to improve a traffic problem by the implementation of traffic engineering and the traffic enforcement program, but there is not enough support to deliver traffic educational program especially for younger generation. Therefore, in this study, a questionnaire survey for motorcycle user in high schools and universities was conducted to analyze the effect of demographic factors on their driving behaviors and the relationship between driving attitudes and behaviors for safety educational purpose. In addition, the video observation was also conducted to get verifications and to understand their driving behavior under the actual traffic environment.

## Prediction of settlement of dredged clay containing prefabricated vertical drains and the history of reclamation in the disposal pond at Kobe Airport

Okada Hirohisa (Kobe City Construction Bureau), Oshima Akihiko and Shibuya Satoru (Kobe University) *Journal of Geotechnical Engineering*, Vol. 12, No. 1, pp. 19-31 (2017) *(in Japanese)* 

In order to dispose of dredged clay effectively, it is important to plan the dredged clay disposal based on the settlement prediction in advance and to understand accurately the acceptable quantity of dredged clay in the disposal pond. However, it is still a great challenge to understand properly the consolidation characteristics of the dredged clay for the settlement prediction. The purpose of this paper is, in the disposal pond at Kobe airport, to calculate the settlement of the clay using the volume ratio *f* represented uniformly by log*f* for the consolidation characteristics of clay (compressibility, permeability and consolidation velocity) and to compare the calculation with the measurements of various properties. Soil improvement was done in the disposal pond by the vertical drain using the difference in the water head after the dredged clay was disposed of several times, and then additional dredged clay was disposed of. The authors performed calculations with the proposed consolidation method against the bed of dredged clay with the complex complicated disposal history. It is reported that the results agree mostly with the measured settlement, pore water pressure and the water content at the site.

## Concentrations of the Naturally-derived Heavy Metals and its Geochemical Characteristics of the Alluvial Clays in Osaka Area

Hiroko Ito (Geo-Research Institut), Harue Masuda (Faculty of Science), Akihiko Oshima, Naoko Kitada (Geo-Research Institut) and Teruyuki Fujiwara (Geo-Research Institut) Proceedings of 12<sup>th</sup> Environment Geotechnical Engineering Symposium, JGS, pp. 443–448 (2017) (in Japanese)

## A Study on Wave Absorption and Flow Characteristics in the Vicinity if a Permeable Breakwater Consists of Vertically-slotted Walls

Takashi YAMANO, Yusuke NAKAHARA, Takaaki SHIGEMATSU and Ryuichi FUJIWARA Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. 72, No. 2, I\_901-I\_906 (2016)

### (in Japanese)

The measure against erosion of sandy beaches on the ocean is one of urgent national issues in view of the predicted sea level rise. Some of the authors have been studied a permeable breakwater with slotted walls supported by piles for last several years. Although the characteristics of wave attenuation of the breakwater with vertical slits has been examined by numerical calculation so far, enough validity has not been verified yet. In this study, comparison between calculated results by CADMAS-SURF/3D and experimental results on wave attenuation and flow in the vicinity of the permeable breakwater is presented. As a result, it is shown that the CADMAS-SURF/3D is a useful tool to design the permeable breakwater in practical use. According to the results of the calculation and PIV measurements, it is implied that upward flow in front and back of the breakwater will be direct relation with local scour and the vertical circulation flow in the chambers of the permeable breakwater will affect sand transfer.

### A Study on Properties of Turbulent Flow Induced by a Horizontally-Oscillating Circular Cylinder

Hiroshi MATSUMOTO and Takaaki SHIGEMATSU

Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. 72, No. 2, I\_919-I\_924 (2016) (in Japanese)

The flow induced by a horizontally-oscillating circular cylinder in stationary fluid was measured by the PTV technique and the relationship of turbulent flow and mean flow was investigated on the basis of the measured data. Transverse velocity of time-mean flow was large in the area that vortexes shed from a circular cylinder distributed. Although turbulent intensity was small in the area that vortexes shed from a circular cylinder did not distribute, the one was large in the area that vortexes shed from a circular cylinder did not distribute, the one was large, transverse velocity of time-mean flow was also large. It was suggested that turbulence induced by vortexes shed from a circular cylinder contributed to occurrence of mean flow generated around a circular cylinder.

## A Numerical Study on Inundation Properties in Maritime Urban Space Induced by Severe Storm Surge and River Flooding

### Shota MORI and Takaaki SHIGEMATSU

*Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 72, No. 2, I\_1645-I\_1650 (2016) (in Japanese)

A numerical simulation model, which can calculate spread of inundation area on the ground and in the space of subway track by a severe storm surge and river flooding simultaneously, is developed and described in detail. Based on the calculation results, quantitative analysis of characteristics of simultaneous occurrence of inundation due to storm surge and river flooding are presented. Moreover, evacuation activities appropriate to occasion of water disaster are also referred.

## Performance Evaluation of a Wave Generation System Using Vertically-Slotted Breakwater for Irregular Wave

## Shinji MORIMOTO, Takaaki SHIGEMATSU, Daichi UEJIMA, Kenji KATOH, Tatsuro WAKIMOTO and Sin'ya YOSHIOKA

*Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 72, No. 2, I\_1537-I\_1542 (2016) (in Japanese)

Authors have been developed a wave generation system using the vertically slotted breakwater and savonius-type water mills for several years. It has been already found from a series of a hydraulic experiment that the wave generation system have a superior wave attenuation function for wide range wave frequency rather than the present breakwater and that rotational velocity of a water mill can be estimated by using water velocity through a slit. However, the knowledge for the irregular wave has never been obtained at all. Hence, in order to obtain the knowledge for the irregular wave, hydraulic experiment was carried. It is found out that attenuation function will be superior by introducing water mills into the chamber. The estimation formula of the power of a water mill from waves is also introduced.

### Sensitivity of Storm Surge Height and Inundation Area on Climate Change in Osaka Bay

Yoko SHIBUTANI, Sota NAKAJYO, Sooyoul KIM, Nobuhito MORI and Hajime MASE

*Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 72, No. 2, I\_217-I\_222 (2016) (in Japanese)

Impact of climate change on tropical cyclones has been assessed for coastal disasters. In this study, we have

carried out a sensitivity tests of storm surge simulations to climate change considering typhoon characteristics and sea level rises in the Osaka bay. The results indicated that the maximum surge height with the worst track is 1.0m higher than the 2nd Typhoon Muroto maximum surge height with the 2nd Muroto track. There are less flooding compared to that of the original track, but the the inundation area is increased signifisantly under the future climate condition. The changes of inundation area due to climate change will be increased about 160 % in comparison with historical run. In addition, we estimated its return period as 21 years based on stochastic tropical cyclone model.

#### **Basic Study on Real-time Prediction of ABIKI around West Kyushu Coast by Using Neural Network Model** Sota NAKAJO, Ryuta YAMAGUCHI, Takaomi HOKAMURA and Sooyoul KIM

Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. 72, No. 2, I\_181-I\_186 (2016) (in Japanese)

Real-time prediction of unusual sea level fluctuation, called as "Abiki", is important from viewpoint of disaster prevention. Atmospheric pressure fluctuation with small amplitude is regarded as one of important factor of Abiki. However, actual real-time prediction of the distribution is difficult. In this study, we developed neural network model for prediction of Abiki and investigated the relationship between the reproducibility and parameters of our basic model. It was shown the importance of information of pressure fluctuation and wind direction from our model again. Then the potential of improvement of our model by using multispot measurement was also shown.

## Sediment Stratigraphy Observed by MASW Survey along an Array Comprised of Supralittoral, Mediolittoral, and Infralittoral Zones

Yoichi WATABE, Takashi KANEKO, Shinji SASSA, Yuji HASHIMOTO and Sota NAKAJO

*Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 72, No. 2, I\_1699-I\_1704 (2016) (in Japanese)

The Okoshiki Coast in Uto City, Kumamoto Prefecture, Japan, is a beautiful sandy tidalflat with rhythmical variation of multi-bar-trough structure. To investigate the sediment stratigraphy, multi-channel analysis of surface waves (MASW) was applied to this sandflat; however, the conventional method using geophones was only applicable to exposed regions in supralittoral and mediolittoral zones. In this study, MASW array was extended from mediolittoral to infralittoral zones by using hydrophones instead of geophones. Sediment stratigraphy was successfully evaluated by using geophones in supralittoral and mediolittoral zones during exposed periods and using hydrophones in mediolittoral and infralittoral zones during submerged periods. In the MASW survey using hydrophones conducted on a boat, it must be noted that the shear wave velocity structure at shallower depth is influenced by the offset distance between the shot point and the nearest hydrophone.

### Long-term Projection of Storm Surge Change by Neural Network Based on Stochastic Tropical Cyclone Model

Shiori IWABE, Nobuhito MORI, Sota NAKAJO, Tomohiro YASUDA and HAJIME MASE

## *Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering)*, Vol. 72, No. 2, I\_1465-I\_1470 (2016) (in Japanese)

A long-term assessment of storm surge using the stochastic typhoon model (STM) is one of the secured methodology with the large number of samples of the reproducibility is desired if we can estimate storm surge from STM. This study has improved statistical maximum storm surge model, which uses only typhoon information, in the three major bays using artificial neural network (NN). In order to estimate long-term changes in storm surge characteristics under future climate conditions, NN uses STM and climate database for Policy Decision making for Future climate change (d4PDF). The long-term impact assessments of storm surge using several scenarios are compared.

### Stochastic Tropical Cyclone Model and Its Application

Sota NAKAJO, Nobuhito MORI, Tomohito YASUDA and Hajime MASE

*The Proc. of the 26<sup>th</sup> Ocean Engineering Symposium*, March 6-7, (2017)

Stochastic tropical cyclone model is one of useful tools for assessment of extreme disaster event from limited observation tropical cyclone data. In this paper, overview of an example of stochastic tropical cyclone model and its validation results have been shown. Probability density function of tropical cyclone properties and its change rate have shown overview of development and dissipation process of tropical cyclone in West North Pacific Ocean and North Atlantic Ocean. Good reproducibility of stochastic tropical cyclone model has been shown by comparison of global distribution of average minimum SLP and time series of minimum SLP of tropical cyclone

arrived at local bay. Two examples of application of stochastic tropical cyclone model have been shown. Properties of tracks of tropical cyclone which would cause heavy rain at Tone River basin was shown and its return period was calculated. The necessary conditions of tropical cyclone properties which would cause severe storm surge event at Yatsushiro Bay was shown and return period was also calculated. Both examples show tracks of tropical cyclone which caused extreme event is not so unusual. However, probability of fulfilling all conditions of TC tracks, minimum SLP and translation speed was very small.

#### Impact Assessment of Climate Change on Coastal Hazards in Japan

Nobuhito MORI, Mark KJERLAND, Sota NAKAJO, Yoko SHIBUTANI and Tomoya SHIMURA

Hydrological Research Letters 10(3), 101-105, (2016)

Understanding future changes of ocean waves and storm surges is important for assessing and mitigating the impact of climate on coastal, marine and ocean environments and on engineering problems. This paper reviews the latest research results of climate change impacts on coastal hazards in Japan. First, future changes of wave climate and storm surges based on MRI-AGCM ensemble experiments are summarized. Second, the applications of coastal hazard projections to coastal structures and beach profiles are summarized as a series of climate impact assessment projects. There are clear increases in extreme values of wave heights and storm surges in the tropical cyclone dominant regions around the middle latitudes of the Western North Pacific including Japan. The influence of future climate change on caisson breakwaters is discussed considering sea level rise, extreme wave conditions and storm surges targeting the Pacific side of Japan.

### Characteristics of CO<sub>2</sub> Absorption and Emission in the High Water Temperature Seasons at the North Salt Marsh of Osaka Nanko Bird Sanctuary

Toshiyuki TANAKA, Toru ENDO, Noriaki IKADA and Susumu YAMOCHI

Journal of Japan Society of Civil Engineers, Ser.B2 (Coastal Engineering), Vol.72, No.1, pp.1-11 (2016) (in Japanese)

Field investigations were conducted at the north salt marsh of Osaka Nanko bird sanctuary (ca. 43100 m2) in high water temperature seasons of 2012-2014 and the amount of net CO<sub>2</sub> absorption was estimated along with the characteristic of CO<sub>2</sub> absorption and emission on the surface of the sediment. Gross CO<sub>2</sub> absorption flux was closely related to sediment temperature, chlorophyll a and photon flux density, while CO<sub>2</sub> emission flux changed depending on the sediment temperature and groundwater level. The groundwater level was thought to be indispensable for estimating the flux of CO<sub>2</sub> emission on the sediment. For instance, when it was supposed groundwater level was equal to tidal level, the CO<sub>2</sub> emission flux from the sediment reached 29 tons. It showed 2.1 times higher than the value which was estimated by using actual ground water level. Using the relationship of CO<sub>2</sub> flux with sediment temperature, chlorophyll a, photon flux density and groundwater level, the total CO<sub>2</sub> absorption and/or emission of the north salt marsh of Osaka Nanko bird sanctuary was estimated as ca. 23 tons for absorption and ca. 14 tons for emission in May to September, 2014. These results suggest that a net of 9 tons CO<sub>2</sub> was absorbed and this salt marsh plays the role of a CO<sub>2</sub> sink in the high temperature season of a year.

## Evaluation Method of CO<sub>2</sub> Exchange at the Intertidal Flat, the Sea Surface and the Sea Bottom of an Artificial Salt Marsh in Urban Coastal Zone

Toru ENDO, Yusuke NAKANO and Noriaki IKADA

Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol.72, No.2, pp.1447-1452 (2016) (in Japanese)

In order to examine the evaluation method of  $CO_2$  exchanges of the artificial salt marsh in urban coastal area,  $CO_2$  exchange of the intertidal flat and the sea surface were reviewed based on the measurement data by chamber method at Osaka Nanko bird sanctuary in 2014-2015. Furthermore, the sea bottom  $CO_2$  emission was measured by conducting laboratory experiment using the sediment. After the gross photosynthesis rate of microalgae on the intertidal flat was approximated by three type models, it was suggested that  $CO_2$  absorption rate of the intertidal flat is able to estimate by the sediment temperature and the light intensity. It was thought that  $CO_2$  emission of the intertidal flat is able to be expressed as a function of the sediment temperature. On the other hand, it is found that the measurement data by chamber method and the estimation data by bulk equation must be used selectively according to wind condition in order to estimate the air-sea  $CO_2$  exchange. Finally, it was thought that the sea bottom  $CO_2$  emission is desirable to estimated from the data of time variation of DIC concentration of the sea water.

### A Research on the Dynamics of the Refractory Organic Carbon in the Sediment of an Artificial Salt Marsh

Naoto NISHIO, Toru ENDO and Susumu YAMOCHI

Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol.72, No.2, pp.1315-1320 (2016) (in Japanese)

Biodegradability tests were conducted and refractory organic carbon in the sediment of an artificial salt marsh was seasonally examined because of increasing demands for the knowledge of carbon storage at the salt marsh. The results revealed that 45.9 - 77.0% of the sedimentary organic carbon were refractory organic carbon at the intertidal area, while the refractory organic carbon increased up to 92.5 - 98.3% at the submerged area. A rough estimation of carbon storage at the upper 5 cm of the sediment was 9.5 ton C for intertidal area and 27.6 ton C for submerged area of the north salt marsh of Osaka Nanko bird sanctuary.

### Seasonal Changes on Characteristics of sediment and Carbon Dioxide Absorption / Emission Rate at mud river Mouth Tidal Flat

Sosuke OTANI, Taiki KAWASAKI, Toru ENDO and Kazuyuki HIGASHI

Journal of Japan Society of Civil Engineers, Ser. B3 (Ocean Engineering), Vol.73, No.2, pp.630-635 (2017) (in Japanese)

To elucidate relationships between  $CO_2$  absorption and emission rates and properties of sediment at Yodo River mouth tidal flat was conducted in this study. Similarly,  $CO_2$  fluxes ( $CO_2$  absorption and emission rate) were also measured using light and dark chamber. Chemical properties of sediment such as Chl.a, ORP, AVS fluctuated and maximal values were different season throughout the year. There is a negative correlation only between ORP and soil temperature. The  $CO_2$  absorption rate fluctuated 0.0675 to 6.63 mg  $CO_2/m^2$  /min, the  $CO_2$  emission rate was 0.038 to 2.82 mg  $CO_2/m^2$  /min, respectively. They showed maximal values in summer season and were positively strongly correlated with soil temperature, Emission rate in water surface was three times higher than emission rate in sediment. Moreover, it is suggested that macrobenthos respiration contributed to emission rate in sediment.

## Effects of Light, Temperature and Ground Water Level on the CO<sub>2</sub> Flux of the Sediment in the High Water Temperature Seasons at the Artificial North Salt Marsh of Osaka Nanko Bird Sanctuary, Japan

Susumu YAOMOCHI, Toshiyuki TANAKA, Yuri OTANI and Toru ENDO

*Ecological Engineering*, Vol.98, pp.330-338 (2017)

Field investigations and indoor experiment were carried out to clarify the effect of temperature and chlorophyll a concentration of the sediment, photon flux density, and ground water level on the absorption and emission of  $CO_2$  from the surface sediment of the artificial salt marsh. The flux of  $CO_2$  absorption was closely related to sediment temperature, chlorophyll a and photon flux density. On the other hand, flux of  $CO_2$  emission changed depending on the sediment temperature and ground water level. The ground water level was thought to be indispensable for estimating  $CO_2$  emission from the sediment of the intertidal zone of the salt marsh. Using equations of  $CO_2$  flux with sediment temperature, chlorophyll a, photon flux density and ground water level, the total  $CO_2$  absorption and emission of the artificial north salt marsh of Osaka Nanko bird sanctuary was estimated as ca.23 tons (4.3 g- $CO_2/m^2/day$ ) for absorption and ca.14 tons (2.6 g- $CO_2/m^2/day$ ) for emission in May to September 2014. These results suggest that a net of 9 tons of  $CO_2$  (1.7 g- $CO_2/m^2/day$ ) was absorbed, and that this salt marsh performs the function of a  $CO_2$  sink in high temperature seasons.

### Fraction of Phosphorus Composition in Sewage Sludge and its State Change by Acid Treatment

Hizuru WAKAYAMA, Yoshinori KANJO, Masafumi OHTA, Mayu SHIRAI and Satoshi MIZUTANI Journal of Japan Society of Civil Engineers, Ser. G (Environmental Research), Vol.72, No.7, III\_243-III\_248 (2016) (in Japanese)

In order to recover the phosphorus from sewage sludge and to prevent from the trouble at incineration plants caused by phosphorus in sludge, fractionation analysis of phosphorus in sewage sludge of eleven municipal sewage treatment plants and acid treatments were performed. The results of fractionation analysis showed that phosphate fractions and particulate phosphate fraction in digested sludge ranged 73 to 89% and 24 to 62%, respectively. The results of acid treatments showed that particulate phosphate fraction could be dissolved to phosphate ion thoroughly at the pH condition of 2 with sulfuric acid, 5 with citric acid, or 4 with acetic acid. Judging from these results, dissolved fraction of phosphorus in digested sludge will be able to increase more than doubled using with acid treatment.

## Relationship between the Distributions of Refuges, Population and Estimated Earthquake Intensity in Osaka City during the Uemachi Fault Earthquake

Kazuki NISHIMURA, Yoshinori KANJO and Satoshi MIZUTANI

### Distribution of Phosphorus Composition in Sewage Digested Sludge and Effects of Acid Extraction Conditions on Phosphorus Recovery

Yoshinori KANJO, Hizuru WAKAYAMA, Mayu SHIRAI and Satoshi MIZUTANI

Proceeding of the 7<sup>th</sup> Forum on Studies of the Environmental & Public Health Issues in the Asian Mega-cities (EPAM2016), pp.114-115 (2016)

In order to develop the new recovery method of phosphorus in sewage sludge, the distribution of phosphorus composition in sewage digested sludge and effects of acid extraction condition on phosphorus recovery as magnesium ammonium phosphate (MAP) or hydoroxyapatite (HAP). According to the fractionation analysis of phosphorus contents in 12 sewage digested sludge, the distributions of P-PO4-P and D-PO4-P were obtained, and it suggested that soluble fractions of phosphorus in these digested sludge after acid treatment reached to around 80%. The results of MAP/HAP formation experiments suggested that formation of MAP from these supernatant of the digested sludge was affected negatively by citric acid and acetic acid, and recovery of phosphorus as HAP was suitable for these digested sludge.

## Basic Study of Heavy Metals and Chelating Agent Behaviour from Chemical-Treated Incineration Fly Ash in Leaching Test

Satoshi MIZUTANI, Yutaro UEDA, Shota MATSUDAIRA, Hirofumi SAKANAKURA (National Institute for Environmental Studies) and Yoshinori KANJO

Proceeding of the9th International Conference on Combustion, Incineration/Pyrolysis, Emission and Climate change (i-CIPEC 2016), September 20-23, Kyoto, Japan (2016)

The unevenness of chemical treated MSWI-FA and the behavior of Pb and chelating agent during agitation time of batch type leaching test are studied. Fly ash sampled from stoker-type incinerator in Japan was used, and it was chemical treated with a chelating agent with dithiocarbamic group belonging to piperazine series in our laboratory. To confirm the unevenness of chemical treated fly ash, multiple experiments for 16 portions of treated fly ash were performed. The variation of the leaching test results was very small and the unevenness of the treated fly ash is negligible. Because a good positive correlation can be observed between chelating agent concentration and TOC concentration, TOC can be used as an alternative indicator for chelating agent concentration. The behavior of Pb and TOC in the leachate during agitation time in JLT-13 was studied. During the agitation time in the leaching test, chelating agent were spiked and time trend of Pb concentration and chelating agent concentration are observed. When the chemical agent was added, both of Pb and TOC concentration decreased. The fact suggests the stabilizing reaction of chelating agent for heavy metals during agitation time in leaching test.

## Heavy Metal Leaching Behaviour from Chemical-stabilized Fly Ash by Column Test under Three Kinds of Flow Rate Condition

Yutaro UEDA, Satoshi MIZUTANI, Hirofumi SAKANAKURA (National Institute for Environmental Studies) and Yoshinori KANJO

Proceeding of the 9th International Conference on Combustion, Incineration/Pyrolysis, Emission and Climate change (i-CIPEC 2016), September 20-23, Kyoto, Japan (2016)

Column leaching tests for both chemical-treated and water-treated fly ash with three kinds of flow rate condition for 60 days were performed and leaching concentration change over time is observed. Fly ash sampled from stoker-type incinerator with dry system,  $Ca(OH)_2$  injection, for acid gas treatment in Japan, were used for experiments. The ash is stabilized in our laboratory by chelating agent, which is the agent with dithiocarbamic group belonging to piperazine series. For comparison, the water-stabilized fly ash is also prepared by addition of only distilled water and kneading. Column experiment is a down-flow test, and the flow rates of leachant are three patterns: 1) Continuous condition, 2) Semi-continuous condition and 3) Intermittent condition. Unsteady leaching of Pb was observed at the initial stage, first several days. Then the concentration slightly increased but remained on the same level. After 60 days, the leaching concentration and cumulative leaching ratios from chemical-treated fly ash were lower in 1- 2 orders of magnitude than water-treated one. The clear correlation between the flow rates and leaching quantity were not observed. These facts suggested that the Pb leaching is controlled not only by advection flow of leachant but by diffusion.

### Total Organic Carbon (TOC) in Leachate from Municipal Solid Waste Incineration Fly Ash in Japan

Satoshi MIZUTANI, Katsunori MATOZAKI, Hirofumi SAKANAKURA (National Institute for Environmental Studies) and Yoshinori KANJO

## Proceeding of the 4th 3R International Scientific Conference on Material Cycles and Waste Management, New Delhi, India, March 8-10, (2017)

TOC in the leachate from four kinds of MSWI fly ash and from two kinds of reactive slaked lime were measured. Higher level of TOC was detected in the leachate from the fly ash from incinerators with dry-acid gas treatment system. The leachates from reactive slaked limes also show high level of TOC. On the contrary, calcium hydroxide did not show the leaching of TOC. Therefore the origin of the organic carbon in fly ash is added organic materials in order to enhance reactivity of lime with acid gas. The contents of TOC in the two kinds of the reactive slaked lime were 1,260 and 5,680 mg/kg respectively and showed very wide range.

### Utilization and Issue of Leaching Tests in Geo-environmental Engineering

Yasutaka WATANABE (Central Research Institute of Electric Power Industry), Tetsuo YASUTAKA (National Institute of Advanced Industrial Science and Technology), Yukari IMOTO (National Institute of Advanced Industrial Science and Technology), Koichi KAWAMURA (Kokusai Kogyo Co., Ltd.), Shinji MIYAGUCHI (OYO Corp.), Mitsuhiro Sumikura (Shimizu Corp.), Hirofumi SAKANAKURA (National Institute for Environmental Studies), Satoshi MIZUTANI, Kei HIRATA (MC Evolve Technologies Corp.) and Research Committee on Developing a New Geo-environmental Management and Standard for Social Imprementation (Japanese Geotechnical Society)

Proceedings of the 12th Japan National Symposium on Environmental Geotechnology, September 25-26, Nagasaki, Japan (2017) (in Japanese)

The best form of the batch type leaching test as a compliance test for environmental geotechnology was discussed. Questionary investigation for specialists and review of scientific papers were performed. In order to increase the repeatability and reproducibility of the results, four kinds of operational steps, that is 1. sampling, 2. sample preparation, 3. leaching procedure, 4. leachate preparation, were focused on this study. Based on the answers, the different elements and the existing problems were marshalled and summarized.

## Hazardous materials used in a large ship: A survey of an example of an inventory of hazardous materials (IHM) for a vessel

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Proceeding of the 8th Forum on Studies of Environmental and Public Health Issues in Asian Mega-cities (EPAM2017), September 1-2, Seoul, Korea (2017)

Contamination of sea and seashore by hazardous materials from shipbreaking industry in Asian countries is often reported. In order to prevent such environmental contamination and to protect industrial health and safety for labors, preparation of inventory of hazardous materials (IHM) is required for the merchant vessel bigger than 500 Gross Tonnage in accordance with Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships. In this study, the contents and systems of IHM for a vessel are summarized firstly. Secondary, based on the examples of IHM of a large ship, hazardous materials used in the ship is summarized. IHM is a list of the hazardous materials used in a ships structure, equipment and machinery and hull. In a case of a certain car carrier vessel (28406 GT), more than 500 kg of asbestos and more than 80 kg of HCFC are used. Regarding heavy metals, tin and lead were indicated. More than 100 kg of TBT is used as paints and coating systems. On the contrary, approximately 440 kg of lead is used in lead-acid storage batteries in a navigation bridge deck.