

# ABSTRACTS

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## Oral Session

### Session 1

--- Fluidized Bed and Multiphase Reactors ---  
November 14, 9:00-12:40, Room 1

#### S1-1

### Influence of Air and O<sub>2</sub>/CO<sub>2</sub> Mixture on the Flow Hydrodynamics in a Full-loop Circulating Fluidized Bed

Mukesh Upadhyay, Hang Seok Choi,  
Hoon Chae Park, Ha-Na Jang, Yong-Chil Seo  
Yonsei University

In this work Computational particle-fluid dynamics (CPFD) simulations were performed to study the hydrodynamic characteristics in which air and oxy (O<sub>2</sub>/CO<sub>2</sub>) mixture were used as fluidizing gas in cold mode full-loop Circulating fluidized bed (CFB). Qualitative and quantitative comparisons were made with experimental measurements to assess the robustness of trends and quantify uncertainties in the simulation results. For the present study four different composition of fluidizing gas were used as fluidizing media and different hydrodynamic behavior were analyzed. It was found that the flow hydrodynamics behave quite different with O<sub>2</sub>/CO<sub>2</sub> mixture compare to air fluidizing media. The model successfully able to capture the difference in air and O<sub>2</sub>/CO<sub>2</sub> mixture cases in the bottom and upper section of the riser. Overall present hydrodynamic study will pave the way to scale-up design and process intensification of oxy-fuel circulating fluidized bed (CFB) combustion technology.

#### S1-2

### Relationship Between Solid Flow Rate and Pressure Drop in the Riser of a Pressurized Circulating Fluidized Bed

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Jeong-Hoo Choi<sup>2</sup>, Yoo SubeWon<sup>2</sup>,  
A-Reum Jeong<sup>2</sup>, Ho-Jung Ryu<sup>3</sup>

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The relationship between the solid circulation rate and pressure drop in the riser of a pressurized circulating fluidized bed (CFB) was investigated. The pressure drop of the riser was measured based on variations in the pressure, gas velocity, solid flux, and particle diameter with a glass bead used as the bed material. The pressure drop of the riser was shown to decrease as the pressure increased. Under the gas flow conditions, the momentum per unit mass of the gas used to accelerate the solid particles was shown to be finite. The pressure drop of the riser increased linearly with the solid circulation rate at the gas velocity. The gas momentum shared by the unit mass of the solids decreased as either the particle density or diameter increased. A correlation was successfully proposed that represents the relationship between the pressure drop and solid circulation rate in the riser of a CFB.

#### S1-3

### 3<sup>k</sup> Factorial Statistical Experimental Design of CO<sub>2</sub> Capture using K<sub>2</sub>CO<sub>3</sub>/Al<sub>2</sub>O<sub>3</sub> Solid Sorbents in Novel Circulating Fluidized Bed Reactor

Chattan Sakaunnaporn,  
Rattapong Tritippayanon, Pornpote  
Piumsomboon,  
Benjapon Chalermisinsuwan  
Chulalongkorn University

In this study, the capturing of carbon dioxide (CO<sub>2</sub>) using potassium carbonate over aluminium oxide (K<sub>2</sub>CO<sub>3</sub>/Al<sub>2</sub>O<sub>3</sub>) solid sorbents in novel circulating fluidized bed reactor was investigated. The in-depth multiphase flow behavior and carbonation chemical reaction were explored using two-dimensional computational fluid dynamics model, together with the 3<sup>k</sup> factorial statistical experimental design, for determining the effect of inlet gas velocity and solid sorbent loading on the CO<sub>2</sub> sorption efficiency. Three different inlet gas velocities and three different solid sorbent loadings were considered. From the results, the novel circulating fluidized bed reactor showed various advantages on the system hydrodynamics and the CO<sub>2</sub> conversion. The increasing of inlet gas velocity and solid sorbent loading gave lower and higher CO<sub>2</sub> sorption efficiencies, respectively. In addition, the statistical analysis between the inlet gas velocity and the solid sorbent loading was concluded its effect on the CO<sub>2</sub> conversion.

#### S1-4

### A Study of Gas-Solid Swirling Flow using CFD Eulerian-DPM Two-phase Approach

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<sup>1</sup> Chang Gung University

<sup>2</sup> Chang Gung Memorial Hospital

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Swirling flow allows long particle-wall contact within a relatively short piping distance and may be used to test the wear properties of particles. In this work, gas phase is simulated by the RNG k-ε turbulent model while solid phase treated as particle is injected to swirling flow in a horizontal pipe using Discrete Particle Model (DPM). The circulating swirling flow patterns are well simulated. The air velocity is the highest in the entrance section. The velocity distribution changes continuously and the velocity reduces downstream as a result of the friction of wall. The velocity remains a relatively stable value at the middle section of the tube. At the exit, the velocity reduces dramatically due to wall friction and pressure criteria. A symmetric distribution of the tangential velocity is obtained at the middle of the tube. The tangential velocity profiles clearly divided into three regions: core region, annular region and wall region as reported by Kitoh<sup>1</sup>. The wearing properties of particles caused by particle-wall attrition were tested by such an apparatus. The highest mass recovery powders does not correspond to the powders with the highest degree of wear. A careful index should be selected to best show the powder wearing properties.

## S1-5

### Effect of gas and liquid properties on gas holdup in bubble column

Jun Young Kim, Bong Jun Kim, Dong Hyun Lee  
Sungkyunkwan University

The flow regime transition point dependence on gas and liquid properties was investigated in a semi-cylindrical bubble column of 1.8 m height and 0.21 m inner diameter operating as a batch system. He, air and CO<sub>2</sub> gases were injected at superficial gas velocities up to 239 mm/s. The liquids were water, aqueous ethanol solutions, and aqueous glycerol solutions, all with a gas-free liquid settled height of 1 m. When the gas density increased, the gas holdup increased at all superficial gas velocities, delaying the flow regime transition. The gas holdups in the liquid mixtures were higher than for tap water. The transition gas holdup was also shown to depend on surface tension. The gas holdup for a glycerol solution increased, passed through a maximum, and then decreased as the liquid viscosity increased. The transition gas holdup was correlated as a function of the gas density, surface tension, and liquid viscosity.

## S1-6

### Takeover Velocity in a Gas-Solid Fluidized Bed with Binary Solids

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Mok Young Lee<sup>2</sup>, Jae Young Jung<sup>2</sup>,  
Dong Hyun Lee<sup>1</sup>

<sup>1</sup> SungkyunKwan University  
<sup>2</sup> RIST

The mixing and segregation characteristics were investigated in gas-solid fluidized beds with binary solid mixture. Bed materials were constituted with binary solids, having different size and density. To investigate the effect of particle size distribution on the mixing characteristics, two other binary solid mixtures were used, which have similar mean particle size and particle density, but their particle size distribution was different to each other. Main column has 0.14 m-inner diameter and 2.14 m-height. Bed aspect ratio (L/D) was 3.0. Bed materials were two sets: one of bed materials was the mixture of ilmenite ( $d_p=153 \mu\text{m}$ ,  $\rho_s=3,860 \text{ kg/m}^3$ ) and coke ( $d_p=582 \mu\text{m}$ ,  $\rho_s=1,762 \text{ kg/m}^3$ ), which has wide size distribution. The other bed materials was the mixture of ceramic beads ( $d_p=122 \mu\text{m}$ ,  $\rho_s=3,800 \text{ kg/m}^3$ ) and plastic beads ( $d_p=813 \mu\text{m}$ ,  $\rho_s=1,500 \text{ kg/m}^3$ ), which has narrow size distribution. Bed composition of ilmenite-coke mixture was determined to 0.7:0.3 by mass ratio. And, bed composition of ceramic beads-plastic media was 0.75:0.25 by mass ratio. Volumetric ratio of both particle mixtures was 0.5:0.5. Axial bed pressure drop was measured according to superficial gas velocity. Bed composition was measured according to axial bed height by sampling. Bed pressure drop of ilmenite-coke mixture was maximized above  $U_o=0.15 \text{ m/s}$ , and fully fluidization was occurred. However, criterion of mixing to segregation was not found in the axial bed composition according to superficial gas velocity. In the case of ceramic-plastic bead mixture, bed pressure drop was maximized at  $U_o=0.05 \text{ m/s}$ . And, the criterion of mixing to segregation was found at the corresponding superficial gas velocity.

## S1-7

### Bed collapse and expansion characteristics of multi-walled carbon nanotubes in the fluidized beds

Sung Woo Jeong<sup>1,2</sup>, Dong Hyun Lee<sup>1</sup>  
<sup>1</sup> Sungkyunkwan University  
<sup>2</sup> Korea Research Institute of Chemical Technology

The bed collapse and expansion characteristics of different types of multi-walled carbon nanotubes (MWCNTs) were investigated in the fluidized bed with a 0.14 m-ID  $\times$  2.4 m-height Plexiglas column. Three types of MWCNTs were used as bed materials: i) N is the NC7000™ prepared by Nanocyl®, ii) S<sub>f</sub> is the agglomerate that is fine entangled MWCNTs agglomerated by strong cohesive force such as van der Waals force, iii) S<sub>c</sub> is the coarse entangled MWCNTs with a single particle. Similarity between the MWCNTs and Geldart group particles was investigated by the bed collapsing process. The bed collapsing processes of N, S<sub>f</sub>, and S<sub>c</sub> were similar to those of Geldart group A, C, and B particles, respectively. Based on the bed collapse and expansion characteristics, emulsion phase voidage of N and S<sub>f</sub> were 0.795 and 0.921 in the bubbling fluidization at the superficial gas velocity of 0.19 m/s, respectively.

## S1-8

### Effects of Particle Properties on Agglomerate Formation of Fine Particles in Vibrating Fluidized Bed

Tomonori Fukasawa<sup>1</sup>, Riho Hiraiwa<sup>1</sup>,  
An-Ni Huang<sup>1</sup>, Shih-Yang Huang<sup>2</sup>, Hsiu-Po Kuo<sup>2</sup>,  
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<sup>2</sup> Chang Gung University

The knowledge of the agglomerates formation from fine particles in the fluidized bed is essential in the powder handling. It is known that fine particles exhibit the unique agglomeration behavior. In this study, the effects of particle properties on the agglomerate formation in the vibrating fluidized bed using homemade apparatus. TiO<sub>2</sub>, ZnO, Fe<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> powder were used as tested powders. The formation mechanism of agglomerates in the vibrating fluidized bed was clarified by the observation using a high-speed camera. Based on the obtained results, it was revealed that the agglomeration ratio depends on the type of the tested powder and it can be also evaluated by its angle of repose.

## S1-9

### Cold flow behavior of rice husk under the strong vortexing effect in an annular vortex fluidized bed reactor (AVFB)

Lihui Zhang<sup>1</sup>, Feng Duan<sup>1</sup>, Yaji Huang<sup>1</sup>,  
Chiensong Chyang<sup>2</sup>

<sup>1</sup> Southeast University  
<sup>2</sup> Chung Yuan Christian University

An annular vortex fluidized bed reactor (AVFB) using various biomass fuels was recently developed and tested for commercial heating applications. The combustor is characterized by a strong vortexing effect. The main purpose of this study is to investigate the flow characteristics of the freeboard zone in AVFB while the rice husk was used as the test material. The effects of primary and secondary air flow rates, and secondary air ratio on the gas-phase flow and particle-phase flow characteristics under the strong vortexing effect in this test facility were investigated. Results show that the fluidized bed combustor with a center cylinder and tangentially secondary air injection has good gas-phase flow characteristics. Center cylinder improves the vortexing effects in the freeboard zone. The maximum value of particle density and mass flow rate appear near the outer tube.

## S1-10

### Investigation of the Particle Motion under Transition State of Amplitude Change of 20-kHz-ultrasound Irradiated in Water

Hiroya Muramatsu, Takayuki Saito  
Shizuoka University

Ultrasound techniques are applied to chemical processes such as cleaning, atomization and mixing very often and widely. MHz-band ultrasound is employed for ultrasound manipulation and separation due to its high directionality. Manipulable particle diameter through MHz-order ultrasound is forced to be smaller than several micrometers due to the limitation of the ultrasound wavelength. To overcome this limitation, we ventured to use kHz-band ultrasound, and discovered that mm-order particles dispersed in water are flocculated into a spherical particle swarm by irradiating kHz-band ultrasound. This phenomenon resulted from Acoustic Cavitation-Oriented Bubbles (ACOBs) adhering to the particle surface. ACOBs promoted the particles motion toward the flocculation position. Furthermore, we discovered that controlling the ultrasound the particles were classified by their diameter. The mechanism of this classification process is still unknown. In order to establish high-precision classification techniques, it is necessary to reveal the interaction among the particles, bubbles and liquid motion. In the present study, we visualized the motion of the particle trapped in the sound pressure field during the transition state of the amplitude change under various conditions. We have obtained new results that gradual change in ultrasound amplitude efficiently classifies the particles by their diameter.

## S1-11

### The relationship between particle flocculation patterns and dissolved gas components in water under kHz-band ultrasonic irradiation

Sayuri Yanai, Takayuki Saito  
Shizuoka University

We have investigated particle flocculation, which is raised by Acoustic Cavitation-Oriented bubbles (ACOBs) in water under kHz-band ultrasonic irradiation. The flocculation particle swarm is spherical, and this spherical pattern is impossible to be formed by conventional techniques using MHz-band ultrasound. This new-type flocculation is caused by the ACOBs

which are forced by the acoustic radiation forces of primary and/or secondary Bjerknes force. The ACOBs adhering to the particle surface, which receive the primary Bjerknes force, moved the particle to the nearest antinode of acoustic pressure in water. In our recent study, we found out that several types of the flocculation pattern were formed: spherical one, chain-like one, and mixed one. Appearance of these patterns depended on the gas components dissolved in water. In the present study, we deeply consider the relationship between the flocculation patterns and the gas components, from the results of visualized flocculation patterns, bubbles' dispersion and acoustic pressure profiles.

## Session 2

--- Membrane Separation ---  
November 14, 9:00-12:20, Room 2

## S2-1

### Development of ion exchange membranes for the redox reaction of the thermochemical hydrogen production IS process

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Kotone Oura<sup>1</sup>, Ayumi Ikeda<sup>1</sup>, Yasuhito Naka<sup>1</sup>,  
Haruyuki Nishijima<sup>1</sup>, Shin-ichiro Imabayashi<sup>1</sup>,  
Shin-ichi Sawada<sup>2</sup>, Tetsuya Yamaki<sup>2</sup>,  
Nobuyuki Tanaka<sup>3</sup>, Shinji Kubo<sup>3</sup>

<sup>1</sup> Shibaura Institute of Technology

<sup>2</sup> National Institutes for Quantum and Radiological Science and Technology

<sup>3</sup> Japan Atomic Energy Agency (JAEA)

Thermochemical hydrogen production IS process decomposes water into hydrogen and oxygen by combining the chemical reactions of iodine (I) and sulfur (S). 2 kinds of acids are produced through the Bunsen reaction ( $I_2 + SO_2 + H_2O = 2HI + H_2SO_4$ ). Large amounts of  $I_2$  was added in order to separate HI and  $H_2SO_4$  in a liquid-liquid separator. A redox reactor with a cation exchange membrane was proposed to reduce the amount of  $I_2$  of the Bunsen reaction. Ion exchange membranes for the redox reactor should be developed. In this study, ion exchange membranes prepared by a radiation-graft polymerization technique have been investigated. Ion exchange capacity and proton transport number ( $t^+$ ) were measured to evaluate the membranes.  $t^+$  and the over potential through the membrane with divinylbenzene were 1 and 0.308 V, respectively. We have successfully prepared the membrane for the Bunsen reaction in the IS process.

## S2-2

### Gas and vapor permeabilities of ionic liquids as liquid membranes

Alina Kudasheva, Tomoki Kamiya, Akira Ito  
Tokyo Institute of Technology

In this study we have applied various ionic liquids as liquid membranes for the vapor and gas separation. A novel method of the liquid membrane fabrication based on the nanoparticles supporting technique was developed and utilized in preparation of the ionic liquid membranes with the average thickness of 10

$\mu\text{m}$ . Vapor and gas permeabilities through the ionic liquid membranes were obtained and discussed. The solute's solubility and diffusivity were measured or estimated, followed by applying the solution-diffusion model in order to predict permeabilities in the liquid membranes. These predicted permeabilities were compared to the experimental data and it was concluded that separation with ionic liquid membranes strongly depends on the permeants solubility by the ionic liquid.

## S2-3

### High Performance Dye Removal by Embedded Activated Carbon in Calcium Alginate Membrane Combination with Low-Molecular-Weight Polyethylene Glycol

Keita Kashima<sup>1</sup>, Kento Osawa<sup>1</sup>, Masahide Hagiri<sup>2</sup>, Masanao Imai<sup>3</sup>

<sup>1</sup> Oyama College

<sup>2</sup> Fukushima College

<sup>3</sup> Nihon University

Novel calcium alginate membrane embedded with activated carbon as an adsorbent was successfully prepared for dye removal from aqueous phase. The membrane had smooth surface and applicable mechanical strength for practical use. Activated carbon was stably embedded by the aid of low-molecular-weight polyethylene glycol (average molecular weight: 1000 Da). The adsorption ability of Methylene Blue was estimated by isothermal adsorption test in batch process. The adsorption results indicated that the Langmuir isotherm fitted the experimental data. The maximum adsorption capacity based on membrane area increased with increasing mass fraction of activated carbon in the membrane. The continuous adsorption test was demonstrated by using membrane permeation system. The rejection of Methylene Blue throughput membrane permeation was achieved 99 % for initial 10 h. The adsorption process combined with membrane separation performed excellently removal ability that adsorption on activated carbon collaborated with molecular size screening.

## S2-4

### Adsorption Characteristics of Lysozyme on Dye Affinity Nanofiber Membrane

Jia-Lin Hsu, Yu-Han Lee, Yu-Kaung Chang  
Ming Chi University of Technology

Polyacrylonitrile (PAN) nanofiber membrane was prepared by electrospinning technique. After heat treatment and alkaline hydrolysis, the ion exchange membrane (P-COOH) was grafted with chitosan molecule. The chitosan modified membrane (P-CS) was then covalently immobilized with Reactive orange 4 to be used as a dye ligand affinity membrane (P-Dye). The dyed membrane was used to evaluate the binding capacity of lysozyme under various operating parameters (e.g., adsorption pH, chitosan and dye concentrations, and temperature) were studied in batch modes. The results revealed that the optimal adsorption pH for lysozyme was pH 8 and the optimal concentration of chitosan for use in preparation of membrane was 1.0%. Moreover, the optimal immobilization density of

dye was 90.52 ( $\mu\text{mol dye/g membrane}$ ). The results showed that the dye affinity nanofiber membrane may be an ideal support for the adsorption and purification of lysozyme because of its low cost, simplicity of its preparation method, and high binding capacity.

## S2-6

### Separation of light gas using zeolite SSZ-13 membranes

Rongfei Zhou, Bin Wang, Qin Wang  
Nanjing Tech University

High-quality SSZ-13 zeolite membranes were successfully synthesized on the outside surface of tubular porous mullite supports, and shown to be useful for light gas separations at low and high temperatures. The SSZ-13 crystals and membranes were characterized by SEM, XRD, adsorption and permeation measurements. The single-gas permeances of  $\text{CO}_2$ ,  $\text{H}_2$ ,  $\text{N}_2$ ,  $\text{CH}_4$ ,  $\text{C}_2\text{H}_6$  and  $\text{C}_3\text{H}_8$  decreased with increasing kinetic diameter at 298 K, except for  $\text{CO}_2$ . The best membrane had a  $\text{CO}_2$  permeance of  $2.0 \times 10^{-7} \text{ mol}/(\text{m}^2 \text{ s Pa})$  with a  $\text{CO}_2/\text{CH}_4$  selectivity of 300 and a  $\text{C}_2\text{H}_4$  permeance of  $2.9 \times 10^{-9} \text{ mol}/(\text{m}^2 \text{ s Pa})$  with a  $\text{C}_2\text{H}_4/\text{C}_2\text{H}_6$  selectivity of 11, at 303 K and 0.2 MPa feed pressure for these equimolar binary mixtures, respectively. SSZ-13 membranes also displayed high performances for  $\text{CO}_2/\text{CH}_4$  and  $\text{C}_2\text{H}_4/\text{C}_2\text{H}_6$  separations at higher feed pressures of 0.8-1 MPa. Steam treatment and long-time operation had no effect on membrane performance.

## S2-7

### Study on membrane reactor for methanol synthesis using Na-ZSM-5 membrane

Masahiro Seshimo, Yusuke Hashizume,  
Masahiko Matsukata  
Waseda University

Methanol is one of the important chemicals for fuels and feedstock such as acetic acid and formaldehyde. However, synthesis of methanol is required high temperature and pressure in production, and one-pass yield is low owing to thermodynamic equilibrium. Membrane reactor in which methanol and water are removed from reaction system has been expected for improving methanol one-pass yield. In our previous study, Na-ZSM-5 membrane showed methanol and water permselective performance under hydrogen/methanol and hydrogen/water mixture conditions. Thus, Na-ZSM-5 membrane has advantages for methanol synthesis membrane reactor. In this study, methanol synthesis membrane reactor using Na-ZSM-5 membrane and  $\text{Cu}/\text{ZnO}/\gamma\text{-Al}_2\text{O}_3$  catalyst was investigated, and we constructed a simulation model of membrane reactor. Performance of membrane reactor was experimentally evaluated at 543 K under 1.0 MPa in the feed side. Reactant gas with equilibrium compositions of  $\text{H}_2$ ,  $\text{CO}$ ,  $\text{CO}_2$ , methanol and water was fed to the exterior of Na-ZSM-5 membrane. The methanol yield improvement, calculated from the total methanol flow rate of permeate and retentate divided by that of feed, showed 2.04. The results of membrane reactor simulation showed 2.00 of methanol yield improvement, being in good agreement with the experimental results.

### Network Tuning of Sol-Gel Derived Triethoxysilane (TRIES) Membranes for Gas Separation

Masakoto Kanezashi<sup>1</sup>, Rui Matsugasako<sup>1</sup>, Hiromasa Tawarayama<sup>2</sup>, Hiroki Nagasawa<sup>1</sup>, Tomohisa Yoshioka<sup>1</sup>, Toshinori Tsuru<sup>1</sup>

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Triethoxysilane (TRIES), which is a pendant-type alkoxy silane and has Si-H bond, was utilized as Si precursor for the fabrication of gas separation membrane. The effect of membrane fabrication parameter such as sol preparation condition and calcination temperature on Si-H groups and network structure was evaluated. The degree of dehydrogenation of Si-H groups in aqueous solution was independent of the H<sub>2</sub>O/Si molar ratio in sol, but the degree of hydrolysis and polymerization of ethoxy groups (-OEt) depended on the H<sub>2</sub>O molar ratio. The TRIES derived network pore size depended on calcination temperature, and network size decreased with calcination temperature. For example, a TRIES membrane calcined at 550 °C showed high selectivity of He/N<sub>2</sub> and H<sub>2</sub>/N<sub>2</sub> of approximately 1000 and 600, respectively, however, in the case of calcination at 300 °C, Knudsen diffusion dominated for small molecules (H<sub>2</sub>/N<sub>2</sub> selectivity: 4.3) and molecular sieving for large molecules (H<sub>2</sub>/CF<sub>4</sub>: >100, H<sub>2</sub>/SF<sub>6</sub>: > 400).

### CO<sub>2</sub> permeation and CO<sub>2</sub>/N<sub>2</sub> separation characteristics of sol-gel derived microporous amino-silica membranes

Tomohisa Yoshioka<sup>1</sup>, Yukiharu Nagao<sup>2</sup>, Hiroki Nagasawa<sup>2</sup>, Masakoto Kanezashi<sup>2</sup>, Toshinori Tsuru<sup>2</sup>

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A membrane separation technology utilizing ceramic-based microporous membranes with chemical and thermal stability is promising for CO<sub>2</sub> capture and storage from a flue gas due to its energy saving and low cost features. Microporous amino-silica membranes can have reversible high adsorption loading of CO<sub>2</sub> by forming an alkyl ammonium carbamate structure between one CO<sub>2</sub> molecule and two-neighboring amino groups on a membrane. Microporous amorphous amino-SiO<sub>2</sub> membranes were prepared by the sol-gel method and CO<sub>2</sub> permeation and separation characteristics on those membranes were studied experimentally. Observed CO<sub>2</sub> permeance increased with decreasing temperature. This was so-called surface diffusion tendency through a membrane, which indicated high interaction of membrane pore surface with permeating CO<sub>2</sub> molecules. Separation experiments of CO<sub>2</sub>/N<sub>2</sub> binary gas mixtures at 35 °C were conducted to examine the effect of CO<sub>2</sub> adsorption on separation characteristics. CO<sub>2</sub>/N<sub>2</sub> permeance ratio under higher CO<sub>2</sub> concentration conditions became greater than the single gas CO<sub>2</sub>/N<sub>2</sub> permeation ratio. For CO<sub>2</sub>/N<sub>2</sub> separation, the obstruction due to blocking of N<sub>2</sub> transport caused by adsorbed CO<sub>2</sub> molecules would be effective around room temperatures.

### Catalytic pyrolysis of palm oil using pyro-GC/MS

Kodchakon Kun-asa<sup>1</sup>, Lalita Attanato<sup>2</sup>, Prasert Reubroycharoen<sup>1</sup>

<sup>1</sup> Chulalongkorn University

<sup>2</sup> Thailand Institute of Scientific and Technological Research

In this work, effect of pyrolysis temperature (400-500°C) and catalysts (MgO, Al<sub>2</sub>O<sub>3</sub>, and SiO<sub>2</sub>) on the conversion of palm oil to a high-quality fuel were studied in pyro-GC/MS. The pyro-GC/MS condition of palm oil was at 450°C for 0.5 min, and 10%wt of catalyst. The results showed that the pyrolysis product composed of hydrocarbon (i.e. olefins, paraffins and naphthenics), free fatty acids, (i.e. palmitic acid and oleic acid) and other oxygenated compound. Chemical structure of hydrocarbon product was a mixture of straight chain and branched chain. Main composition of oxygenate compound is ketone, aldehyde, and ester. The amount of hydrocarbon product increased when increasing the pyrolysis temperature, contrary to the amount of oxygenated compounds that decreased with the increasing of temperature. At 450 °C, pyrolysis with Al<sub>2</sub>O<sub>3</sub> as a catalyst gave high hydrocarbon content in the product but the amount of free fatty acid was higher than the other catalysts. When using MgO as a catalyst, the main products consisted of ketones and esters. SiO<sub>2</sub> catalyst showed low hydrocarbon content in the product with high triglyceride content.

### Fast Pyrolysis of Paper Reject in a Bubbling fluidized-bed System

Seng-Rung Wu<sup>1</sup>, Hou-Peng Wan<sup>1</sup>, Chih-Chiang Chang<sup>1</sup>, Ying-Hsi Chang<sup>1</sup>, Meng-Yuan Tsai<sup>2</sup>, Chien-Song Chyang<sup>3</sup>

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<sup>3</sup> Chung Yuan Christian University

Paper-reject waste, a mix of 50 wt% waste plastics and 50 wt% fiber, was produced from a local pulp and paper mill. Thermogravimetric analysis of paper reject in nitrogen atmosphere indicated that when the analyzer temperature gradually increased from 0 to 800°C, the fiber was quickly degraded at temperature of 250 °C followed by the decomposition of plastics at 400°C. The paper-reject waste was almost completely decomposed after 500°C with residue of 8 wt%. A bubbling fluidized-bed fast pyrolysis system was utilized to convert the paper-reject waste into useful fuel. The handling capacity of the bubbling fluidized-bed fast pyrolysis system was 30 kg h<sup>-1</sup>. A packaged tower design was devised to collect wax produced from the plastics, preventing the wax clogging the system. The collected wax showed that the packaged tower design not only collected the wax but also collected the char and ash from the fiber and plastics. The yields of wax, char and ash, pyrolysis oil, balanced pyrolysis

gas from the paper reject were 18 wt%, 2 wt%, 23 wt% and 57wt%, respectively. The wax and pyrolysis oil with high energy contents can be considerable as potential fungible fuel for heavy-fuel-oil boiler. Nevertheless, necessary precautions should be taken to against the sulfur and chlorine contents of the wax and pyrolysis oil which may corrode the facility. Furthermore, results of this study were used as a basis for the design of a fast pyrolysis plant with paper-reject handling capacity of 5 tonnes per day at a paper mill. The plant is expected to be completed in the end of 2016.

### S3-5

#### Investigation of reactivity of coal in a downer pyrolyzer with heat carrying particles and steam

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Pyrolysis of Loy Yang coal was carried out in a downer pyrolyzer (20 mm in i.d. and 1000 mm in length) in the presence of steam and pre-heated heat carrying particles (silica sand) to investigate the coal reactivity. The silica sand, preheated in a fluidized bed at 900 °C, and steam were fed from the top of the downer pyrolyzer. The temperature of the pyrolyzer was kept at 900 °C. The yields of gas, tar and char were measured by changing feed rates of the silica sand and steam. The results suggest that gas yields of H<sub>2</sub> and CO<sub>2</sub> increases with the increase of the steam feed rate due to shift reaction. In addition, yield of deposited carbon increased with the increase of silica sand feed rate.

### S3-6

#### Numerical Simulation of Two Stage Entrained Flow Coal Gasifier in Oxy-Fuel IGCC Condition

Kenji Tanno<sup>1</sup>, Ahn Seongyool<sup>1</sup>, Hiroaki Watanabe<sup>2</sup>, Hisao Makino<sup>1</sup>

<sup>1</sup> Central Research Institute of Electric Power Industry

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In order to reduce CO<sub>2</sub> emission from thermal power stations with keeping high thermal efficiency, a new concept of IGCC system, namely oxy-fuel IGCC, is recently proposed. Hence CO<sub>2</sub> is recycled in this system, the effect of CO<sub>2</sub> recycle should be clarified. In this study, the effect of recycled CO<sub>2</sub> injection on coal gasifier performance was investigated by means of three-dimensional RANS-based numerical simulation. For calculation of coal gasifier, coal gasification and water-gas shift reaction are key phenomena. Therefore, the partially active site sharing coal gasification model and detailed chemistry of water-gas shift reaction model were implemented. The results show that recycled CO<sub>2</sub> injection promotes coal gasification for the lower oxygen concentration condition in which gaseous concentration temperature is relatively high. The condition inside the gasifier is strongly affected by coal property, especially, the composition of volatile gas. On the other hand,

for higher oxygen and CO<sub>2</sub> concentration condition in which gaseous temperature level is relatively low, it is important that how much the higher gasification reactivity in a gasifier is exploited by optimizing local heat balance.

### S3-8

#### Gasification of Torrefied Woody Biomass with Carbon Dioxide in a Fluidized Bed

Yu-Shan Shih, Kai-Cheng Yang, Keng-Tung Wu, Clement Tseng, Kanit Manatura  
National Chung Hsing University

Biomass torrefaction at mild pyrolysis temperature is usually applied to improve the fuel quality of biomass. However, removal of a large amount of volatiles after torrefaction, torrefied biomass gasification with air cannot enhance the syngas production. Therefore, applying the Boudouard reaction, gasification of torrefied biomass with CO<sub>2</sub> at higher temperature could improve the syngas quality. In this study, gasification of torrefied biomass with CO<sub>2</sub> was carried out in a 30 kW<sub>th</sub> bubbling fluidized bed gasifier to investigate the effects of the air equivalence ratios (ER) and gasification temperatures on the syngas components, the higher heating value (HHV) and tar content. The preliminary results show that the syngas content of CO<sub>2</sub> increased with increasing the ER, but that of H<sub>2</sub>, CO, CH<sub>4</sub> shows the contrary results. In addition, at higher temperature above 800°C, gasification with CO<sub>2</sub> can enhance CO concentration compared with the air-blown gasification process, due to the Boudouard reaction for the higher carbon content of torrefied biomass.

### S3-9

#### Interaction between Biomass Ash and Bed Material during Combustion of Oil Palm Residues in a Fluidized Bed of Alumina Sand

Vladimir I. Kuprianov<sup>1</sup>, Pichet Ninduangdee<sup>2</sup>

<sup>1</sup> Thammasat University,

<sup>2</sup> Phetchaburi Rajabhat University

Oil palm kernel shell and empty fruit bunch with elevated/high potassium contents were combusted for 60 h in a fluidized bed of alumina sand with the aim to investigate the mutual impact of fuel-ash and bed material particles. The experiments were conducted under steady-state conditions at a 200 kW<sub>th</sub> heat input to the reactor with excess air of 40%. An interaction between ash-derived compounds and alumina sand grains resulted in formation and growth of a coating layer on the surface of bed particles. An elemental analysis of the coating was examined in some selected spots on the grain surfaces using a SEM-EDS system at different operating times, whereas an XRF technique was employed for monitoring the composition of the bed material and particulates emitted from the biomass combustion. No any evidence of bed agglomeration was observed during the entire test period. However, a time-related accumulation of the ash-derived compounds and lowering alumina content in the bed material indicated a reducing capability of the reused alumina sand to prevent bed agglomeration.

**Session 4**  
**--- Project and Program Management ---**  
**November 14, 13:40-17:00, Room 2**

**S4-1**

**Review of Essentials of P2M Theory and Practices -Japanese Program Management Framework for Smart Innovation-**

Shigenobu Ohara  
President of Project Research Corporation

P2M is the acronym of Program and Project Management guide which reflects Japanese version of a body of knowledge and good practice. Review of essentials in theory and practices shall be fundamental to social, community and industrial developments to cope with external changes in terms of managing technologies. Japanese way steers to “*smart innovation*” by program management.

**S4-2**

**A case study on how to increase energy efficiency of natural gas in Taiwan**

Lu-Sheng Hong,  
Taipei economic and Cultural Representative Office in Japan

Taiwan is facing a difficult situation in the choice of energy sources for the government approved to reduce greenhouse gas emissions 20% less than 2005 levels by 2030 under the choice not to build new nuclear power plant or even intent to phase out all in service by 2025. As of 2013 coal counts for 37.2% of the total primary energy consumption, while oil comes next with 38.7%, followed by natural gas with 12.1% and nuclear energy with 10.1%. Aside from increasing the use of renewable energy, the emission of carbon dioxide could be efficiently reduced by using more natural gas to substitute coal and oil. Nevertheless, being much higher in cost for natural gas, enhancing its energy use efficiency would be a key issue to support the adoption of more natural gas. This work describes the ideas and scenarios for Taiwan’s society to adopt natural gas as a transitional fuel up to 2030.

**S4-3**

**Introduction of Human-Centered Design to Program Management**

Hideo Yamamoto  
Chuo University

In developing new and attractive services or products, it is necessary to observe and identify human behavior when such new services or products are used. Management subjects participating in a program designed to reveal such human behavior represent both an artificial system and human activity that influences future intentions. A particular emphasis is placed on the introduction of human-centered design thinking to program management to create new value in the future. Previous research on the application of program management to special mission work shows that the key factor determining

management success is whether it provides a platform for communication with end users from the outset. In addition, an iterative trial-and-error process allowing for the best solution to be identified is found to be efficient for determining product user interface.

**S4-4**

**Boost Gate’s Practical Applications to Corporate Research and Development**

Yoshiaki Wada  
Kewpie Corporation

Integrating basic research and technology into business is a critical factor in corporate competitive strategy. While certain corporations whittle down a wide range of prospective R&D topics, others utilize the “Boost Gate (hereafter BG)” method for providing recommendations on promising research topics and promoting R&D projects. It is suggested that the use of this method leads to invigorated fundamental research activities within corporate R&D. Existing research on BG has provided certain details on the type of advice provided at each gate. Yet, these details have not provided methods for handling promising topics that still did not meet decision criteria, including whether to revert these topics or clear them to the next gate after advice is provided. Further, there are limited cases available for reference wherein BG has been implemented. This paper outlines the advising method for topics that do not meet a gate’s criterion in BG. It also provides a reference for leveraging BG in corporate R&D by presenting an actual implementation case of that method.

**S4-5**

**A Methodology of Green Multi-dimensional Bookkeeping System for Green Project and Program Management**

Keiko Zaima<sup>1</sup>, Hiroshi Deguchi<sup>2</sup>  
<sup>1</sup>Kyoto Sangyo University  
<sup>2</sup>Tokyo Institute of Technology

The objective of the paper is to provide a methodology of an environmental information system named Green Multi-dimensional Bookkeeping System (Green MDBS) for green program and project management. The suggest that all materials and services can be regarded as potential of environmental burdens. Green MDBS enables to describe all potential of environmental burdens in any process of any activity. Although Green MDBS is based on Multi-dimensional Bookkeeping System (MDBS) developed by Deguchi (2004), new concepts and methods are introduced: a dichotomy of processes, a classification of materials and services, a description of a multi-dimensional bookkeeping table enabling a linkage with IPO (Input-Process-Output) analysis, and a definition of Exchange Algebra of potential environmental burdens. This paper provides a methodology of Green MDBS and discusses an applied methodology of green project and product management based on Green MDBS.

**S4-6****Study on Program Profiling and Implementation Management with Intervention from Outside for Sustainable Value Creation in Ambiguous and Social Missions**Fumihiko OKIURA, Hiroshi KUBO

Chiba Institute of Technology

Although numerous official development assistance (ODA) projects are conducted, some cannot sustain and do not create value, especially when tackling social issues with many stakeholders. To improve this situation, by applying the Project and Program Management (P2M) theory, this paper examines important factors for profiling and implementing ODA programs/projects using case studies in Vietnam, and suggests necessity of program basis stakeholder management and a precise approach for sustainable value creation.

**S4-7****An Investigation Research of the Tendencies and Overcome Means of the Conflicts for the Emergent Regional Activation Projects**Ryusei Matsuda, Hironori Takuma

Chiba Institute of Technology

We targeted emergent regional activation projects by reporting the tendencies in, and means to overcome, human conflict factors. We created a questionnaire regarding conflict factors and solutions according to the activity level of participants in an emergent program of regional activation with renewable energy. We derived the frequency of occurrence and guidelines for conflict resolution based on these results. Conflicts caused by a mismatch between the interpretation and understanding of concepts frequently occur at the program level, and participants tended to resolve them using both compromise and reconciliation. However, conflicts caused by resource procurement occur frequently at the working level, and tended to be resolved by cooperation and problem-solving. Therefore, it is important to form a consensus on resource procurement at the program level.

**S4-8****Agile Program Management for Chemical Engineering and the IoT**

Tatsuo Sato

Hiroshima Shudo University,

The internet of things (IoT) has accelerated the attempts to strengthen Japan's domestic manufacturing industry. The same is true of the chemical engineering industry. To fully exploit the IoT, which facilitates a rapid and flexible response to changes in markets and technologies, it is important to achieve both trans-organization and trans-industry cooperation. To take advantage of the IoT in the chemical engineering industry, the paper proposes an agile program management model.

**S4-9****P2M methods in R&D to Overcome the Darwinian Sea**Mamoru Kiyota, Hiroshi Kubo

Chiba Institute of Technology,

When a technology developed by the research and development (R&D) department of a manufacturing firm reaches the commodification stage in the market, it is faced by an obstacle called the "Darwinian Sea." This study is focused on a method, currently not well known yet, which incorporates customer requests into R&D as a means of overcoming the Darwinian Sea. This study develops a new method of communicating customer requests taken from the market by the product division to the R&D department with reference to a structure provided by the Japan Quality Award (JQA) that was proven to be effective. Furthermore, a strategic method was proposed to appropriately incorporate customer requests into the complex system of developing R&D strategy and set a target for R&D by using the project and program (P2M) structure. The result proved the effectiveness of these methods to overcome the Darwinian Sea.

**S4-10****Value Creation Process Assisted by P2M for Innovative Energy & Environmental Chemical Engineering**

Hideo KAMEYAMA

Tokyo University of agriculture &amp; Technology

In formulating the fifth Science and Technology plan, the study of new concepts that contribute to the sustainable growth of our country has been promoted. The science and technology innovation is required to be the future creation type to create the future business. This study, proposed a value creation process needed to take advantage of the results of such scientific research to innovation to win the value in the market. It is a process to be sequentially performed in conjunction with the value discovery step and the value realization step and the value acquisition step. The value creation process is described in the 3S model. It was shown that the scheme model is the discovery process of academic and technical value and the discovery process of social and economic value, the system model is the value realization process, the service model is the acquisition process of economic and social value in market. In this paper, these things have been demonstrated by showing the several cases.

**Session 5**  
**--- CO<sub>2</sub> Capture and Storage**  
**Energy Engineering---**  
**November 16, 9:00-12:20, Room 1**

**S5-1**

**Influence of Post-combustion CO<sub>2</sub> Capture on Energy Performance of a Thermal Power Plant**

Kazuya Goto

Research Institute of Innovative Technology for the Earth (RITE)

Carbon dioxide capture and storage (CCS) is one of the countermeasures against global warming. Currently, low-cost CO<sub>2</sub> capture technologies have been under development for the purpose of implementing the CCS commercially. Various gas separation technologies such as absorption, adsorption and membrane separation have been investigated to apply them to post-combustion CO<sub>2</sub> capture and to reduce energy consumption of CO<sub>2</sub> capture. In this study, energy analysis was conducted to evaluate performance of CO<sub>2</sub> capture technology integrated with a coal-fired power plant. The influences of the CO<sub>2</sub> capture on energy performance of the thermal power plant were discussed. The chemical absorption with the amine-based solvent has a potential to reduce the thermal energy requirement. It was estimated to improve the energy efficiency of the coal-fired power plant with CO<sub>2</sub> capture by about 0.16% by lowering 0.1GJ/t-CO<sub>2</sub> in thermal energy requirement of CO<sub>2</sub> capture technology.

**S5-2**

**Evaluation of CO<sub>2</sub> Capture in a Fluidized Bed Reactor Using Amine-grafted Silica Sorbents**

Abidov Aziz<sup>1</sup>, Rajangam Vinodh<sup>1</sup>, Rramaswamy Ravikumar<sup>1</sup>, Wang Seok Cha<sup>2</sup>, Hyun Tae Jang<sup>1</sup>

<sup>1</sup> Hanseo University

<sup>2</sup> Kunsan National University

In this study, we have synthesized amine-grafted silica (AGS) adsorbent and evaluated its CO<sub>2</sub> capture performance in a laboratory-scale Circulating Fluidized Bed (CFB) reactor. AGS sorbent was prepared by mixing, appropriate quantities of 3-Aminopropyl Triethoxysilane (APTES), Tetraethyl ortho silicate (TEOS), alcohol and DI water. The mixture forms gel and pelletized using extrudate method, pelletized sorbent was dried in R.T. for 6 h. The dried sample is a void-enriched solid with high sorption capacity (15%) and selectivity to CO<sub>2</sub>, and adequate thermal stability (decomposing above 200 °C), according to thermal gravimetric analysis data (TGA). Subsequently (CFB) reactor was constructed to assess process validity for CO<sub>2</sub> capturing for a large scale process with low adsorption temperature (40 °C) and high desorption temperature at 150 °C. Experimental results showed ~80% efficiency from the TGA data. However using the water steam, the efficiency was increased to approximately 90~95% and this reaction mechanism was narrated.

**S5-3**

**Molecular Dynamics Simulation for Effect of the Amino-group Densities of Functionalized Ionic Liquids for CO<sub>2</sub> Capture**

Shaikh Abdul Rajjak<sup>1</sup>, Eiji Kamio<sup>1</sup>, Hiromitsu Takaba<sup>2</sup>, Hideto Matsuyama<sup>1</sup>

<sup>1</sup> Kobe University,

<sup>2</sup> Kogakuin University

Emission of greenhouse gases and the efforts to capture of CO<sub>2</sub> from fossil fuel combustion represents a crucial part of efforts aimed at reducing greenhouse gases in the atmosphere. In this regard, amino acid ionic liquids (AAILs) are gaining significance as a carrier of CO<sub>2</sub> facilitated transport membrane. Molecular dynamics simulations were performed for neat and aqueous solution of AAILs, namely tetramethylammonium glycinate, tetrabutylammonium glycinate, and 1,1,1-trimethylhydrozinium glycinate. These AAILs have been synthesized and demonstrated to have much higher capacities for CO<sub>2</sub> due to their reactivity with CO<sub>2</sub>, as well unusually high viscosities in both the neat and complexed states. The ILs with two amino group have found to be have higher CO<sub>2</sub> absorption and lower N<sub>2</sub> absorption under humid conditions. The current work extends the seminal studies of CO<sub>2</sub> capture with ILs by providing insight from simulations into the mechanism responsible for the dramatic increase in viscosity upon complexation. In addition, effect of water on CO<sub>2</sub> absorption was also studied. Results were compared with experimental studies. This has significant implications for the design of new materials involving ILs for CO<sub>2</sub> capture. The computational study provides quantitative microscopic insight into the role of amine group in CO<sub>2</sub> sorption and diffusion.

**S5-5**

**Enclathration of CO<sub>2</sub> as a Co-guest of Structure H (sH) Hydrates in the CO<sub>2</sub> + N<sub>2</sub> + Methylcyclopentane (MCP) + Water systems.**

Dongyoung Lee, Yohan Lee, Jiyeon Lim, Yongwon Seo

Ulsan national Institute of Science and Technology (UNIST)

Gas hydrates have various technological applications such as gas storage and transportation, CO<sub>2</sub> capture and sequestration, and desalination. Unlike sI and sII hydrates, sH hydrates can enclathrate large hydrocarbon molecules in the structure lattices in the presence of help gases such as CH<sub>4</sub> and N<sub>2</sub>. There have been several studies to investigate help gases of sH hydrates including CH<sub>4</sub>, N<sub>2</sub>, and CO<sub>2</sub>. However, there is also a controversy over the fact that CO<sub>2</sub> can function as a co-guest or a help gas in forming sH hydrates. In this study, the enclathration of CO<sub>2</sub> as a co-guest in the CO<sub>2</sub> + N<sub>2</sub> + methylcyclopentane (MCP) hydrates was examined for potential applications to CO<sub>2</sub> capture and storage. Thermodynamic, microscopic, and kinetic experiments were conducted to understand the influence of enclathrated CO<sub>2</sub> on structural transition. The hydrate phase equilibria demonstrated the equilibrium line shift for the N<sub>2</sub>-rich systems, indicating the possibility of structural transition. The microscopic analysis revealed that the initial sH hydrate was transformed into sI hydrate as CO<sub>2</sub> concentration increased. Lastly, it was found

from compositional analysis that sI hydrates showed higher CO<sub>2</sub> selectivity than sH hydrates.

## S5-6

### Development of CeO<sub>2</sub> supported metal catalysts for CO<sub>2</sub> methanation

Shohei Tada<sup>1,2</sup>, Ryuji Kikuchi<sup>3</sup>

<sup>1</sup> Seikei University

<sup>2</sup> Japan Society for the Promotion of Science

<sup>3</sup> The University of Tokyo

We investigated the following three things for development of a new CO<sub>2</sub> methanation catalyst: (i) active species (Ni, Co, Fe, and Ru) for CeO<sub>2</sub> supported metal catalysts, (ii) support materials (CeO<sub>2</sub>, Sm-doped ceria, Gd-doped ceria, Y-stabilized zirconia) for Ni catalysts, and (iii) La additive to Ni/CeO<sub>2</sub>. Based on the first and second investigations, Ni/CeO<sub>2</sub> catalyst exhibited the highest CO<sub>2</sub> conversion and CH<sub>4</sub> selectivity at low temperatures. In the case of Ni/CeO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>, NiAl<sub>2</sub>O<sub>4</sub> can be formed during its catalyst preparation process, resulting in suppression of metallic Ni formation even after H<sub>2</sub> pre-reduction step at 600 °C and then lower activity in CO<sub>2</sub> methanation compared to Ni/CeO<sub>2</sub>. Note that adding La species to Ni/CeO<sub>2</sub> enhanced CO<sub>2</sub> conversion at 300 °C from 67% to 74% without dropping CH<sub>4</sub> selectivity from 99%. Therefore we succeeded to develop a new CO<sub>2</sub> methanation catalyst Ni-La/CeO<sub>2</sub>.

## S5-7

### Hydrogen Production by Ethanol Steam Reforming using Ni-Cu Catalysts

Shawn D. Lin, Li-Chun Chen, Chih-Wei Chiang, Cheng-Hong Yu

National Taiwan University of Science and Technology

Hydrogen, a clean energy carrier, can be sustainably produced when renewable raw materials and renewable energy are used. The steam reforming of bio-ethanol at low temperature can be a possible solution. We examine the influence of preparation parameters on the ESR (ethanol steam reforming) activity over CuNi/SiO<sub>2</sub> catalysts. The results suggest that Cu-NiO interface may possibly suppress CH<sub>4</sub> formation and consequently promote H<sub>2</sub> production. We use a hard template method to prepare mixed Cu-Ni oxide followed by a partial reduction to prepared CuNi-NiO catalyst in order to increase Cu-NiO interface. The prepared catalyst shows high hydrogen yield when ethanol is completely converted at 300°C. This provides an opportunity to sustainably produce hydrogen.

## S5-8

### Ammonia Decomposition over Ni Catalysts Supported on Rare-earth Oxides

Hiroki Muroyama, Kaname Okura, Takeou Okanishi, Toshiaki Matsui, Koichi Eguchi

Kyoto University

Ammonia decomposition has attracted much attention as a promising process for the on-site generation of hydrogen. In this study, Ni catalysts supported on various rare-earth oxides were fabricated by the impregnation method and employed for ammonia decomposition. The Ni/Y<sub>2</sub>O<sub>3</sub> catalyst exhibited the best performance among all the samples investigated. The reaction kinetics study suggested that some rare-earth oxide supports were effective for the alleviation of hydrogen inhibition in the decomposition reaction.

## S5-9

### Characteristics of hydrogen generation from ammonia by plasma membrane reactor

Daiki Matsunami<sup>1</sup>, Yukio Hayakawa<sup>1</sup>, Shinji Kambara<sup>1</sup>, and Tomonori Miura<sup>2</sup>

<sup>1</sup> Gifu University

<sup>2</sup> Sawafuji Electric Co.

Ammonia is an excellent hydrogen carrier to solve the problems related to hydrogen transportation and storage in the hydrogen economy. In this study, pure hydrogen production was performed by a pulsed plasma membrane reactor equipped with a hydrogen separation membrane. Without the hydrogen membrane, the hydrogen conversion was 13 %. On the other hand, the hydrogen conversion of 21.9 % was attained by the plasma membrane reactor (PMR). The advantage of the PMR was to obtain pure hydrogen, which can apply to a fuel cell. The flow rate of hydrogen production by plasma decomposition of 100% ammonia was 20 mL/min.

## S5-10

### The use of industrial off gas as fuel in chemical looping for hydrogen production

Won-Chul Cho<sup>1</sup>, Do Yeon Lee<sup>2</sup>, Hae In Lee<sup>1</sup>, Kyoung Soo Kang<sup>1</sup>, Seong Uk Jeong<sup>1</sup>, Chu Sik Park<sup>1</sup>, Ki Kwang Bae<sup>1</sup>, Sang Done Kim<sup>2</sup>

<sup>1</sup> Korea Institute of Energy Research (KIER)

<sup>2</sup> Korea Advanced Institute of Science and Technology (KAIST)

The chemical looping strategy for hydrogen production (CLH<sub>2</sub>) offers a viable method for efficient fuel conversion, producing highly pure hydrogen and simultaneously capturing CO<sub>2</sub>. This process relies critically on an effective reactor design and the development of an oxygen carrier with high reactivity and stability. In this study, a novel by-product CLH<sub>2</sub> scheme was proposed, reusing iron (III) oxide powder and Finex off-gas (FOG) produced in the iron and steel industry. The fluidization characteristics of binary mixtures of iron oxide powder and sand were investigated. Then, cyclic redox performance and stability were evaluated in a batch fluidized bed reactor simulating both single- and multi-stage FOG-varying gas-solid contacting modes. Both Fe<sub>2</sub>O<sub>3</sub> and Fe<sub>3</sub>O<sub>4</sub> were tested as inlet solid reactants, while operating temperatures of 650-850 °C were used in order to achieve an optimal fuel reactor design. Binary mixtures containing 60 vol% 200-300 μm sand showed consistent catalytic activity under multiple redox cycles. Meanwhile, gas-solid conversion was maximized with a two-stage fluidized bed using Fe<sub>2</sub>O<sub>3</sub> at temperatures greater than 750 °C

**Session 6**  
**--- Sustainable Engineering**  
**Environmental Protection ---**  
**November 16, 9:00-12:20, Room 2**

**S6-1**

**Simultaneous Azo Dye Decolorization, Organic Removal and Bioelectricity Generation by Using a Double Chambered Biocathode Microbial Fuel Cell**

Yoong-Sin Oon, Soon-An Ong, Li-Ngee Ho, Yee-Shian Wong, Yoong-Ling Oon, Harvinder Kaur Lehl, Wei-Eng Thung  
Universiti Malaysia Perlis

The objectives of this study are to investigate the effect of organic loading on colour removal and bioelectricity generation, as well as the effect of dye concentrations on bioelectricity generation. The results showed that the colour removal improved with higher organic loading; while, the power density decreased when higher organic loading was supplied to the system. It was ascribed to the declined in dissolved oxygen as electron acceptor in the cathodic chamber. This study demonstrated more electron donors were utilized for colour removal than for bioelectricity generation. When 25 mg/L NC was supplied together with the substrate to the system, maximum power density of 20.13 W/m<sup>3</sup> was achieved. The internal resistant decreased from 50 to 32 Ω. The UV-visible spectra showed the NC azo band centered at 517 nm reduced significantly after the anaerobic treatment in the anodic chamber, and further decolourization was observed in cathodic chamber, such phenomenon can be associated with competition between azo dye and oxygen as electron acceptor. While further increase of NC concentrations inhibited the bioelectricity generation ascribed to the competition between azo dye and anode for electrons produced from the oxidized substrate

**S6-2**

**A Design of a Software System Supporting to Appropriately Perform the Management of Change Procedure**

Hirotsugu Minowa<sup>1</sup>, Kazuhiro Takeda<sup>2</sup>, Yukiyasu Shimada<sup>3</sup>, Tetsuo Fuchino<sup>4</sup>

<sup>1</sup> Okayama Shoka Univ.

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<sup>4</sup> Tokyo Institute of Technology

A change in criteria, procedure, and method of maintenance or design of chemical and nuclear plants can have high associated risks, resulting in large-scale accidents. Therefore, a management of change (MOC), which dictates managing change correctly when it comes to criteria, procedure and method of maintenance or design, is important for life cycle engineering. MOC is a type of business process management using business process model (BPM). The problem with executing an MOC is that it lacks explicit defined procedures and sufficient time for execution. Such problems will result in

accidents in the future. To solve these problems, we propose a solution by using a software system to support the execution of MOC procedure. Software support will be helpful as it can be used anytime/anywhere. Our developing system supports operators to follow MOC procedure correctly according to a rule defined as plant-life cycle engineering (Plant-LCE) based on IDEF0 by controlling their execution, and sharing and updating the information of changes to each administrator. This is expected to decrease operator's loads and increase efficiency. This study describes a support methodology by a software system based on BPM and Plant-LCE. The results of the study show that it is advantageous and useful to implement a software system, using an algorithm that supports MOC procedures. And shows a prototype software incorporates our proposed idea.

**S6-3**

**Stimulating Sustainable Innovation: A Case Study of Smart Cities**

Masaru Yarime<sup>1,2</sup>

<sup>1</sup> University of Tokyo

<sup>2</sup> University College London

Smart cities are considered as a key area where innovation plays a critical role in moving towards sustainability. A smart city would involve an advanced technological system for efficient electricity supply and applications, incorporating all the behavior of the actors involved, including generators, distributors, technology developers, and consumers, through an intelligent information network. In this paper, we examine the technological innovation system of smart cities in terms of their functions, namely, knowledge development and diffusion, guidance of the search, resource mobilization, entrepreneurial experimentation, market formation, legitimization, and development of positive externalities. Network analysis is conducted to identify the relevant stakeholders and to examine their relationships in the innovation communities. Smart city projects in Japan are analyzed with regard to the actors involved, the technological areas emphasized, and the processes in which the actors collaborate with each other. Fragile business models, asymmetry of knowledge and capacities among the stakeholders, uncertainty and unpredictability of the regulatory and institutional environment, and the lack of communication and engagement with end users of electricity are among the challenges in facilitating innovation on smart cities.

**S6-4**

**Crystallization-Mediated Synthesis of Semiconductor Microparticles toward Degradation of Organic Pollutants under Visible Light**

Yang Yang, Yun Cai, Jun Fang, Hongli Wang  
Nanjing Tech University

We report simple and cost-effective fabrication of amorphous Cu<sub>x</sub>O (x = 1, 2)/crystalline CuI p-p type heterojunctions based on crystallization-mediated approaches including antisolvent crystallization and crystal reconstruction. Starting from CuI acetonitrile solution, large crystals in commercial CuI can be

easily converted to aggregates consisting of small particles by the crystallization processes while the spontaneous oxidation of CuI by atmospheric/dissolved oxygen can induce the formation of trace  $\text{Cu}_x\text{O}$  on CuI surface. As a proof of concept, the as-fabricated  $\text{Cu}_x\text{O}/\text{CuI}$  heterojunctions exhibit effective photocatalytic activity towards the degradation of methyl blue and other organic pollutants under visible light irradiation. It is suggested that the  $\text{Cu}_x\text{O}/\text{CuI}$  interface can enhance the spatial separation of the electron-hole pairs with the excitation of  $\text{Cu}_x\text{O}$  under visible light and prolong the lifetime of photogenerated charges with high redox ability.

## S6-5

### Catalytic combustion of toluene over Cu-Mn mixed oxide catalyst

Yi Liu<sup>1</sup>, Yi Lin<sup>1</sup>, Qing Li<sup>1</sup>, Fei Chen<sup>1</sup>, CaiYuan Cao<sup>1</sup>, Lu Jia<sup>2</sup>, Hideo Kameyama<sup>2</sup>, Yu Guo<sup>1</sup>

<sup>1</sup> NanJing Tech University

<sup>2</sup> Tokyo University of Agriculture and Technology

A series of Cu-Mn mixed oxide catalysts  $\text{Cu}_{1-x}\text{Mn}_x$  ( $x=0\sim 1.0$ ) with high surface area were synthesized by using carbonate co-precipitation method in the whole range of  $x$  from 0 to 1.0, and their performance in catalytic combustion reaction of toluene was investigated by varying the ratio of Cu and Mn. XRD, DRIFT,  $\text{H}_2$ -TPR, XPS,  $\text{N}_2$  adsorption/desorption were used to characterize the structure and textural properties of catalysts. The resulting  $\text{Cu}_{1-x}\text{Mn}_x$  catalyst gives the catalytic activity superior to the mono-metal oxide catalyst, especially in the Mn-rich case. With the change of Mn doping amount, a volcano-like activity tendency is observed. Results of catalyst characterization reveal that the promoted activity can be associated with certain interrelated factors, such as depressed crystallinity, highly-dispersed oxide particles onto the other, easier catalyst reducibility, more surface oxygen and enhanced surface area. It is difficult to attribute the promoted catalytic activity only to a single and specific factor. A synergistic effect between Mn and Cu species is considered to be the most intrinsic reason.

## S6-6

### Discharge-Plasma Treatment for NO and $\text{NO}_2$ adsorbed on Mn-Cu mixed oxide

Keiichiro Yoshida

Osaka Institute of Technology

The author reports about a  $\text{NO}_x$  control system that uses adsorption and desorption by Mn-Cu mixed oxide. In this study, first, NO and  $\text{NO}_2$  adsorption characteristics of the oxide were investigated using temperature programmed desorption (TPD). The results showed that the Mn-Cu mixed oxide tested in this study had at least two kinds of surface compound of  $\text{NO}_x$ , which had different desorption temperatures. One of them had a desorption temperature of around 150 °C. Next, discharge plasma was applied to the oxides bed with NO and  $\text{NO}_2$  adsorbed onto it. The TPD test after the plasma treatment showed that those  $\text{NO}_x$  were successfully desorbed and to some extent decomposed by the plasma.

## S6-7

### Preparation of manganese oxide based on activated carbon as low temperature desulfurization materials for diesel exhaust emission control

Xuecheng Liu<sup>1</sup>, Yugo Osaka<sup>2</sup>, Hongyu Huang<sup>1</sup>, Zhaohong He<sup>1</sup>, Xixian Yang<sup>1</sup>, Huhetaoli<sup>1</sup>, Jianjun Li<sup>3</sup>

<sup>1</sup> Chinese Academy of Sciences

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<sup>3</sup> Sichuan University

In this study, manganese oxide/activated carbon ( $\text{MnO}_2/\text{AC}$ ) composite was proposed as low temperature desulfurization materials for  $\text{SO}_2$  trap. The  $\text{MnO}_2/\text{AC}$  composite were prepared by translating potassium permanganate into  $\text{MnO}_2$  which formed the above composite with residual carbon material using the redox deposition method and carbon as a reducer. The products were characterized by SEM, and the  $\text{SO}_2$  capture capacity of  $\text{MnO}_2/\text{AC}$  was measured by thermogravimetry at 100°C ~250 °C with a 2 L/min flow gas containing 500 ppm  $\text{SO}_2$  in nitrogen. The  $\text{SO}_2$  capture capacity of  $\text{MnO}_2/\text{AC}$  composite initially increases and then decreases with  $\text{MnO}_2$  loading amount rising.  $\text{SO}_2$  absorption capacity of  $\text{MnO}_2/\text{AC}$  composite can achieve as high as 29% of weight increase at 100°C, significantly higher than conventional low temperature desulfurization materials.

## S6-9

### The Sulphation Behavior of Inactivating High-efficiency Ca-based During Sequential $\text{CO}_2/\text{SO}_2$ Capture Process

Feng Duan<sup>1,2</sup>, Xiaoru Sun<sup>2</sup>, Yaji Huang<sup>1</sup>, Chiensong Chyang<sup>3</sup>

<sup>1</sup> Southeast University

<sup>2</sup> Anhui University of Technology

<sup>3</sup> Chung Yuan Christian University

The inactivating high-efficiency Ca-based absorbent can be used to adsorb  $\text{SO}_2$  directly, which can avoid the decline of carbonation conversion in the process of the cyclic calcination /carbonation reaction (CCCR) because of the presence of  $\text{SO}_2$  in flue gas. The sulphation behavior and the kinetic characteristic of the deactivation high-efficient absorbent after the CCCR was evaluated in this study. The pore structure characteristics of spent CMA particles were also studied. Results show that the carbonation conversion of CMA decreases significantly first, and then keep level with increases of cycle number. Sulphation processes of all spent CMA can be divided into two distinct stages including the rapid adsorption stage controlled by the specific surface area and the gas diffusion stage controlled by the dense of product layer.

## S6-10

### Roles of various supports in formation of structure of sulfided Co-Mo hydrotreating catalysts

Thanh Tung Nguyen, Hiroyuki Tominaga, Eika W. Qian

Tokyo University of Agriculture and Technology

CoMo catalysts supported on various supports such as Al<sub>2</sub>O<sub>3</sub>, 20%SAPO-11-80%Al<sub>2</sub>O<sub>3</sub>, 20%TiO<sub>2</sub>-80%Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> were prepared to investigate the relationship between metal-support interaction and catalytic hydrogenation activity. The catalysts were characterized by means of BET measurement, XRF, NH<sub>3</sub>-TPD, XPS and TEM. The catalytic activity tests were carried out in hydrodesulfurization (HDS) of 4, 6-dimethyldibenzothiophene, hydrodenitrogenation (HDN) of acridine, and hydrodearomatization (HDA) of phenanthrene. The results indicated that the acidity of the supports affected the catalytic activity. 20%CoMo/80%SAPO-11- Al<sub>2</sub>O<sub>3</sub> with weaker interaction between active metal species and - support showed low HDA activity than conventional CoMo/Al<sub>2</sub>O<sub>3</sub> catalyst, but the former also showed lower HDS, HDN activities. CoMo/ 20%TiO<sub>2</sub>-80%Al<sub>2</sub>O<sub>3</sub> which shows weak the active metal species support interaction and high stacking layer of CoMoS phase showed high HDS, HDN activity and low HDA activity than conventional CoMo/Al<sub>2</sub>O<sub>3</sub> catalyst. The XPS results also reveal that Ti-Mo-S phase plays a role as a new activity site in hydrotreating reaction.

## Session 7

### --- Energy Engineering ---

November 16, 13:40-18:00, Room 1

## S7-1

### The Synthesis of Catalyst Cu/Zn/Al by Microwave Co-precipitation Technique on Zr Doped Zeolite HZSM-5 Type for DME Process from Syngas

Chotima Ratanasakprakan<sup>1</sup>,

Samart Kongtaweelert<sup>1</sup>, Montree Thongkam<sup>1,2</sup>

<sup>1</sup> King Mongkut's Institute of Technology Ladkrabang

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The synthesis of bifunctional catalyst for producing dimethyl ether (DME) is a renewable energy from syngas. The catalyst can be synthesized by the physical mixing of a metal oxide catalyst and an acid catalyst. The metal oxide catalyst, Cu/Zn/Al oxide was synthesized by a modified microwave co-precipitation technique. The effect of synthesizing time on metal oxide properties was studied at 5, 10, 15, 20, 25 and 30 minutes. The calcination processes and thermal characteristic of precipitated metal oxide were investigated by Thermal gravimetric analysis (TGA). The acid catalyst "Zr doped zeolites HZSM-5 type" was prepared via ultrasonic ambient incipient wetness impregnation technique (ICP) with Zr in 2%, 4% and 6% by weight. The catalyst performance was tested in a fixed bed DME reactor. The physical properties of catalysts were analyzed with X-ray diffraction (XRD) determined crystallinity and catalysts composition. The scanning electron microscope (SEM) was used to determine the morphology and

dispersion of the catalysts. Brunauer-Emmet-Teller Surface Area Analysis (BET) determined a specific area and porosity in active phase and temperature programmed desorption of ammonia for acidity (NH<sub>3</sub>-TPD) studied surface acidity on catalyst properties.

## S7-2

### Successful Operation of Up-Flow Constructed Wetland - Microbial Fuel Cell (UFCW-MFC) in Promoting Sustainable Wastewater Treatment and Bioelectricity Production

Yoong-Ling Oon, Soon-An Ong, Li-Ngee Ho, Yee-Shian Wong, Farrah Aini Dahalan, Yoong-Sin Oon, Harvinder Kaur Lehl, Wei-Eng Thung

Universiti Malaysia Perlis

This study demonstrates simultaneous wastewater treatment and bioelectricity generation by using a novel up-flow constructed wetland - microbial fuel cell. Carbon felt was employed as the bioelectrodes and the system was operated in continuous mode under 1 day HRT. Synthetic wastewater was used as fuel in the MFC system and oxygen was used as the electron acceptor for electrical current generation. The aim of this study is to investigate the effect of supplementary aeration in UFCW-MFC on the performance of organic pollutant removal and bioelectricity generation. Significant redox gradient was developed along the vertical wetland bed and evidenced by the dissolved oxygen profile. The system with supplementary aeration achieved 92 % of NH<sub>4</sub><sup>+</sup> removal compared to non-aerated system (49 %). The maximum Coulombic efficiency and normalized energy recovery were 124 W/kg COD and 7 %, respectively. However, poor NO<sub>3</sub><sup>-</sup> removal was observed during aeration, which was due to denitrification inhibition. When UFCW-MFC operated without supplementary aeration, low voltage output was observed as a result of insufficient electron acceptor as the oxygen provided by the macrophytes was limited.

## S7-3

### Application of etched aluminum flow-through membrane as a catalyst support

Hiroshi Hiramatsu<sup>1,2</sup>, Makoto Sakurai<sup>1</sup>, Hironari Sasagawa<sup>1</sup>, Hideo Kameyama<sup>1</sup>

<sup>1</sup> Tokyo University of Agriculture and Technology

<sup>2</sup> Japan Capacitor Industrial Co., Ltd.

We developed a novel catalyst supports using aluminum etched with microchannels as microreactors. To date, electrochemical etching has been used to obtain high surface areas on aluminum foils for use as electrolytic capacitor electrodes. 1st etching generates straight microchannel, and then 2nd etching enlarges microchannels. In the present work, we investigated the etching of aluminum for use as catalyst supports. Our aims are to provide a reaction space with short and controlled residence time, and high catalytic activity. The novel catalyst support membrane contains penetrating microchannels with a diameter of about 3.5 μm (10,000–15,000 microchannels/mm<sup>2</sup>) formed on the aluminum foil substrate by etching. Therefore, flow was

through an applied porous membrane. The aluminum membrane was characterized by forming a coating catalyst support layer by anodic oxidation, hydration and calcination. The steam reforming of methanol was assessed in this microreactor. We confirmed whether reactions occur in membrane microchannel and evaluated the performance of this membrane compared with alumina granular. And also, we examined whether the aluminum catalyst membrane can be stacked one on top of the other.

#### S7-4

### Ammonia synthesis from N<sub>2</sub> and steam in intermediate temperature range using a CsH<sub>2</sub>PO<sub>4</sub>/SiP<sub>2</sub>O<sub>7</sub> composite electrolyte and supported noble metal catalysts

Ryuji Kikuchi<sup>1,2</sup>, Shota Kishira<sup>1</sup>, Geletu Qing<sup>1,2</sup>, Atsushi Takagaki<sup>1</sup>, Takashi Sugawara<sup>1</sup>, Shigeo Ted Oyama<sup>1,3</sup>

<sup>1</sup> The University of Tokyo

<sup>2</sup> Japan Science and Technology Agency (JST)

<sup>3</sup> Virginia Tech,

Ammonia is one of the most important industrial products and expected to be a hydrogen carrier. Electrochemical synthesis of ammonia directly from H<sub>2</sub>O and N<sub>2</sub> is a promising process. There has been no research about electrochemical synthesis of ammonia using a solid phosphate-based electrolyte in intermediate temperature range. When CsH<sub>2</sub>PO<sub>4</sub>/SiP<sub>2</sub>O<sub>7</sub> was used as the electrolyte, ammonia was successfully synthesized. In NH<sub>3</sub> synthesis from H<sub>2</sub>-N<sub>2</sub> ammonia synthesis, ammonia formation rate and faradaic efficiency decreased as applied voltage was increased larger than 0.3 V. This is possibly because the coverage of the cathode catalyst surface was high under the large applied voltage. In NH<sub>3</sub> synthesis from H<sub>2</sub>O-N<sub>2</sub>, a cathode catalyst containing Ru showed high activity per electrochemical surface area. Maximum ammonia formation rate was 1.2×10<sup>-11</sup> mol cm<sup>-2</sup> s<sup>-1</sup>. These results indicate that when a highly-dispersed Ru catalyst is manufactured and electrolyte of moderate proton conductivity is used, ammonia formation rate and faradaic efficiency will be improved.

#### S7-5

### A Performance of Alkaline Membrane Fuel Cell Study with Different Cathode Catalysts

Rajangam Vinodh<sup>1,2</sup>, Aziz Abidov<sup>1</sup>, Dharmalingam Sangeetha<sup>2</sup>, Muthiahpillai Palanichamy<sup>1,2</sup>

Wang Seog Cha<sup>3</sup>, Hyun Tae Jang<sup>1</sup>

<sup>1</sup> Hanseo University

<sup>2</sup> Anna University

<sup>3</sup> Kunsan National University

In this present study, two polymers were selected namely poly styrene (ethylene butylene) poly styrene [PSEBS] and polysulfone [PSU] to prepare anion exchange membrane. In order to convert polymer into a polymer electrolyte, PSEBS and PSU were quaternized following chloromethylation and the membranes were prepared by solution casting method. Prepared quaternized poly styrene (ethylene butylene) poly

styrene (QPSEBS) and quaternized polysulfone (QPSU) showed good thermal and chemical stabilities. For comparison purpose, a commercially available anion exchange membrane, AMI-7001 was purchased from Membranes International Inc., USA. The synthesized membranes were tested in an in-house fabricated alkaline membrane fuel cell set up using Pt/C as the common anode catalyst and three different cathode catalysts namely Pt/C, Ag/C and Pd-Ni/C. Among the above mentioned catalysts, Ag/C and Pd-Ni/C prepared by wet impregnation and reduction method respectively were characterized by XRD, SEM, TGA, DRS-UV, Raman and cyclic voltammetry studies. In the AMFC performance, QPSEBS and QPSU possessed maximum power density of 115.2 and 95 mW/cm<sup>2</sup> respectively while AMI-7001 exhibited a maximum power density of 108.8 mW/cm<sup>2</sup> under identical experimental conditions.

#### S7-7

### Numerical Study on the Momentum, Heat and Mass Transfer in a Heat and Moisture Exchanger with Filter

Yoshihito Okinaga<sup>1,2</sup>, Takahiro Sakamoto<sup>1</sup>, Kunihisa Eguchi<sup>2</sup>, Toshihisa Ueda<sup>1</sup>

<sup>1</sup> Keio University

<sup>2</sup> Teikyo University

Characteristics of momentum, heat and mass transfer in a heat and moisture exchanger with a filter (HMEF) are numerically investigated to evaluate basic phenomena within the HMEF. Non-steady, three-dimensional numerical simulation of momentum, heat and mass transfer has been carried out, by using a commercially available software "ANSYS FLUENT". Thermo-fluid flow motion is simulated for periodically repeated motion between breathing-out air of high temperature and high humidity, and dry breathing-in air of low temperature. When the sponge-type filter is sintered with a hygroscopic material of CaCl<sub>2</sub>, the moisture in a breathing-out gas is once captured by the sponge, and returned in a breathing-in gas, and as a result, water-content of respiratory organs is maintained at a moderate humidity condition. The filter also plays an important role of a heat exchanger between breathing-in and -out air, in order to keep the breathing-in air at the nearly same temperature in lung. Addressed herein are more details of heat and moisture exchange behavior in the HMEF.

#### S7-8

### A Novel Double-column Drying Process for Energy-saving Drying of Low-rank Coal and Biomass

Lu Chen, Yasuki Kansha, Masanori Ishizuka, Atsushi Tsutsumi  
The University of Tokyo

To further reduce energy consumption for drying materials with internal water (e.g. low rank coal, biomass, inorganic salt with crystal water), a novel double-column drying process was proposed. In this process, surface water is removed in one column at a relatively high pressure while internal water is removed in another column at a relatively low pressure. Steam evaporated in each column is compressed by a compressor into higher-pressure superheated steam, which flows through the

column to provide heat for water removal. Energy consumption for drying brown coal with an initial moisture content of 65%(wb) to 10%(wb) with this process was calculated by simulation and compared to that with other existing drying processes. Result showed that energy consumption of this process could be reduced to ~1/10 of that of conventional heat recovery process in this simulation case. As for different inconstant-pressure combinations of two columns, energy consumption of [high pressure+ normal pressure] is ~7% lower than that of [normal pressure+low pressure].

## S7-9

### Experimental Studies on Solar Chemical Heat Pump for Year Through Operation

Keitaro Muramatsu, Hironao Ogura  
Chiba University

From the viewpoint of energy and environmental problems, it is essential to use renewable energy. Chemical Heat Pump (CHP) can store various heat such as solar heat and release it as cold/hot heat using chemical reaction. Solar Chemical Heat Pump (SCHP) combines solar energy and CHP in order to convert solar heat to cold/hot heat effectively. Previous experiments showed the effectiveness of SCHP for possible use in air conditioners etc, however, there were concerns remaining with the unit which includes efficiencies of solar energy conversion, heat exchange, and insulation. Such concerns will make SCHP difficult to be operational throughout the year especially during winter season. Our laboratory has performed theoretical verification on the SCHP by the simulations for enhanced SCHP. In this study, the have performed alteration from the original experimental unit to enhanced SCHP unit and used it to acquire further efficiencies of the issues mentioned above. The effects of insolation by tracking and heat exchange by inserting a new heat exchanger on the characteristics of the enhanced SCHP. The experimental result showed improvements and possibility of SCHP operating during winter season therefor allowing for year through operation.

## S7-10

### Hollow ceramic heat storage ball with gas flow holes for regenerative burner systems

Hideki Kita, Seiji Yamashita  
Nagoya University

As a heat storage body of regenerative burner system (RGS), the solid-core alumina ceramic ball with ca. 20 mm in diameter has been conventionally used. For RGS, further energy efficiency improvement and downsizing have been required. In this report, as a new thermal storage body, hollow sphere structure with perforation was designed and the potential have been examined.

## S7-11

### Structural design of core-shell ball for high efficiency heat storage in high temperature

Seiji Yamashita, Sakiko Nagaoka, Hideki Kita  
Nagoya University

Core-shell heat storage structure which had metal core as latent heat material and ceramic shell was applied for high efficiently heat storage system. Conventionally, bulk ceramic has been used as the heat storage body for high-temperature range. These sensible type heat storage system is very simple and cost is low, however, the energy density is not sufficient and the heat input speed is slow. Those problems might be fateful for sensible heat utilization system. It was confirmed that the newly developed structure provided a high-speed heat input and high-energy density compared with conventional ceramic body. The metal core has high thermal conductivity and it stores high latent heat through the solid-liquid phase transition. The core shell structure design was important for utilization of their heat storage potential. In this study, the interspace of core shell structure was optimized for more high efficiency and durability of high speed heat storage

## S7-12

### Thermochemical energy storage material developments for surplus heat recovery

Yukitaka Kato, Massimiliano Zamengo  
Tokyo Institute of Technology

Heat storage function for surplus heat is important for an efficient operation of energy processes. Thermochemical heat storage (TCES) has possibility to store surplus heats. Magnesium oxide/water reaction system (MgO/H<sub>2</sub>O) is a candidate for TCES at around 300°C. Although the TCES material has high reactivity, thermal conductivity enhancement of the materials is important for efficient heat exchange and thermal performance for a heat storage system because of low effective thermal conductivity of the materials. Expanded graphite (EG) is a good candidate for thermal conductivity enhancement. Composite material mixed with TCES material and EG (EM) was developed. The EM composite has higher thermal conductivity and mold-ability in comparison with pure-material. EM is expected to have better thermal performance, and to contribute on re-utilization of surplus heats.

## S7-13

### The Use of Bio-Diesel Oil Produced From Anhydrous Ethanol in an Automobile

Mattana Santasnachok<sup>1</sup>, Ekkachai Sutteerasak<sup>2</sup>

Charoen Chinwanitcharoen<sup>1</sup>

<sup>1</sup> Burapha University

<sup>2</sup> Faculty of Engineering

The main objective of this study is to investigate the fuel properties and the automobile and engine performance. Diesel engine is direct-injection diesel engine, 4 cylinders and 4 strokes which is connected with the manual gear box, 5 gears, into a pick-up automobile by using diesel fuel mixed with biodiesel from 10 to 50% and biodiesel oil compared with diesel fuel. Biodiesel oil was prepared by transesterification process which the palm olein reacted with anhydrous ethanol. The engine testing is under the condition of different engine speed from 1,000 to 2,500 rpm at full load. The result shows that biodiesel has the ethyl esters 99.89%, the fuel heating

valve equals 36.87 MJ/kg and the fuel density equals 0.870 kg/m<sup>3</sup>. While comparing biodiesel oil with diesel fuel reveal that the fuel heating valve decreases 17.07% but the fuel density increases 6.1%. Results of investigated automobile and engine performance show that the vehicle speed has not changed but the rear-wheel drive power from using net biodiesel is lower than net diesel fuel. Brake specific fuel consumption from using net biodiesel is higher than net diesel fuel, thermal efficiency from using net biodiesel is lower than net diesel fuel and smoke density from using net biodiesel is lower than net diesel fuel.

## Session 8

### --- Environmental Protection + Biomass, Biofuel and Biochemicals --- November 16, 13:40-18:00, Room 2

#### S8-1

#### Effects of the Flow Field of the Cyclone Inlet on its Separation Performance

An-Ni Huang<sup>1</sup>, Daiki Shibata<sup>1</sup>, Tomonori Fukasawa<sup>1</sup>, Hideto Yoshida<sup>1</sup>, Hsiu-Po Kuo<sup>2</sup>, Kunihiro Fukui<sup>1</sup>

<sup>1</sup> Hiroshima University

<sup>2</sup> Chang Gung University

Hollow tubes are horizontally placed in the entrance of the cyclone as the rectifiers. The effects of the rectifier addition on the cyclone performance are evaluated by experiments and CFD simulations. Rectifier alters the air mass flow rate and particle flow distributions at the entrance. At the inlet gas velocity of 11 m/s, the rectifier fitting causes a slight increasing of the pressure drop across cyclone and a slight decreasing of the gas tangential velocity. The installation of the rectifier increases the fraction of air mass flow rate at the outer part of entrance. The number flow rate of particles through the inner part of the entrance decreases by 20.23% after rectifier installation. Higher particle number flow rates are found in the outer part of entrance where partial separation efficiency is typically high. 50% cut size decreases from 2.04 μm to 1.89 μm. The results indicate that cyclone with rectifier at entrance shows better performance.

#### S8-2

#### Enhancement of Oxygen Absorption in Micro-Bubble Dispersion with Oxygen-Nitrogen Mixture

Katsuhiko Muroyama, Hiroyuki Ishikawa, Keisuke Umehara, Jun'ichi Hayashi

Kansai University

Micro-bubble dispersion of oxygen-nitrogen mixture with diameters less than approximately 50 μm exhibited significant enhancement in oxygen absorption, compared with conventional milli-bubble dispersion. In the micro-bubble dispersion, the final attained dissolved oxygen concentrations in the middle gas-phase oxygen fractions significantly exceeded the corresponding intrinsic equilibrium values in the milli-bubble dispersion. This unique feature was apparently

supersaturation of oxygen, established at the liquid-side interface by the self-compression and shrinking mechanism related to micro-bubbles. The values of kLa in the micro-bubble dispersion increased with increasing superficial gas velocity of oxygen-nitrogen mixture feed, while increasing with increasing gas-phase oxygen fraction. In addition, the values of kLa in the micro-bubble dispersion were markedly greater than those in the milli-bubble dispersion of pure oxygen. The oxygen absorption efficiency, E, was defined as the percentage of the ratio of the oxygen absorption rate to the oxygen supplying rate for specified oxygen-nitrogen mixture feed. The values of E in the micro-bubble dispersion were markedly greater than those in the milli-bubble dispersion, indicating that the self-compression and shrinking mechanism selectively enhanced absorption of oxygen with higher solubility relative to nitrogen at the liquid-side interface.

#### S8-4

#### Effects of Adding Biochar and Graphene in the soil on Plant Growth

Wei-Chun Chang<sup>1</sup>, Keng-Tung Wu<sup>2</sup>, Clement Tseng<sup>1</sup>, Yi-Hui Yen<sup>2</sup>

<sup>1</sup> National Chung Hsing University

<sup>2</sup> Hsinchu Forest District Office

In this study, plant growth promotion by using graphene and biochar was investigated. All plant growth experiments were carried out in pots containing 200 g soil which was mixed with the biochar, graphene, graphite and active carbon after grinding and sieving (<1.25 mm) and sandy soil. The biochar adding rates were 0, 2.5, 5, and 7.5 wt.%, and also graphene, graphite and active carbon were employed as another additives. The plant, *Brassica rapa chinensis*, was grown in the biochar-added soil to examine NH<sub>4</sub>-N, total phosphorous contents, and cation exchange capacity (CEC). The weight of plants after growing in the soil was also investigated. The preliminary results show that the pore diameter and specific surface area (SSA) of biochar dominate nutrient retention in the soil, which increased with increasing the preparation temperature.

#### S8-5

#### Optimization of solvent extraction process by heat recovery in large-scale biofuel production from microalgae

Chiemi Tachibana, Ryo Tomita, Chihiro Fushimi  
Tokyo University of Agriculture and Technology

Biofuel from microalgae is an alternative to petroleum because growth rate of microalgae is high and also microalgae contain lots of lipids. Major steps involved to produce biofuel from microalgae are, (i) culturing, (ii) harvesting, (iii) extraction and (iv) conversion. Among these, extraction process consumes large of heat as well as power. Thus, it is necessary to reduce consumption of heat and electric power. In solvent extraction process, lipids are extracted from dewatered algae with hexane and then hexane is recovered by distillation then producing bio-oil. Algae dewatering and hexane removing processes consumes large amount of heat and power. In this study an attempt is made to optimize both heat and power consumption of the solvent extraction process by introducing mechanical

vapor recompression or self-heat recuperation technology. Results from the study shows that both energy and cost can be saved significantly.

## S8-6

### Plasma processing for cracking vegetable oil to short chain hydrocarbon as liquid fuels via pyrolysis reaction

Phimpaka Meeprasertsagool<sup>1</sup>,  
Anyarat Watthanaphanit<sup>2</sup>, Tomonaga Ueno<sup>3</sup>,  
Nagahiro Saito<sup>3</sup>, Prasert Reubroycharoen<sup>1</sup>

<sup>1</sup> Chulalongkorn University

<sup>2</sup> Mahidol University

<sup>3</sup> Nagoya University

Green liquid fuels derived from vegetable oil are still very attractive even if in the oil price down situation, due to their environmental and sustainable human friendly. Green liquid fuels such as diesel are produced by 2 well know method, transesterification/esterification and pyrolysis (cracking). Pyrolysis is more attractive than transesterification/esterification, but this process requires high processing temperature and high energy consumption per unit cost of fuel product. Recently, solution/liquid-phase plasma is the novel method to provide the direct energy at highly excited energy state. The application of the plasma to pyrolysis of vegetable oil could be an alternative way for reducing the production cost of the green fuel. In this study, the investigation of the green fuel synthesis from vegetables oils using solution plasma was examined. The solution pulse reactor was connected to a bipolar pulsed power supply under 200 ml of palm oil and the pulse frequency adjusted to from 100, 150, 190 kHz with 40 min of discharge times. Properties of generated plasm were investigated by optical emission spectroscopy methods. The liquid products were analysed by GC-MS. In conclusion, the results showed that plasma has a potential and enough energy to convert vegetable oils in liquid fuels at room temperature which consume less energy than pyrolysis and can also provide the direct energy.

## S8-7

### The Hydrodeoxygenation of Bio-crude Oil via Molybdenum-based Catalysts Catalytic Reaction

Chia-Chia Chang<sup>1</sup>, Li-Xuan Huang<sup>1</sup>, Sheng-Wei Chiang<sup>2</sup>, Yen-Hao Chen<sup>3</sup>, Meng-Tse Yang<sup>1</sup>, Ke Li<sup>1</sup>, Min-Yi Tsai<sup>1</sup>, Ching-Yuan Chang<sup>1</sup>, Yi-Hung Chen<sup>4</sup>

<sup>1</sup> National Taiwan University

<sup>2</sup> North branch bureau of environmental inspection, Environmental Protection Administration

<sup>3</sup> Ministry of education

<sup>4</sup> National Taipei University of Technology

In this study, a molybdenum-based catalyst ( $\text{MoS}_2$  coating on alumina sphere surface,  $\text{MoS}_2/\gamma\text{-Al}_2\text{O}_3$ ) was used to enhance the bio-crude oil hydrodeoxygenation (HDO) reaction. A continuous HDO system was used for upgrading the performance of the bio-crude oil from biomass extraction. The

Taiwan native Tung oil was carried out to be raw material to produce liquid bio-fuel as an alternative aviation fuels via catalytic HDO reaction. The reaction temperature (T) is from 573 to 773 K. The effects of T for bio-fuel oil (BFOs) yield and their characteristics, such as acid value (AV), iodine value (IV), density ( $\rho_{\text{LO}}$ ), heating value (HHV), and distribution of carbon numbers was also investigated in this research. The HDO reforming bio-oil can be used not only blend with gasoline but also directly used as green liquid fuel for vehicles and aircrafts.

## S8-8

### Preparation of Weak-Acid Functionalized Mesoporous Carbon Solid Acid from Tannic Acid and Its Use for Saccharification of Cellulose

Luh Putu Pitrayani Sukma, Eika W. Qian

Tokyo University of Agriculture and Technology

A series of mesoporous carbon-based solid acid catalysts were prepared using tannic acid ( $\text{C}_{76}\text{H}_{52}\text{O}_{46}$ ), a polyphenol compound, as starting carbon materials and SBA-15 as silica template. The catalysts were characterized by using FT-IR and XPS. Various parameters in preparation of the catalysts were investigated. Carbonization process was important for coating of tannic acid to the surface of silica. Phenolic hydroxyl group with weak acidity was confirmed as main functional groups in these catalysts. Post-synthetic functionalization by oxidation using  $\text{H}_2\text{SO}_4$  was important factor determined the high catalytic activity of catalysts. Also, a catalyst that treated by short oxidation time (2 h) could exhibit higher catalytic activity compared to catalysts that treated by longer oxidation time. Higher carbon coating also promoted good catalytic activity. With a ratio of catalyst/substrate: 0.5/1 (g/g) and reaction temperature of 180 °C for 1 h, glucose yield and selectivity of 31.45% and 58.39% could be obtained. This research proved that relatively good saccharification activity and selectivity could be obtained in saccharification of cellulose by using only weak-acids phenol as active site on the catalysts.

## S8-10

### Utilization of the Incineration Fly Ash from Biomass Power Plant for Zeolite Synthesis from Coal Fly Ash by Hydrothermal Treatment

Tomonori Fukasawa<sup>1</sup>, Akira Horigome<sup>1</sup>, Achmad Dwitama Karisma<sup>1</sup>, Norio Maeda<sup>1,2</sup>, An-Ni Huang<sup>1</sup>, Kunihiro Fukui<sup>1</sup>

<sup>1</sup> Hiroshima University

<sup>2</sup> TAKUMA Co., Ltd.

In Japan, the amount of the incineration fly ash discharged from biomass power plants increases rapidly due to the feed-in tariff (FIT). Since expenses for disposing of the incineration ash press the management of the biomass power plants, we must develop the utilization method of it. Therefore, as the novel utilization method, we propose the potassium type zeolite synthesis from the incineration fly ash and coal fly ash by hydrothermal synthesis.

The aqueous solution extracted from the incineration fly ash which contain high concentrate potassium component was used

as the substitution of KOH solution for the potassium type zeolite synthesis from coal fly ash by hydrothermal treatment. As a result, we were able to synthesize potassium type phillipsite and chabazite from coal fly ash with the extract from the incineration fly ash.

## S8-12

### **Silicon production from rice husk for rechargeable battery anode material**

Myung Won Seo, Jin Woo Kook, Hae In Lee, Ho Won Ra, Won Chul Cho, Sang Jun Yoon, Tae Young Mun, Yong Ku Kim, Jae Ho Kim, Jae Goo Lee

Korea Institute of Energy Research

Rice husk accounts for 20% of the weight of the rice plant, and 94 million tons of rice husk are produced globally every year. Rice husk can be utilized for the biomass gasification feedstock and can be used for silicon production from its high ash content upto 20%. The rice husk ash contains more than 95 % of amorphous silica which can be used for manufacture of ceramics, solar grade silicon, cosmetic powder and secondary battery anode material. In this study, the pilot-scale fluidized bed (5kg/h) process for the production of silicon for the secondary battery anode materials as well as energy production was developed. The silica compound after rice husk gasification was reduced into high purity (>99%) porous Si. To evaluate the Si as a Lithium ion battery, coin type half cells were prepared with coating with carbon layers. The porous Si reached a high reversible capacity of 1400 mAh/g with 114.43% capacity retention after 100 cycles.

## S8-13

### **Effect of pelletizing and temperature in Silicon production using magnesiothermic reduction**

Hae In Lee, Jin Woo Kook, Myung Won Seo, Won Chul Cho

Korea Institute of Energy Research (KIER),

The magnesiothermic reduction of silica into silicon has been suggested as an energy efficient method because of low operating temperature and high yield of Si. The porous characteristics of silicon is preserved at mild operating condition; therefore it can be used for potential application of Si to the lithium ion battery, car, etc. However, there are sparse research on the Si production via magnesiothermic reduction in a lab-scale and pilot-scale process. In this study, we studied the effect of pelletizing and temperature on magnesiothermic reduction of RHA (Rice husk ash) derived silica into high purity Si. We used magnesium-RHSiO<sub>2</sub> mixture powder and pellets with a diameter of 10mm. The sample were heated in the temperature range of 600°C ~ 900°C under flowing argon. The products are analyzed by SEM, BET, XRD and the Si yield has been calculated. As a result, high yield of Si was observed with pellets and the intermediate phase was not detected for high temperature treated samples.

## Poster session

November 14, 17:00-19:00, Room 1 and 2

### Poster001

#### Bubble Properties and Mass Transfer Model in Bubble Columns with Electrolyte Solutions

Dae Ho Lim, Si Woo Yang, Dong Jun Yoo, Yong Kang

Chungnam National University

Bubble properties such as size and rising velocity were examined in a bubble column (0.102 x 2.5 m) with electrolyte solutions. Effects of gas (0.02 ~ 0.10 m/s) and liquid (0.02 ~ 0.12 m/s) velocities and ionic strength (0 ~ 3.0 mol/L) of liquid phase on size ( $D_B$ ) and rising velocity ( $U_B$ ) of bubbles were discussed. The properties of bubbles were measured by means of dual-electrical resistivity probe method. Filtered and compressed CO<sub>2</sub> and sodium carbonate/sodium bicarbonate solutions with a buffer ratio of 1.0 containing NaCl solutions were used as the gas and liquid phases, respectively. The analog signals obtained from the probe circuit were processed to produce the digital data. The selected sampling rate and time were enough to detect the bubble properties in the column. The values of surface renewal rate between the bubble and the fluid element of liquid phase and liquid side mass transfer coefficient ( $k_L$ ) were estimated from the bubble properties based on the non-stationary mass transfer model.

### Poster002

#### Interfacial area and liquid-side and volumetric mass transfer coefficients in bubble columns with electrolyte solutions

Si Woo Yang, Dae Ho Lim, Dong Jun Yoo, Yong Kang

Chungnam National University

Interfacial area and liquid-side and volumetric mass transfer coefficients were examined in a bubble column (0.102 x 2.5 m) with electrolyte solutions. Effects of gas (0.02~0.1 m/s) and liquid velocities (0.02~0.12 m/s) and ionic strength (0~3.0 mol/L) of liquid phase on the volumetric gas-liquid mass transfer coefficient( $k_L a$ ), interfacial area( $a$ ) and liquid side mass transfer coefficient( $k_L$ ) were discussed. The simultaneous physical desorption of O<sub>2</sub> and chemical absorption of CO<sub>2</sub> into the liquid phase were employed to determine the interfacial area and volumetric mass transfer coefficient between the gas and liquid phases. Sodium carbonate/sodium bicarbonate solutions with a buffer ratio of 1.0 containing NaCl solutions were used as the liquid phase and CO<sub>2</sub> and O<sub>2</sub> as the gas phase for the chemical absorption system. The values of  $k_L a$  and  $a$  increased but liquid side mass transfer coefficient decreased slightly, with increasing ionic strength of liquid phase. The mass transfer coefficients were well correlated in terms of operating variables and dimensionless groups.

### Poster003

#### The Effect of Liquid Bridge Forces on the Bed Hydrodynamics and Bed Pressure Drop at Incipient Fluidization

W.Y. Hsu<sup>1</sup>, H.P. Kuo<sup>1,2</sup>

<sup>1</sup> Chang Gung University

<sup>2</sup> Department of Otorhinolaryngology, Chang Gung Memorial Hospital,

Characterization of flow properties of powders is essential for appropriate design or operation of powder industrial process. The flowability is related to the interparticle forces. In this study, a dynamic test is carried out in a fluidized bed. Glass beads with diameter between 53  $\mu$ m to 105  $\mu$ m mixed with silicon oil are fluidized and defluidized. The influences of the amount of silicone oil added on the powder behavior and pressure drop across the bed are observed. Interparticle forces of the glass beads are calculate by the relationship between the tensile stress and pressure drop overshoot (Molerus, 1975; Rumpf, 1975). The results show that the interparticle forces are between 300 nN and 820 nN. The interparticle forces increase with the increasing of the added liquid volume.

### Poster004

#### Mechanism of air bubble formation in dispersion medium with surfactant during and after microwave irradiation

Shunsuke Nishijima<sup>1</sup>, Ryosuke Nakata<sup>1</sup>, Shungo Matsumura<sup>1</sup>, Yusuke Asakuma<sup>1</sup>, Saptorio Agus<sup>2</sup>

<sup>1</sup> University of Hyogo

<sup>2</sup> Curtin University Sarawak Campus

In this study, size profiles of bubble in dispersion medium with surfactant were measured during and after irradiation because we expected that the bubble becomes more stable by the addition of surfactant in the dispersion medium. First, higher surfactant concentration showed larger maximum bubble size. Secondly, when particle number density is lower, surfactant addition was influential for the bubble size during the irradiation. Moreover, surfactant addition indicated an important role in preventing nucleation of bubbles around particles because it contributed stability of liquid-air interface.

### Poster005

#### Effect of Gas Properties on Bubble Characteristics in a Fluidized Catalyst Bed

Takami Kaj, Keita Eto, Tsutomu Nakazato  
Kagoshima University

The emulsion phase in a fluidized catalyst bed with fine particles shows greater expansion than that in a settled bed. The expansion ratio is affected by the properties of the fluidizing gas. Because bubble behavior is affected by the characteristics of the emulsion phase, the bubble size is affected by the gas properties. However, the previously proposed models for predicting the bubble size do not consider the effects of gas properties. In this study, the expansion ratio of the emulsion

phase and bubble size were measured in a two-dimensional fluidized bed, and the effects of viscosity and density of the fluidizing gas on the emulsion phase and bubble size were studied. The expansion ratio of the emulsion phase was affected by not only the gas viscosity but also the gas density. It was found that the mean bubble size increased with decreasing gas viscosity. The bubble size was related to the apparent viscosity of the emulsion phase obtained by correlation, considering the emulsion phase voidage. It was found that the effects of the gas types on the bubble size could not be ignored for the fluidized catalyst bed with small particles.

## Poster006

### Mean Gas Holdup and Liquid Circulation Time in Four Types of Loop Airlift Bubble Column

Tatsumi Yamamoto, Hiroyuki Kawasaki,  
Hidetoshi Mori  
Univ. Toyama

The mean gas holdup and the liquid circulation time ( $T_C$ ) have been measured in four types of airlift type bubble column: concentric tube internal loop airlift type, rectangular internal loop airlift type, external loop airlift type, external loop airlift with separator. Tap water was used as working liquid. The mean gas holdups ( $\epsilon_{GR}$ ) in riser increased in proportion to the superficial gas velocity in the riser ( $U_{GR}$ ), but the behaviours in down comer ( $\epsilon_{GD}$ ) changed according to the geometric parameters of each bubble column.  $T_C$  was found to follow an empirical equation depending on UGR and the length of draft tube or division plate ( $L_R$ ) in the region of  $0.33 < R < 1$ , where  $R$  represents a ratio of the cross-sectional area of a down comer to that of a riser.

## Poster008

### Hydrodynamic Behavior of Interconnected Fluidized Beds for Chemical Looping Processes

Yau-Pin Chyou<sup>1</sup>, Yin-Ching Tung<sup>2</sup>, Keng-Tung Wu<sup>2</sup>, Chia-Ju Tsai<sup>2</sup>, Po-Chuang Chen<sup>1</sup>, Hung-Te Hsu<sup>1</sup>

<sup>1</sup> Institute of Nuclear Energy Research

<sup>2</sup> National Chung Hsing University

The inter-connected fluidized bed (IFB) cold model with four 10 cm x 10 cm compartments was built to establish operational parameters and provide the information for future commercial design of an IFB gasification system. Glass beads, dolomite and limestone were employed as bed materials to investigate the effects of those materials. The effects of the particle weight, gas velocity, orifice diameter, and orifice height on the circulation rate of solids (CRS) in the IFB were investigated. The preliminary results show that the CRS increases with increasing gas velocity of the lean bed, bed weight and orifice diameter. The diameter of limestone decreases during the operation and the value changes from 0.2483 mm in the beginning to the 0.1799 mm after 30 minutes. The diameter of dolomite keeps near constant value of 0.18 mm during the operation. It shows that dolomite is better than limestone if the

CO<sub>2</sub> capture sorbent is require to cycle use. The hot model will be designed and commissioned based on the present results to carry out the further investigation.

## Poster009

### Flow Characteristics of Plunging Jet Absorber Using Liquid Jet Containing Small Solute Bubbles

Hiroki Uchiyama, Yosuke Matsukuma, Mitsuharu Ide  
Fukuoka University

The dependence of the bubble diameter in a bubble-dispersed phase generated by a plunging jet absorber employing a liquid jet containing small solute bubbles on various structural factors of nozzles and column diameter was investigated. Two methods, namely, the photographic method and the single-tip optical fiber probe method were employed for this purpose. The bubble diameter determined by the optical fiber probe method was compared with the mean volume-surface bubble diameter obtained by the photographic method.

## Poster010

### Two- and Three-dimensional Analysis on the Bubble Flow Characteristics using CPFD Simulation

Jong Hun Lim, Dong Hyun Lee  
Sungkyunkwan University

Bubble flow characteristics in the fluidized beds were analyzed by CPFD simulation. Fluidized bed which has the size of 0.3 m-ID x 2.4 m-high was modeled by commercial CPFD Barracuda®. Properties of bed material were  $d_p = 150 \mu\text{m}$ ,  $\rho_p = 2,330 \text{ kg/m}^3$ , and  $U_{mf} = 0.02 \text{ m/s}$ . Gas was uniformly distributed and the range of superficial gas velocity was 0.07 to 0.16 m/s. Two other geometries were modeled. First one was three-dimensional model, and another one was two-dimensional model which gas the size of 0.01 m x 0.3 m x 2.4 m. Bubble size and rising velocity were simulated by axial and radial position according to superficial gas velocity. In the case of three-dimensional model, simulated bubble rising velocity was different from correlations, because there was zigzag motion in bubble flow, and bubble detection was duplicated. To exclude zigzag motion of bubble flow, bubble rising velocity was simulated in the two-dimensional model, and compared to the result from three-dimensional model.

## Poster012

### Aggregation separation of powdered fat by gas-liquid slug flow

Yuki Mizoguchi<sup>1</sup>, Yuichi Hiraguchi<sup>1</sup>,  
Hayato Tokumoto<sup>1</sup>, Akinori Muto<sup>1</sup>  
Osaka Prefecture University

An aqueous solution in which dilute powdered fat is dispersed is hard to treat. In this study, a powdered fat composite containing casein sodium was adopted as a model material. Casein sodium is a surface acting agent that helps the dispersion of the powdered fat in food. The surfactant effect of casein sodium reduces in the range of pH3-5. Therefore, we adjusted pH of the dispersion water to 3-5 by dissolving carbon dioxide gas. Carbon dioxide and the dispersion water were contacted at Y-junction and the gas-liquid slug flow was formed in a 3 mm inner diameter perfluoroalkoxyalkane tube. In gas absorption, gas-liquid slug flow has higher efficiency than conventional gas absorption methods. The aggregation substance generated by gas-liquid contact was removed by using a filter paper. We could separate more than 90 percent powdered fat composite from the dispersion water in short gas-liquid contact time. This result suggests that gas-liquid slug flow makes treating the wastewater containing casein sodium easy.

## Poster013

### Attrition of Iron Ore Particles in a Gas-Solid Fluidized Bed with the Single Hole Distributor

Dong Hyun Kang<sup>1</sup>, Chang Kuk Ko<sup>2</sup>, Dong Hyun Lee<sup>1</sup>

<sup>1</sup>Sungkyunkwan University

<sup>2</sup>Ironmaking Research Group, POSCO

The influences of distributor hole size (8.0 – 12.4 mm) and gas velocity ( $U_g = 1.25 - 3.00$  m/s) on the attrition characteristics of iron ore in a gas-solid fluidized bed with 0.076 m ID  $\times$  3.7 m height with or without circulation were investigated. The particle density and the Sauter mean diameter of fresh iron ore were 3,705 kg/m<sup>3</sup> and 357  $\mu$ m, respectively. When the kinetic energy rate from the single orifice distributor was equal or greater than 180 J/s, the trend of attrition rate could be determined precisely. The attrition rate should be determined by measuring the mass fraction of fine particle formation (threshold value: 500  $\mu$ m) during 30 min without circulation. In experiments with circulation, the attrition rate should be determined by measuring a different threshold size (threshold value: 63  $\mu$ m). The attrition rate increases with increasing kinetic energy rate from the single orifice (J/s). The kinetic energy rate from the orifice was calculated using the mass flow rate and orifice gas velocity as those of previous studies. The correlation of attrition rate as a function of the kinetic energy rate from the orifice was induced as  $\Phi/N = 0.1214E_K - 1.3587$ .

## Poster014

### Hydrogen Reduction of a Black Nickel Oxide Ore in a Fluidized-bed Reactor without Sticking

Yong Ha Kim, Hang Goo Kim, Jun Ik Jo, Hye In Hwang

Pukyong National University

A black nickel oxide powder, one of the commercial nickel oxide ores, was reduced by hydrogen gas in a batch-type fluidized-bed reactor in a temperature range of 350 to 500°C

and in a residence time range of 5 to 120 min. The hydrogen reduction behavior of the black nickel oxide was found to be somewhat different from a green nickel oxide ore. For the black nickel oxide, the maximum temperature (below which nickel oxide particles can be reduced without any agglomeration) was significantly lower than that observed from the green nickel oxide. In addition, the best curve fittings of Avrami model were obtained at higher values of the overall rate constant “k” and at lower values of the exponent “m” than those for the green one. It may be inferred from the results that in the early stage the hydrogen reduction rate of the black nickel oxide is faster than that of green one but the situation is reversed in later stages. For a black nickel oxide ore, in spite of the low temperature sintering, a high degree fluidized-bed reduction could be achieved at lower temperatures and at lower gas consumption rates compared to a green nickel oxide. In this regard, the use of black nickel oxide is expected to allow a benefit if its ore price is sufficiently lower than that of the green one.

## Poster015

### Effect of binder solution component (particle/polymer) on fine powder coating with a circulating fluidized bed

Yoshihide Mawatari, Shoto Torigoe, Masato Yamamura, Hiroyuki Kage

Kyushu Institute of Technology

This study investigated the effects of operational conditions on the fine powder coating process with a circulating fluidized bed (CFB). The core particles (43 $\mu$ m) were circulated by high gas velocity in a loop reactor that consisted with a riser, cyclone, and down-comer. Then, the binder solution including coating materials of fine particle (80nm, carbon) and binder polymer (Poly vinyl alcohol) was atomized with a two-fluid spray nozzle during core particles were circulated in CFB. The mass of core particle was directly affected on the coating amount on the core particle while the fluidizing gas flow rate was insignificant on the coating amount. The morphology of coated particle surface was transitioned from island state to film state by varying the polymer concentration in the atomized binder solution. In this study, the weight ratio of coating fine particle/binder polymer was varied and its effect on the coating efficiency was examined by the estimation of coating amount on the core particle surface.

## Poster016

### Thermal oxidation of detonation nanodiamond in a fluidized bed reactor

Jae Hoon Lee<sup>1</sup>, Sung Woo Jeong<sup>1,2</sup>, Dong Hyun Lee<sup>1</sup>

<sup>1</sup> Sungkyunkwan University

<sup>2</sup> Korea Research Institute of Chemical Technology

The effect of the reaction temperature and reaction time on the thermal oxidative purification quality of detonation nanodiamond (NDsoot) was investigated in a medium gas-solid fluidized bed reactor of a 0.10 m-ID  $\times$  1.0 m-height stainless steel column with zirconia beads ( $d_{SV} = 99.2$   $\mu$ m). The carbon conversion increased when increasing the reaction temperature.

However, when the reaction temperature was greater than 773 K, the carbon conversion did not increase. The purification level of sp<sup>2</sup>-hybridized carbon increased with the increasing reaction temperature and reaction time; however, at a reaction temperature of 773 K, the remaining fraction of sp<sup>2</sup> carbon was greater than that of sp<sup>2</sup> carbon at a reaction temperature of 703 K when the reaction time was the same. At the reaction temperature of 703K, the fraction of sp<sup>3</sup>-hybridized carbon increased until the reaction time was 30 minutes and then barely changed when the reaction time was increased. When the reaction temperature was 773 K, the fraction of sp<sup>3</sup> carbon increased until the reaction time was 30 minutes; however, the contents of sp<sup>3</sup> carbon then decreased rapidly.

## Poster017

### Direct Recovery of Malate Dehydrogenase from Unclarified Yeast Cell Homogenate Using Dye Affinity Chromatography in Stirred Fluidized Bed

Jheng-Yu Wu, Shih-Cheng Hong, Yu-Kaung Chang  
Ming Chi University of Technology

In this work, dye affinity chromatography in stirred fluidized bed has been developed for purification of malate dehydrogenase (MDH) from baker's yeast homogenate. To obtain optimal dye concentration immobilized onto the STREAMLINE matrix (GE Healthcare), various dyes were investigated in the adsorption performance of MDH. The adsorption and elution experiments for MDH under various dye immobilized density were carried out using clarified feedstock in a batch modes. For considerations of binding capacity and elution efficiency for MDH, the optimal dye density (i.e., Reactive Orange 4 dye) onto the matrix was found to be 8.78 µmol dye/ml adsorbent. Measurements of adsorption breakthrough curves in packed beds have shown that the dynamic binding capacity (DBC) appeared to be significantly affected by the immobilized density, concentration of disrupted cells, liquid velocity, and column aspect ratio. Moreover, the optimal condition for elution of the adsorbed MDH were determined in small scale packed bed experiments conducted with clarified cell homogenates. The one-step elution was carried out with 0.6 M NaCl (pH 8) at a liquid velocity of 200 cm/h, resulting in adsorbed MDH completely eluted from the dyed adsorbent. On the basis of the results, the MDH enzyme could be recovered with a purification factor of 73.54 and recovery yield of 73.6% by stirred fluidized bed dye affinity chromatography in a single step.

## Poster018

### The study of flash drying characteristics with sub-bituminous coals in a pressurized micro-riser

In Seop Gwak, You Ra Gwak, See Hoon Lee  
Chonbuk National University

Due to the unstable price and the depletion of conventional fossil fuels, low grade coal has been emerging as a new energy source. Low grade coal is rich in reserves, so the price of low

grade coal is very affordable than conventional coal. However, the usage of low grade coal with high moisture content might decrease power generation efficiency and has problems in storage and transport. Therefore, drying or dewatering processes are necessary to use low grade coal economically. Previous studies about flash drying of low grade coal were done at normal pressure. In this study, the flash drying characteristics of 2 different types of coals (particle sizes: 212~300µm and 300~355µm) were determined in a pressurized micro-riser. The micro-riser consisted of M.F.C., disk type feeder, rolled tube with oven (tube length: 2m, 4m, 6m), cyclone, back filter and back pressure regulator. The effect of operation conditions, such as pressure (up to 40bar), drying temperature (up to 600°C), and residence time (up to 1sec), on drying ratio were investigated.

## Poster019

### Drying characteristics of freezing pretreated carrots in a fluidized bed of hygroscopic porous particles under reduced pressure

Akihiro HAGIMOTO, Yuji TATEMOTO  
Shizuoka University

A drying method with a low temperature and a high drying rate is required for heat sensitive materials such as food materials. A fluidized bed drying under reduced pressure was used as a method with the low temperature and the high drying rate. As a drying material, cylindrical carrot, which was frozen (233K), was used and it was immersed in the fluidized bed of hygroscopic porous particles. The drying finished earlier in the fluidized bed of hygroscopic porous particles than that of inert particles at the atmospheric pressure, though the difference is insignificant under reduced pressure. The drying rate is higher for freezing pretreated carrots than for untreated ones regardless of fluidizing particles. The volume change becomes small for freezing pretreatment and drying under reduced pressure. It was found that the high drying rate at the low temperature with minimal sample shrinkage in drying were achieved via the combined freezing pretreatment and fluidized-bed drying under reduced pressure.

## Poster020

### Tar reduction in biomass gasification according to ER with bed material

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<sup>1</sup> Korea Institute of Industrial Technology

<sup>2</sup> Sungkyunkwan University

A fluidized bed reactor (FBR) with an inside diameter of 0.1 m and a height of 1.2 m was used to study the effect of different equivalence ratios (ERs) and bed materials on air-blown biomass gasification for the generation of producer gas. Experimental equipment comprised an FBR, a fuel supply, a cyclone, two condensers, and an online gas analyzer. Nonspherical sand (average particle size: 340 µm) and spent gypsum (average particle size: 295 µm), which is a by-product of petroleum coke, were used as bed materials. Empty fruit bunches (EFBs) in pellet form were used as the biomass supply. The experimental temperature of 800 °C created an operational

variable ER of 0.35–0.25. Lower heating value and composition of generated gas and tar were estimated. The results were compared to those from previous studies in which calcined dolomite was used. Result of experiment used spent gypsum showed rate of rejection up to 37.9%.

## Poster021

### Low Temperature Synthesis of Dimethyl ether from Synthesis gas over Zr modified CuZnO/HZSM-5 Catalysts

Suwattana Thongkam, Akapong Kongjaroen, Samart Kongtaweelert, Montree Thongkam  
King Mongkut's Institute of Technology Ladkrabang

A series of  $ZrO_2CuOZnO$  catalyst with different Zr loading were prepared by co-precipitation method. The catalysts were characterized by SEM-EDS, BET, XRD and  $H_2$ -TPR. The catalysts were mixed with HZSM5 catalyst and the catalytic activity was investigated toward direct conversion of synthesis gas. The reaction was carried out in temperature 493 and 523 K, 4 MPa, W/F 5.18 gh/mol. The 3% $ZrO_2CuOZnO/HZSM5$  catalyst exhibited highest CO conversion of 28.73% and Dimethyl ether yield of 27.55%. The suitable addition of Zr significantly improved Cu dispersion and reducibility of CuO. At low reaction temperature can be attributed to decrease the dehydration ability of HZSM5 acid catalyst and leading to enhance the dimethyl ether selectivity.

## Poster023

### Synthesis of Cu/ZnO-ZrO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst and silica fiber coated by ZSM-5 for LPG synthesis

Wittawat Ratanathavorn<sup>1</sup>, Prasert Reubroycharoen<sup>2,3</sup>

<sup>1</sup> Suan Dusit Rajabhat University

<sup>2</sup> Chulalongkorn University

<sup>3</sup> Chulalongkorn University Research building

The LPG synthesis was performed by using of Cu/ZnO-ZrO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst and ZSM-5/silica fiber. The methanol synthesis catalyst as Cu/ZnO-ZrO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst was prepared by co-precipitation method and ZSM-5/silica fiber fibrous catalyst was carried out by electrospinning technique and the hydrothermal synthesis. Tetraethylorthosilicate (TEOS) and Aluminiumnitrate nonahydrate were used as Si source and Al source respectively. ZSM-5/silica fiber was synthesized by varying pH of sol-gel solution (8, 9 and 10) and crystallization times (24, 48, 72 and 120 h). The ZSM-5/silica fiber under the conditions of pH 9 for 48 h is the most suitable condition since it still remained the fiber morphology and has the surface area of 322.02 m<sup>2</sup>/g. The catalytic activity of ZSM-5/silica fiber was performed by mixing with Cu/ZnO-ZrO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst in fixed bed reactor for LPG synthesis from syngas comparing with powder form catalyst. The highest CO conversion was achieved by Cu/ZnO-ZrO<sub>2</sub>-Al<sub>2</sub>O<sub>3</sub> catalyst and ZSM-5/silica fiber at the condition of 2 MPa, 260 °C with W/F=40 g.h/mol. It provided the 27.8% of CO conversion and 58.3% of LPG selectivity that higher than CO conversion of powder form catalyst around 30.6% and 36.8% of LPG selectivity.

## Poster024

### Production of Biomass Fuel Pellets Mixed With Thermally Treated Waste

Jang-Soo Lee<sup>1</sup>, Md Tanvir Alam<sup>1</sup>, Yong-Chil Seo<sup>1</sup>, Dhruva Bhatta<sup>1,2</sup>, Kunio Yoshikawa<sup>2</sup>, Woo-Hyun Kim<sup>3</sup>

<sup>1</sup> Yonsei University

<sup>2</sup> Tokyo Institute of Technology

<sup>3</sup> Korea Institute of Machinery & Materials

Thirteen types of fuel pellets were prepared from the mixture of hydrothermally treated clean hospital solid waste, hydrothermally treated rice straw, pyrolytic plastic waste residue, and Sakhalin fir residue using a flat die pellet machine. Various pellet properties such as pellet density, pellet durability, aspect ratio, physicochemical characteristics, gross calorific value etc. were evaluated, as well as compared with respect to European standard specification for residential/commercial densified fuel. The results showed that most of the pellets satisfied the requirement of pellet properties according to the European standard, although few failed to meet up few individual criteria.

## Poster025

### Effects of Promoters on Activity and Carbon Deposition of NiMo Catalyst for Hydrodeoxygenation

Napida Hinchiranan, Patiphat Sangnikul  
Chulalongkorn University

Effects of copper- (Cu-) and cerium- (Ce-) promoters on carbon resistance and efficiency of nickel-molybdenum supported on gamma alumina (NiMo/ $\gamma$ -Al<sub>2</sub>O<sub>3</sub>) catalyst used for hydrodeoxygenation (HDO) of guaiacol (GUA), a model compound of bio-oil, were investigated. All catalysts were prepared by successive impregnation method. Compositions in the obtained liquid product were identified by using gas chromatography-mass spectrometry (GC-MS) and the amount of coke formed on the surface of catalyst was determined by using thermogravimetric analysis (TGA). When HDO of GUA was conducted under 10 bar initial H<sub>2</sub> pressure and 300 °C for 1 h, the results showed that NiMo/ $\gamma$ -Al<sub>2</sub>O<sub>3</sub> catalyst promoted by Cu (NiMoCu/ $\gamma$ -Al<sub>2</sub>O<sub>3</sub> : Ni = 10 wt%, Mo = 7 wt% and Cu = 4 wt% based on  $\gamma$ -Al<sub>2</sub>O<sub>3</sub> content) could inhibit the coke formation (coke content = 3.54 wt%) with 19.1% GUA removal, whilst unpromoted one showed the higher coke content (5.18 wt%) deposited on the catalyst surface with 16.4% GUA removal. Therefore, Cu-promoter could act as both coke inhibitor and catalyst activity improver for NiMo/ $\gamma$ -Al<sub>2</sub>O<sub>3</sub> in HDO process.

## Poster026

### Development of Microbial Pretreatment Method on Methane Fermentation of Organic Solid Materials

Hidenori Matsumura<sup>1</sup>, Mitsuaki Mochizuki<sup>1</sup>,  
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Methane fermentation is a promising technique to create renewable energy from food waste and other biomass. In this study, we developed a microbial pretreatment method of organic solid materials for efficient methane fermentation. The method had a modification process, which is the continuous supernatant collection, to avoid the loss of dissolved organic materials by microbial degradation. Commercially available rabbit food was used as an organic solid material. Efficiency of microbial pretreatment was evaluated by degradation rate of suspended solids (SS) and recovery rate of dissolved organic material in liquid. Under the modified method, degradation rate of SS was 62.6 % and recovery rate of dissolved organic material for 11 days was 0.196 g-C/g-ds. In contrast, unregulated batch processing decreased the recovery rate of dissolved organic material for 11 days to 0.077 g-C/g-ds (degradation rate of SS was 62.0%). The results indicated that continuous supernatant collection prevents excessive degradation of dissolved organic material.

## Poster027

### Mass Balance of Phorbol Esters in *Jatropha curcas* Biodiesel Fuel Process

Koji Tosa, Ryochi Togashi

Kanazawa Institute of Technology

The purpose of the present study is to determine the mass balance and kinetics of phorbol esters in *Jatropha* BDF process. The density of phorbol esters in *Jatropha curcas* oil was almost constant during degumming process. The density of phorbol esters in the oil decreased with increasing alkali concentration during deacidification. The density of phorbol esters in deacidification foots increased with increasing alkali concentration. The density of phorbol esters in BDF decreased with increasing alkali methanol concentration. These results are useful for production of safer *Jatropha* BDF.

## Poster028

### Effect of Unsaturated Fatty Acid Side Chain on Deoxygenation of Triglycerides in Catalytic Cracking Process

Iori Shimada<sup>1</sup>, Yoshitaka Nakamura<sup>1</sup>,  
Mitsumasa Osada<sup>1</sup>, Hiroshi Fukunaga<sup>1</sup>,  
Nobuhide Takahashi<sup>1</sup>, Haruhisa Ohta<sup>2</sup>,  
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With the aim of efficient utilization of plant oils as alternative fuels, deoxygenation of triglycerides in a catalytic cracking process was investigated using a fluid catalytic cracking catalyst with enhanced hydrogen transfer activity. Deoxygenation proceeded rapidly and completely and large amount of aromatic hydrocarbons were produced from unsaturated triglycerides whereas small amount of oxygenated products were produced from saturated triglycerides. In the case of reactions with mixed feedstock of saturated and unsaturated triglycerides, hydrodeoxygenation of saturated triglycerides yielding H<sub>2</sub>O was accelerated by strong hydrogen-donating ability of unsaturated fatty acid carbon chains in the hydrogen transfer reactions. On the other hand, hydrocarbon compositions produced from the cracking of the mixture was similar to that from the cracking of saturated triglycerides alone; they contained large amount of paraffins and small amount of aromatics. These results suggest the possibility for achieving both rapid deoxygenation and desirable hydrocarbon composition by mixing saturated and unsaturated triglycerides in a catalytic cracking process.

## Poster032

### Effect of additives on the low-temperature separation properties of fatty acid methyl ester mixtures

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Additive winterization processes using sorbitan monopalmitate and sorbitan monostearate were compared with a conventional agitation winterization for the separation of saturated FAMES from a mixture of saturated and unsaturated FAMES. The additive winterization process led to greater improvements in the low-temperature flow properties of the FAME mixtures by a single stage. Furthermore, the agitation winterization required at least three cycles of sequential cooling, agitation and filtration to obtain similar results. This study therefore highlights the potential of additive winterization for improving the low-temperature flow properties of biodiesel fuels containing sorbitan mono fatty acid esters as a simple, energy-saving process.

## Poster033

### Ionic Liquids for Aqueous Two-Phase Extraction of C-Phycocyanin from Disrupted *Spirulina platensis*

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Yu-Kaung Chang  
Ming Chi University of Technology

A novel extraction technique, aqueous two-phase extraction system (ATPs) based on various imidazolium ionic liquids (ILs) and potassium salts (K<sub>2</sub>HPO<sub>4</sub>, K<sub>2</sub>CO<sub>3</sub>, and K<sub>3</sub>PO<sub>4</sub>) have been used for extraction of C-phycocyanin (C-PC) from cyanobacteria *Spirulina platensis*. Three kinds of ILs were chosen in this work, including 1-butyl-1-3-methylimidazolium bromide ([C4mim]Br), 1-hexyl-3-methylimidazolium bromide

([C6mim]Br), and 3-methyl-1-octylimidazolium bromide ([C8mim]Br). The two-phase forming ability by adding approximately amount of potassium salts to aqueous ILs solution has been observed very similar. The potassium salt,  $K_2HPO_4$  was chosen for further study because of its strong phase forming ability and can result in an approximate pH range for C-PC extraction. The influence of extraction pH, loading volume and concentration of disrupted algae, temperature, and alkyl chain length of ILs on the extraction efficiency of C-PC was investigated. The extraction efficiency of The C-PC was found to increase with increasing the temperature and alkyl chain length of the ILs. It indicated that the hydrophobic interaction was the main interaction force, although the electrostatic interactions and salting-out effects may also play an important role. The order of extraction efficiency for C-PC was [C8mim]Br > [C6mim]Br > [C4mim]Br. The optimal extraction condition for extraction of CPC was 1% and 0.5 mL of disrupted algae, and temperature of 37°C at pH 7. The partition coefficient of [C8mim]Br and  $K_2HPO_4$  system for C-PC was as high as 36.60 with a extraction yield of approximately 100%.

### Poster034

#### CO<sub>2</sub> Capture from CO<sub>2</sub>/CH<sub>4</sub> Gas Mixture Using Clathrate Hydrates in the Presence of Thermodynamic Promoters

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Gas separation process using clathrate hydrate was applied for the CO<sub>2</sub> capture from CO<sub>2</sub> (50%)/CH<sub>4</sub> (50%) mixed gas, which is a general composition of acidic natural gas and biogas. In order to achieve milder operation conditions in the hydrate-based separation process, thermodynamic promoters of THF and TBAC were used. Raman spectroscopy revealed that guest molecules of CO<sub>2</sub>/CH<sub>4</sub> were captured in the cages of different hydrate structures. Gas uptake and gas composition in the vapor and hydrate phases were measured by gas chromatography. Pure water system showed the largest gas consumption during hydrate formation, whereas TBAC system showed the highest CO<sub>2</sub> concentration in the hydrate phase.

### Poster035

#### Cost study of high-pressure CO<sub>2</sub> capture processes

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Kawasaki Heavy Industries, Ltd. (KHI) has been conducting a joint research with the Research Institute of Innovative Technology for the Earth (RITE) and has implemented the development of processes for a chemical absorbent to capture CO<sub>2</sub> under high-pressure conditions. In this presentation, we report the results of a study on plant costs as a part of the practical studies for use of a new high-pressure CO<sub>2</sub> chemical absorbent "RH-x" independently developed by RITE; these

practical studies are conducted in collaboration with KHI and RITE. RH-x is an aqueous solution primarily comprising amine compounds; this CO<sub>2</sub> absorbent shows high CO<sub>2</sub> absorption/desorption performance under high-pressure conditions. Using general process simulators "Aspen Plus" and "Aspen Process Economic Analyzer," we compared the plant cost using RH-x to another absorbent to show the advantages of using RH-x in a typical CO<sub>2</sub> capture process with an absorber/stripper. As a result of plant cost calculations that integrate the cost of each device, we have found that RH-x can reduce the number of compressors needed for compressing stripped CO<sub>2</sub> because the absorbent can function under high pressure, significantly reducing the cost.

### Poster037

#### CO<sub>2</sub> Adsorbent Material from Natural Rubber with Tetraethylenepentamine

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Benjapon Chalermisinsuwan, Sirilux Poompradub  
Chulalongkorn University

Carbon dioxide (CO<sub>2</sub>) is one of the major causes of global warming which is a worldwide issue. In the atmosphere, CO<sub>2</sub> is shooting up increasingly from emission of industry, power plant and fossils fuel. CO<sub>2</sub> adsorption can be divided into 2 categories, which are physical and chemical adsorptions. Physical adsorption requires porous and high surface area materials to adsorb CO<sub>2</sub>. On the other hand, chemical adsorption uses chemicals which are mostly amine compounds. Accordingly, in this research, natural rubber that shows the high elasticity and great resistance to abrasion is chosen to develop as a CO<sub>2</sub> adsorbent in the form of rubber foam. Natural rubber was blended with tetraethylenepentamine (TEPA) with various contents (2.5, 5.0 and 7.5 parts by weights per hundred parts of rubber: phr) to investigate the interaction between adsorbent and CO<sub>2</sub> by chemical adsorption. Then, the CO<sub>2</sub> adsorption capacity was determined under a fluidized bed reactor and the mechanical properties of adsorbent material were examined.

### Poster038

#### Energy Saving CO<sub>2</sub> Separation Process Using Fluidized Bed

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The University of Tokyo

In this paper, an innovative energy saving CO<sub>2</sub> separation process using chemical absorption was proposed. In this process, metal oxide particles were selected as absorbents. These particles were fluidized by feed gas for increasing segregation effect in the bed and heat transfer rate from chemical reaction to a heat pump system. Heat of absorption was recuperated and supplied as heat of thermal decomposition through a heat pump system based on exergy recuperation. In addition, some of the heat was circulated with the absorbents. The energy saving performance of the proposed process was evaluated by simulations.

## Poster040

### EDI-type zeolite, a novel adsorbent for CO<sub>2</sub> capture

Motomu Sakai, Kohei Matsumoto,  
Masahiko Matsukata  
Waseda University

CO<sub>2</sub> adsorption property of EDI-type zeolite, a kind of small pore zeolites which has distorted 8-membered ring (0.28 × 0.31 nm) was investigated. EDI powder was prepared by a hydrothermal treatment method. Adsorption tests were performed by volumetric gas adsorption method to obtain isotherms of N<sub>2</sub>, Ar, CO<sub>2</sub> and CH<sub>4</sub>. EDI powder was outgassed at 623 K for 8 h under vacuum condition prior to the adsorption test. We found that EDI had a high CO<sub>2</sub> adsorption capacity of 90 cm<sup>3</sup> (STP) g<sup>-1</sup> at atmospheric pressure. In contrast, N<sub>2</sub>, Ar and CH<sub>4</sub> hardly adsorbed on EDI up to an atmospheric pressure. The synthesized EDI powder had extremely small micropore which cannot be measured by commonly used adsorption methods, such as N<sub>2</sub> and Ar adsorption. Therefore, EDI exhibited CO<sub>2</sub> adsorption selectivity and expected to be a new adsorbent for CO<sub>2</sub> capture.

## Poster041

### CO<sub>2</sub> separation by AEI-type zeolite membrane

Motomu Sakai, Kei Yoshihara, Masahiko  
Matsukata  
Waseda University

CO<sub>2</sub> separation from flue gas and natural gas is important from the viewpoints of environmental issues and energy production. Capturing CO<sub>2</sub> from coal-fired power plants is proposed to reduce the CO<sub>2</sub> emission to the atmosphere. In addition, CO<sub>2</sub> is generally contained in natural gas as an impurity, reduces energy density and frets a pipeline in the presence of water. Whereas being conventionally used for CO<sub>2</sub> separation, amine scrubbing is cost intensive because a large amount of thermal energy was needed for regeneration of adsorbents. Then, we focused on membrane separation which is expected as energy saving process. Microporous aluminophosphates (AIPOs) are a class of zeolites with structures built of equimolar AlO<sub>4</sub><sup>-</sup> and PO<sub>4</sub><sup>+</sup> tetrahedral building units, being free from exchanged-cation in the micropore. Particularly, AlPO<sub>4</sub>-18 (AEI-type) has a three-dimensional pore system possessing eight-membered ring with a diameter of 0.38 nm and a low framework density of 15.1 T atoms nm<sup>-3</sup>. Therefore, it is expected that AlPO<sub>4</sub>-18 membrane can selectively separate CO<sub>2</sub> (0.33 nm) with high CO<sub>2</sub> permeability from gas mixtures including CH<sub>4</sub> (0.38 nm) or N<sub>2</sub> (0.36 nm). In this study, we synthesized AlPO<sub>4</sub>-18 membrane and investigated its CO<sub>2</sub>/CH<sub>4</sub> and CO<sub>2</sub>/N<sub>2</sub> permeation properties.

## Poster042

### Investigating Catalytic Behavior of Mineral Matters in CO<sub>2</sub> gasification and Steam gasification by Extended Random Pore Model

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Central Research Institute of Electric Power Industry

Char gasification is a rate-limiting step in coal gasification process. The random pore model (RPM) is one of the theoretical models, which are used for evaluating surface reaction rate of char gasification. However, the char gasification reaction rate cannot be represented by the RPM when the reaction rate is accelerated by mineral matters in coal char. Therefore, the extended RPM was proposed empirically and is now being developed to represent catalytic char gasification reaction rate. In this study, in order to investigate catalytic activities of mineral matters at various gasification temperatures, gasification experiments of raw coal char and metal-loaded coal char were conducted under CO<sub>2</sub> and steam atmosphere with thermogravimetric analysis (TGA) at various gasification temperatures. The empirical parameters of the extended RPM were compared between raw coal char and calcium loaded coal char in gasification with CO<sub>2</sub> or steam at various gasification temperatures. It was found that the catalytic effect of loaded calcium on CO<sub>2</sub> gasification was larger than that on steam gasification, and the rate of catalytic deactivation during steam gasification was different between inherent calcium in raw coal and loaded calcium. It was clarified that catalytic activity of calcium is different between CO<sub>2</sub> gasification and steam gasification because the gasification mechanism was different between them.

## Poster043

### Co-combustion of waste solvent with coal in a bubbling fluidized bed combustor

Hung-Wen Ni, Chien-Song Chyang, Pin-Wei Li,  
Jian-Zhou Yin  
Chung Yuan Christian University

In recent years, energy recovery is one of methods for waste disposal, and the focus is mostly directed to the solid waste. However, the reports on the treatment of liquid wastes are notably few, and the behavior of liquid wastes during combustion is different from that of solid waste. This study aims to investigate the behavior and pollutant emissions occurring during co-combustion of coal and liquid fuel. Experiments in this study are performed in the pilot-scale vortexing fluidized bed, which is 0.8 m length × 0.4 m width × 4.7 m height. In the case of fixed total heat release (130,000 kcal/hr), liquid waste, jatropa oil and coal were used as fuels. Total primary air is 3 Nm<sup>3</sup>/min, and excess air is 50%. The bed temperature and liquid-fuel ratio are adjusted to explore the effect of operating conditions on the temperature of the furnace, combustion fraction and NO<sub>x</sub> emissions. The results indicate that the in-bed combustion fraction in the case of co-combustion of solids and liquids increases with the bed temperature but decreases with the ratio of the liquid increases. The NO<sub>x</sub> emissions increases with bed temperature. As the liquid fuel increases, depending on the amount of nitrogen content, the results varied; if the nitrogen content of the liquid

fuels is higher than that of the coal, nitrogen oxide emissions will increase accordingly, and vice versa.

## Poster044

### Sludge combustion in a fluidized-bed incinerator

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Chung Yuan Christian University

For sludge disposal, incineration is considered to be better than direct burial because of regulations and space limitations in Taiwan. Additionally, burial after incineration can effectively prolong the lifespan of a landfill. Therefore, it is the most satisfactory method for treating sludge at present. Of the various incineration technologies, the fluidized bed incinerator is a suitable choice due to its fuel flexibility. In this work, sludge generated from industrial plants was treated in a pilot-scale vortexing fluidized bed. The moisture content of the sludge was 48.53%, and its LHV was 454.6 kcal/kg. Primary gas and secondary gas were fixed at 3 Nm<sup>3</sup>/min and 1 Nm<sup>3</sup>/min, respectively. Diesel burners with on-off controllers were used to control the temperature; the bed temperature was set to 750±20°C, and the freeboard temperature was 850±20°C.

## Poster045

### Study on chemical degradation behavior of SOFC anode caused by trace contaminants in coal-derived fuel gas

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To explore the probability and feasibility of coal-syngas use as a fuel for SOFC, we need to clarify the effects of chemical interaction of trace contaminants with the materials of SOFC anode and electrolyte with respect to the performance of the SOFC system. The purpose of the present experimental study is to see whether the chemical degradations takes place when moistened H<sub>2</sub> gas or simulated coal syngas with trace level of H<sub>2</sub>S is injected. Injection of ppm-level H<sub>2</sub>S resulted in the non-reversible performance loss. We also observed faster performance loss in the simulated coal syngas contaminated with H<sub>2</sub>S than the situation with H<sub>2</sub>+H<sub>2</sub>S injection.

## Poster046

### Chemical Looping Combustion of Methane using CaSO<sub>4</sub> as Oxygen Carrier with MgO Addition

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Chemical-looping combustion (CLC) is a recent promising technology that employs metal oxides as oxygen carriers to convert fuel into CO<sub>2</sub>. This work focused on the performance of CaSO<sub>4</sub> oxygen carrier with the addition of MgO. The reduction of the oxygen carrier by CH<sub>4</sub> was investigated in a lab-scale fixed-bed reactor. The gas evolution profile was monitored by an online micro-gas chromatography. The effect of reaction temperature was examined using CaSO<sub>4</sub>. The result indicated that a higher temperature leads to high combustion efficiency. However, such a high temperature induces the CaO formation which decreases the performance and recyclability of CaSO<sub>4</sub>. The effect of MgO addition on the reduction efficiency and recyclability of CaSO<sub>4</sub> was revealed. The results demonstrated the positive effect of MgO, accelerating reduction reaction and impeding the formation of CaO. Moreover, the MgO-CaSO<sub>4</sub> oxygen carrier manifests the better recyclability. However, the selectivity of CO<sub>2</sub> with respect to CH<sub>4</sub> conversion became lower at relatively high MgO. Therefore, the mass fraction of MgO must be controlled to confine the side reactions which are catalyzed by MgO itself and still help improve the overall performance of CaSO<sub>4</sub> based oxygen carrier.

## Poster047

### Equilibrium Analysis on the Pyrotechnic Reactions of Igniters (BKNO<sub>3</sub>, THPP, ZPP)

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This study investigates the pyrotechnic reactions of three kinds of igniters, BKNO<sub>3</sub>, THPP (titanium hydride/potassium perchlorate), and ZPP (zirconium/potassium perchlorate). To be more specific, the equilibrium analysis is used to clarify the influence of the operating parameters such as initial temperature, composition, etc. on the flame temperature of pyrotechnic reactions. For example, if magnesium (Mg) is contained in the BKNO<sub>3</sub> system, it reacts with oxygen and water to form oxide and hydrate competing with BKNO<sub>3</sub>. Accordingly, the flame temperature would change. Meanwhile, the performance of igniters definitely depends on the inclusion of oxygen and moisture in the system (in other words, the aging of the system). The gradually increased oxygen content by time considered in the equilibrium analysis would then give a clue to the aging of igniters. For example, if the combustion is not sufficient due to the aged igniters, the flame temperature would be formed at a low range. The equilibrium analysis is very useful in the explanation of these igniter systems because the kinetic barriers of intermediate reactions are lifted with huge reaction energies generated.

## Poster048

### Thermodynamic Equilibrium Analysis of Combined Biomass Pyrolysis with Carbon Dioxide Reforming of Methane for Bio-fuel and Synthesis Gas Productions

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In this study, effects of temperature and carrier gas on pyrolytic characteristics of biomass obtained from mushroom cultivation waste (MCW) were studied based on thermodynamic equilibrium analysis. In addition to N<sub>2</sub>, greenhouse gases (CH<sub>4</sub> and CO<sub>2</sub>) were also used as the carrier gases. Using the results obtained from using N<sub>2</sub> as carrier gas as the comparison basis, it was found that pyrolytic solid yield was enhanced and H<sub>2</sub>S formation was suppressed by using CH<sub>4</sub> as carrier gas. By using CO<sub>2</sub> as carrier gas, the solid yield can be reduced due to carbon gasification reaction while pyrolytic liquid can still be found at high temperature due to reverse water-gas shift reaction. The result also showed that higher bio-oil yield can be obtained by using N<sub>2</sub> as carrier gas and contained relatively high amount of acetic acid.

## Poster050

### Simulation of co-Gasification of Coal and Biomass in A Circulating Fluidized Bed Using ASPEN PLUS

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This study developed a circulating fluidized bed co-gasification of coal and biomass model using ASPEN PLUS-based Gibbs free energy minimization. *Dimocarpus longan* was used as the biomass contents for model simulation to discuss the sensitivity analysis of the two major influencing factors of model gasification operations regarding syngas. The simulation results show that CO<sub>2</sub> content decreased with rising co-gasification temperature; however, the H<sub>2</sub> and CO contents increased, while the CH<sub>4</sub> content changed little. In addition, with the rising equivalence ratio value, the CO, H<sub>2</sub>, and CH<sub>4</sub> contents decreased while the CO<sub>2</sub> content increased.

## Poster052

### Co-Combustion of Pelletized and Moisturized Rice Husks in a Fluidized-Bed Combustor Using Fuel Staging and Reburning for Reducing NO<sub>x</sub> Emissions

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This work was aimed at investigating the potential of using fuel staging (with a single airflow) and reburning to reduce NO<sub>x</sub> emissions of a fluidized-bed combustor co-fired with rice husk pellets (primary fuel) and moisturized rice husk (secondary fuel). Three groups of experiments, for (i) conventional burning of rice husk pellets, (ii) fuel-staged co-firing of the two fuels at bottom air injection, and (iii) co-firing them by using a reburning method, were performed at a 200 kW<sub>th</sub> heat input to the reactor. Effects of the energy fraction of secondary fuel (EF<sub>2</sub>), excess air (EA), and the secondary-to-total air ratio (SA/TA) in reburning tests on the combustion and emission performance of the combustor were investigated. With the fuel

staging and reburning methods, the NO emission of the combustor can be reduced by up to 50% and 60%, respectively, compared to burning pure rice husk pellets. However, the use of the proposed co-firing methods may result in some deterioration of the combustion efficiency.

## Poster055

### FISCHER-TROPSCH SYNTHESIS OVER COBALT SUPPORTED ON SILICA HOLLOW SPHERE CATALYST

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Silica hollow sphere as mesoporous molecular sieve which had high potential various usability have been synthesized by the simple and inexpensive method from the reaction of sodium silicate and NH<sub>4</sub>HCO<sub>3</sub> using a water/oil/water (W/O/W) emulsion interface. The silica hollow sphere was used as support of cobalt catalysts for Fischer-Tropsch synthesis (FTS) compared with a commercial available porous silica. The cobalt catalysts supported on silica hollow sphere were prepared with the incipient wetness impregnation and then characterized by N<sub>2</sub>-adsorption and desorption, X-ray diffraction, and transmission electron microscope. The results showed that the metallic cobalt supported on silica hollow sphere had smaller particle size than that supported on commercial available porous silica. However, there is core-shell for increased contact-time of the reactants and heavy hydrocarbon inside the hollow catalyst. Therefore, superior performance on the catalytic activity in FTS of cobalt supported on silica hollow sphere was proposed based on the mesoporous structure in the hollow sphere.

## Poster056

### Ammonia production from nitric acid for hydrogen carrier system

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An original energy carrier system has been developed, which is consisted of a reactor of HNO<sub>3</sub> production from NO<sub>x</sub> in flue gas generated from combustors, an NH<sub>3</sub> production reactor by reduction of HNO<sub>3</sub>, and a H<sub>2</sub> production device from NH<sub>3</sub>. NH<sub>3</sub> is a key material as a hydrogen carrier and storage in the system. The objective of this study is to develop an effective reaction method of ammonia production from HNO<sub>3</sub>. Diluted HNO<sub>3</sub> solution was mixed with Al as the proton source, Cu, and Ni as a catalyst for reduction, and then pH was adjusted into 12 by potassium nitrate solution. The reduction was carried out at solution temperature of 100 °C. In this reaction method, ammonia yield was attained approximately 40%. And more, a

difference reaction method has been tried to reduce production cost, which was to find alternative source of Al; it is using Ni catalyst and hydrogen gas. In this system, the maximum  $\text{NH}_4^+$  yield was approximately 80%.

## Poster057

### Proposal of original hydrogen carrier system using $\text{NO}_x\text{-HNO}_3\text{-NH}_3$ conversion

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Hydrogen carrier system is desired for use of the excess power of renewable energy such as solar power. A typical hydrogen carrier system has been proposed, which is consist of the hydrogen production by electrolysis of water using excess solar power, the ammonia generation using hydrogen and nitrogen, and the hydrogen generation from ammonia using catalyside composition. However, the comprehensive energy efficiency of the hydrogen carrier system is not clear. In this paper, simple hydrogen carrier system that is consisting the solar power panels, an electrolysis of water, the hydrogen storage metal alloy, and the proton exchange membrane fuel cell was examined to investigate the comprehensive energy efficiency. The performance of the system was 11.8 % efficiency. To improve the energy efficiency, an innovative hydrogen storage, carrier, and utilization system was proposed.

## Poster058

### Development of carbon nanoparticle aerogel as porous electrode by supercritical carbon dioxide drying

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Carbon nanoparticle aerogel, high porosity carbon electrode for Li-air battery was generated by supercritical carbon dioxide drying of black viscous slurry. This slurry consisted of carbon black (CB) and PVDF as a polymer binder in N-Methyl-2-pyrrolidone. A conventional drying method, evaporation method at 80°C, was conducted to compare with the electrode from supercritical drying method at 10-20 MPa, 40°C. FE-SEM, electrical conductivity, porosity measurement, TG, XRD analysis were conducted to investigate structure and electrical properties of each electrode. Additionally, specific capacity measurement was conducted with dried air as inlet gas to investigate effect of porosity on performance of batteries. The results show that, carbon electrode dried by supercritical drying has approximately 1.6 times higher porosity than those dried by normal evaporation method. Moreover, porosity of carbon electrode is increased but electric conductivity is decreased with increment of supercritical pressure. Capacity measurement results show that electrode from supercritical drying at 20 MPa gave 30 times higher specific capacity than electrode dried from evaporation in the first discharge-charge cycle. This shows that porosity of electrode considerably affected the performance of battery that high porosity electrode could improve the transportation of oxygen and could have

more space for non-conductive discharge product,  $\text{Li}_2\text{O}_2$ , than low porosity electrode.

## Poster059

### Development of Ru-based catalysts prepared by a liquid phase reduction method for hydrogen production from ammonia decomposition at low Temperature

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Utsunomiya University

$\text{Ru/CeO}_2$  and  $\text{Ru/ZrO}_2$  catalysts were prepared by an impregnation method and a liquid phase reduction with  $\text{NaBH}_4$  from cheap Ru precursor and conventional oxide supports. The catalysts prepared by  $\text{NaBH}_4$  reduction showed a higher  $\text{NH}_3$  conversion than the catalysts prepared by the impregnation method. X-ray fluorescence spectrometry suggested that the catalysts prepared by  $\text{NaBH}_4$  reduction was Cl-free, whereas the catalyst prepared by the impregnation method contained more than 1.7 wt% of Cl derived from the Ru precursor. Furthermore, the formation of Ru metal on the catalyst prepared by  $\text{NaBH}_4$  reduction was confirmed by  $\text{H}_2$  chemical adsorption technique and X-ray photoelectron spectroscopy, whereas  $\text{RuCl}_3$  phase was remained even after  $\text{H}_2$  pretreatment for the catalyst prepared by the impregnation method. These results were main factors to have different catalytic activities. In addition, it was found that  $\text{Ru/CeO}_2$  catalyst exhibited a higher  $\text{NH}_3$  decomposition activity than  $\text{Ru/ZrO}_2$  catalyst, especially at lower reaction temperatures from 573 to 673 K. The characterization results obtained by several techniques indicated that the support basicity probably affected the catalytic performances of the prepared catalysts.

## Poster060

### Effect of hydrogen donor on catalytic cracking of polycyclic aromatic hydrocarbons

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To increase the production of light fractions in the heavy oil processing, we studied catalytic cracking of polycyclic aromatic hydrocarbons (PAHs) with enhanced hydrogen transfer activity. The addition of hydrogen donor accelerated the decomposition of 3-ring PAHs and suppressed the coke formation. In conversion of 3-ring PAHs, both hydrogen transfer reaction and cracking reaction play an important role. High hydrogen-donating ability accelerated the hydrogen transfer reaction, whereas high reaction temperature accelerated the cracking reaction.

## Poster061

### Adhesive Polyvinyl Alcohol Particles as a Buffer for Silicon Anode in Lithium Ion Batteries

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Silicon has attracted attention as a promising anode material in lithium ion batteries (LIBs) owing to its high theoretical capacity (4,200 mAh/g). On the other hand, its large volume expansion during charging and discharging leads to a severe crack in the electrode. Fortunately, a size dependence of fracture was discovered and it turned out that there is a critical size of ~150 nm for avoiding fracture in silicon nanoparticles. This study has introduced the adhesive space for the expansion of silicon nanoparticles by adding polyvinyl alcohol (PVA) using the electrospray method. PVA is well known to be practically insoluble in organic solvents such as electrolytes without heating. Therefore, PVA particles would make sufficient pores to withstand the expansion of silicon nanoparticles and bond to the partially hydrolyzed silicon oxide surface layer on silicon nanoparticles. This study has showed a simple method by adding PVA particles by electrospray method to overcome crack problem in silicon-based electrodes without introducing any expensive nanoscale structuring method.

## Poster062

### Fermentative Hydrogen Production with a Small Pilot Plant by using Molasses as Substrate

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BioHydrogen Technologies, Inc.

Hydrogen was produced from molasses by a small pilot plant equipped with 200L volume of fermenter. The fermenter contained 160L fermentation liquid and 80L was exchanged periodically with new feed. A newly found microflora was used as the organisms of the hydrogen fermentation. The hydrogen productivity of the microflora was examined under three kinds of hydraulic retention time (HRT) of the feed such as 6, 12 and 24hours. Biogas production rate and the yield of biogas were ca. 100L/h and ca. 3.0mol-biogas/mol-hexose at 6hr-HRT, ca. 75L/h and ca. 4.6mol-biogas/mol-hexose at 12hr-HRT, and 60L/h and ca. 6.6 mol-biogas/mol-hexose at 24hr-HRT. The only thing was that the biogas consisted of H<sub>2</sub> and CO<sub>2</sub> contained hydrogen only ca. 30% while 52% at 3L bench scale fermenter experiment. However, since the hydrogen yield at 24hr-HRT becomes ca. 2.0mol-H<sub>2</sub>/mol-hexose, the flora is a hopeful microflora for hydrogen production.

## Poster063

### Steam Reforming of Ethanol over Electrically-Heated Anodic Alumina Ni Catalysts for Hydrogen Production

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High selectivity of hydrogen and low-priced anodic alumina-supported Ni catalyst was synthesized for hydrogen production from steam reforming of ethanol (SRE). Previous studies have shown Ce addition as co catalyst to Ni/Al<sub>2</sub>O<sub>3</sub> increased its durability by suppressing the coke deposition during the steam reforming reaction through the ability of its OSC (Oxygen Storage Capacity), and improves the catalyst performance from only 22 h to 1022 h in practical use. As the test condition, pre-reduction with hydrogen was required to activate Ni catalyst as nickel oxides are inactive in the beginning. For present study, the variation of pre-reduction temperature was found to change Ni state which is affecting the catalyst performance during SRE reaction.

## Poster064

### Corrosion Resistance of Plasma Sprayed and Laser Treated Material with Curvature for Thermochemical Water-splitting Iodine-Sulfur Process

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Hydrogen is one of the promising major energy sources in the future. A thermochemical water-splitting iodine-sulfur processes (IS process) is one of candidates for the large-scale production of hydrogen using heat from solar power. Severe corrosive environment which is thermal decomposition of sulfuric acid exists in the IS process. To achieve an industrialization of massive hydrogen production system, one of the key engineering factors is the development of structural materials for the severe corrosive environment. A hybrid material that combined the corrosion-resistant and the pressure-resistant functions was made by a plasma spraying and laser treatment. The flat specimen of the hybrid material showed enough corrosion resistance in boiling sulfuric acid, though some cracks were observed in the surface layer from the cross section observation. To confirm the applicability of the hybrid material as the structural material, corrosion tests were performed in 95 mass% and 47 mass% boiling sulfuric acid at 300 °C and 120 °C until 300 hours using the round bar specimens with the curvature. The round bar specimen had excellent corrosion resistance in the condition of 95 mass% boiling sulfuric acid. This was attributed to the formation of SiO<sub>2</sub> on the surface. The corrosion rate of the round bar specimen in 47% boiling sulfuric acid was fifty times higher than that in 95 mass% boiling sulfuric acid. The cracks of the surface layer weren't sealed up perfectly in the condition of 47 mass% boiling sulfuric acid. However, there is a possibility of the improvement of corrosion resistance in 47 mass% boiling sulfuric acid by the pre-filming.

## Poster066

### Effect of surfactant on surface tension reduction behavior under microwave

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In our previous study, surface tensions reduction of water droplet under microwave irradiation was found as a non-thermal effect. Water molecule network near the interface was considered as the reason. In this study, surface tension of water with various surfactants was measured during and after microwave irradiation. Surfactant addition is effective in stability of the liquid-air interface because it is adsorbed on the interface. Surface tensions remain lower than that of its original value (before the irradiation) even after temperature returned to the room temperature after the microwave. Although the surface tension reduction depended on surfactant concentration and microwave power, effect of kinds such as ionic and nonionic surfactant on the reduction was not so clear.

## Poster067

### Microwave-assisted synthesis of polyaspartic acid and its scale inhibition

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Heng Hsu

Ming Chi University of Technology

In this work, the intermediate product of polysuccinimide (PSI) is first synthesized by maleic anhydride (MA) and ammonium carbonate (AC) through microwave-assisted heating and followed by base hydrolysis to product PASP. The structure of as-made PASP was characterized with <sup>1</sup>H-, <sup>13</sup>C-NMR, FTIR, and GPC analysis. The results were compared with those of a commercial product and showed the structure of as-made product is similar to the standard. The effect of molar ratio of MA/AC and scale inhibition conditions on calcium carbonate and calcium sulfate precipitation of as-made and commercial PASP, including heating method, inhibition temperature, inhibition time, dosage of inhibitor, concentration of cation and anion, have been examined using static precipitation method.

## Poster068

### Si modified nano-titanium oxide support for SCR catalysts

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SCR-NH<sub>3</sub> of NO<sub>x</sub> (Selective Catalytic Reduction of NO<sub>x</sub> with NH<sub>3</sub>) is the preferred technology for controlling emissions from diesel engines or boilers operating under oxygen-rich conditions. Nano TiO<sub>2</sub> has been widely employed as the support for the SCR catalysts, e.g. classical V<sub>2</sub>O<sub>5</sub>-WO<sub>3</sub>-TiO<sub>2</sub> catalyst.

In this study, in order to develop TiO<sub>2</sub> support with high thermal resistance and SCR activity, a series of Si and Ce doped TiO<sub>2</sub> were synthesized by a hydrothermal synthesis method (HTS) conducted under atmospheric pressure and low temperature conditions, in which metatitanic acid was adopted as raw material. Comparison with commercial TiO<sub>2</sub> samples shows that the HTS TiO<sub>2</sub> gives higher thermal durability. Moreover, Si or Ce doping can enhance further phase transformation temperature of TiO<sub>2</sub> from anatase to rutile, and high surface area and fine particles size can be achieved even when the sample is exposed to a 600–900°C calcination. More significant modification effect on the resistance of the structure and textural properties to thermal treatment is observed over the Si doped TiO<sub>2</sub> than that of Ce. After aging at 700°C for 3 h, V<sub>2</sub>O<sub>5</sub>-WO<sub>3</sub>-TiO<sub>2</sub> with Si doping shows a favorable SCR activity than those without Si (including some commercial catalysts).

## Poster069

### Optimum Conditions of Low Temperature SNCR by Hydrogen Injection

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Selective non-catalytic reduction (SNCR) of NO<sub>x</sub> using activated ammonia generated by pulsed plasma has been developed to expand the narrow temperature window for deNO<sub>x</sub>. The temperature window enlargement of 150 °C was achieved at the lower boundary of the temperature window by activated ammonia injection. Molecular hydrogen in activated ammonia played a key role in the enlargement of the temperature window. The purpose of the present study is to investigate optimum conditions for the low temperature SNCR. DeNO<sub>x</sub>, which were examined by using an NH<sub>3</sub>/H<sub>2</sub> gas mixture at the temperature ranges of 650–750 °C. The optimum H<sub>2</sub>/NH<sub>3</sub> molar ratio changed by the reaction temperature. The optimum value of H<sub>2</sub>/NH<sub>3</sub> molar ratio was decreased with an increase in the reaction temperature; the ranges of optimum H<sub>2</sub>/NH<sub>3</sub> ratios at NH<sub>3</sub>/NO = 1.0 were 0.5–0.2 at the temperature range of 650–750 °C. It found that injected hydrogen contributed production of OH radical, which was available for deNO<sub>x</sub> reactions at the low temperatures. The deNO<sub>x</sub> level was approximately 80% at NH<sub>3</sub>/NO = 1.0 under the optimum H<sub>2</sub>/NH<sub>3</sub> ratio at the temperature ranges of 650–750 °C.

## Poster070

### Swelling Behavior of Chitosan Hydrogel by Carbon Dioxide Switchable Effect

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Yusuke Shimoyama

Tokyo Institute of Technology,

Chitosan hydrogel beads were tested for its adsorption towards an anionic dye, Brilliant Blue FCF in an acidic condition. The focal point of this study was the method of providing the required low pH condition with CO<sub>2</sub> switchable system, a concept that use CO<sub>2</sub> instead of conventional acidic compounds. With the use of acids avoided and thus corrosion to process

equipment reduced, this new technique offers an extremely practical option for industrial processes. The effects of pH and temperature were investigated in comparison with adsorption in pure water (pH 6) and in HCl (pH 3.1). An increase in temperature showed an interesting result where chitosan might be cross-linked by CO<sub>2</sub> and possessed a much more improved adsorption capacity than at lower temperatures. Adsorption in CO<sub>2</sub> switchable system also took a shorter time to reach equilibrium than adsorption in pure water, which was another advantage.

## Poster071

### An Experimental Study of the Separation of Cobalt from LiCoO<sub>2</sub> Cathode of Li-ion Battery with Spinel Material as the Adsorbent

Rong-Chi Wang, Bo-Yan Chen  
Tatung University

Spinel lithium manganese oxide (LMO) material used as a cobalt adsorbent was prepared with solid-state method. After Li<sup>+</sup> extraction, LMO converts to hydrogen manganese oxide (HMO). All materials were characterized by XRD, SEM, BET and TGA. XRD spectra show that the spinel LMO powder prepared at a calcination temperature of 800 °C has higher pure-phase than those prepared at lower calcination temperatures. The HMO powder after adsorption reaction was characterized by XRD, of which peaks slightly shift. Finally, the adsorption performance of spinel sorbent was evaluated by ICP-OES to detect the concentration of Co<sup>2+</sup>. The operating conditions such as sorbent dosages, initial concentrations of cobalt ion, temperatures and stirring speeds were investigated in batch system. The adsorption processes followed the Langmuir isotherm and pseudo-second-order equations. Further study of the separation of cobalt from LiCoO<sub>2</sub> powder is in progress.

## Poster072

### Characteristics of Ammonia Removal from a Synthetic Wastewater in a Semi-batch Jet Loop Reactor

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Yong-Sun Won, Tae-Yoon Lee, Jea-Keun Lee  
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In this study, we investigated ammonia removal characteristics by air stripping from synthetic wastewater in jet loop reactors (JLRs) with the two-fluid venturi-type nozzle (TVN) and the two-fluid venturi-type swirl nozzle (TSN), with the variation of pH, liquid circulation flow rate (QL), and gas flow rate (QG). Throughout the experiment, we obtained higher ammonia removal efficiency when the pH, QL, and QG were increased. In particular, ammonia was removed more efficiently by increasing QG than by increasing pH and QL. The ammonia removal efficiency in a JLR with TSN was higher than in a JLR with TVN. This may be due to the enhanced turbulent intensity in the JLR with TSN compared to that with TVN. In the JLR with TSN applied, the efficiency of ammonia removal was 95% with the conditions of pH of 12, QL of 30 L/min, QG of 20 L/min, temperature of 30 °C, and operating time of 2000 min.

## Poster073

### Mercury Emission and Distribution from Major Sources in Annex D of Minamata Convention and Estimation of Future Trend

Jin-Ho Sung, Yong-Chil Seo, Seong-Heon Kim,  
Joo-Soeng Oh, Seung-Ki Back, A H M Mojammal,  
Eun-Song Lee  
Yonsei University

This study discusses the present status of mercury emission and distribution from major anthropogenic sources in Korea and the future trend of mercury emission by activity changes and application of Best Available Technologies. Atmospheric mercury emission from major anthropogenic sources based on Annex D of Minamata convention was estimated to around 4.89 tonne in 2012. Emission ratios of cement clinker production, coal-fired power plant, waste incineration and non-ferrous metal smelting were 68.68%, 24.75%, 6.29% and 0.28%, respectively. High mercury emission regions were characterized by the presence of cement clinker production facilities and coal-fired power plants. Prediction of future activities in those emission sources was carried out by linear regression of the previous year data. In addition, mercury emission to atmosphere could be changed by applying BATs. As a result, the (total) mercury emission would be estimated to decrease up to 48% by considering the scenario of BATs and the change of future activities in those emission sources. Emissions from coal-fired power plants and cement clinkers facilities would be expected to decrease significantly.

## Poster074

### A role of calcium on leaching of trace elements from coal fly ash

Farrah Fadhillah Hanum, Akihiro Takeyama,  
Shinji Kambara  
Gifu University

Calcium has been known has a good decreasing in the leaching concentration of arsenic (As) and selenium (Se). This study aims to provide the useful reference in controlling As and Se leaching concentration into the environment through the effect of suppressing material addition. Suppressing material, as the by-product of some industries which contains of high calcium and there are three suppressing materials that have been tested, that are: paper sludge ash (PS 3 and PS 4) and filter cake (FC). PS 3 shows the closest effect to Ca(OH)<sub>2</sub> which is used as the standard, it shows almost 80-90% decreasing in As and Se leaching concentration based on ICP analysis. FC did not show an effect in As leaching concentration, but in the contrary with Se leaching concentration, it shows almost 60% decreasing. Calcium oxide has been known as the almost calcium compound which is containing in PS 3 and also known has the best decreasing on As and Se leaching concentration amongst the others calcium compound tested. Could be concluded that CaO is the most wanted calcium compound in controlling the As and Se leaching concentration into the environment.

## Poster075

### MFI Membranes Prepared on Porous Silica Substrates for Acetic Acid Concentration

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Efficient dehydration of acetic acid from water is important. Distillation consumes a large amount of energy especially for separation of low relative volatility mixtures. In order to reduce the energy consumed at the distillation procedure, hydrophobic membranes for selective permeation of acetic acid can be applied at the top of a distillation tower. Membranes with acid resistance, water resistance and heat resistance should be developed. We have focused on zeolite membranes. MFI zeolite is one of the hydrophobic zeolite that consisted of Si for the most part. MFI membranes have been mainly synthesized on porous alumina substrates. In this study, high flux MFI membranes had obtained on novel silica substrates. The effects of Al in the parent gel were investigated. Vapor permeation tests were carried out at 110°C, and the feed vapor was supplied from the 95 wt.% acetic acid aqueous solution. Acetic acid permeance was  $2.6 \times 10^{-7}$  mol m<sup>-2</sup> s<sup>-1</sup> Pa<sup>-1</sup> with the separation factor of 175 through the MFI membranes prepared from the gel of Si/Al = 75.

## Poster076

### Ethanol Separation through Zeolite Membranes for Low Ethanol SAKE

Hitoshi Aoki, Ayumi Ikeda, Mikihiro Nomura  
Shibaura Institute of Technology

Japanese "Sake" is Japan's national liquor that is brewed from rice grains. Ethanol concentration of Sake is usually at around 15 wt%. Recently, Japanese people prefer light liquor with lower ethanol concentration. Ethanol concentration of Sake should be diluted keeping its unique smell and taste. Thus, ethanol separation procedures must be conducted under room temperature to keep their smell and taste. Membrane separation is one of the separation methods that can be operated without heating. We have been developing inorganic membranes such as silicalite membranes to separate ethanol from water. In this study, effects of impurities of Sake such as acids on ethanol permeation through the silicalite membranes were investigated. Ethanol permselective silicalite membrane having higher ethanol flux was prepared by using the ultra-milling silicalite seed crystals. Silicalite membranes were synthesized by the secondary growth method. The ultra-milling seed crystals were prepared by the planetary ball mill. Seed crystals were coated on a substrate, the silicalite layer was grown by a hydrothermal synthesis method. Ethanol permeance increased to  $1.6 \times 10^{-6}$  mol m<sup>-2</sup> s<sup>-1</sup> Pa<sup>-1</sup> from  $1.4 \times 10^{-6}$  mol m<sup>-2</sup> s<sup>-1</sup> Pa<sup>-1</sup> by using the ultra-milled crystals. However, separation factor of ethanol was 18 through the membrane prepared by using the ultra-milled crystals, while that prepared by using the as-made silicalite

crystals was 25. The effects of acids on the total fluxes were discussed. Succinic acid was the most effective acid for decrease of the fluxes among malic acid and lactic acid. The molecule size of the succinic acid is smaller than that of silicalite pores. The decrease by the acid can be explained by the acid adsorption in the pores of the silicalite membranes.

## Poster077

### Preparation of amorphous silica separation membrane via atmospheric-pressure plasma-enhanced chemical vapor deposition

Yuta Yamamoto, Hiroki Nagasawa, Masakoto Kanezashi, Tomoisa Yoshioka, Toshinori Tsuru  
Hiroshima University

## Poster078

### Preparation and gas permeation properties of triethoxyfluorosilane (TEFS)-derived membrane with controlled silica network structure

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Triethoxyfluorosilane (TEFS), which consists of Si-F bonds, was used as a silica precursor to fabricate TEFS-derived membrane with loose amorphous silica networks. Single-gas permeation characteristics, FT-IR and XRD analysis for TEFS-derived membranes were evaluated to discuss the effect of Si-F bonds on physicochemical properties (network size, surface chemistry). FT-IR spectra indicated that the peak position of the Si-O-Si bonds in TEFS-derived gel was shifted to a high wave number (blue-shift) rather than tetraethoxysilane (TEOS)-derived gel. The pore size distribution, as determined by single-gas permeation, suggested TEFS-derived membranes have loose amorphous silica network structures rather than TEOS-derived membranes, due to enlarged Si-O-Si bonds as suggested by FT-IR spectra. For example, TEFS-derived membranes showed high hydrogen permeances ( $1.9\text{--}2.0 \times 10^{-6}$  mol m<sup>-2</sup> s<sup>-1</sup> Pa<sup>-1</sup>) with high selectivity of N<sub>2</sub> to SF<sub>6</sub> (N<sub>2</sub>/SF<sub>6</sub> selectivity: 485-2100) and low selectivity of H<sub>2</sub> to N<sub>2</sub> (H<sub>2</sub>/N<sub>2</sub> selectivity: 10) at 300 °C. A steam treatment (300 °C, partial pressure of steam: 30 kPa) for TEFS-derived membrane was quite effective to control the affinity between unsaturated hydrocarbon and TEFS-derived structures, due to increased silanol group density via replacement of Si-F bonds into silanol groups.

## Poster079

### Hydrocarbon Gases Separation Properties of Sol-Gel Derived Organosilica Membranes

Yuri Yoneda, Masakoto Kanezashi, Hiroki Nagasawa, Toshinori Tsuru  
Hiroshima University

The membrane-based hydrocarbon gas separation is considered to be quite attractive as a simple and energy conservative separation method. In this study, BTESM (bis (triethoxysilyl) methane), BTESB (bis (triethoxysilyl) benzene) and BTESP (bis (triethoxysilyl) propane) membranes were fabricated by sol-gel method. BTESM and BTESP membranes showed higher permeances ( $H_2$ :  $0.82\text{--}1.3 \times 10^{-6} \text{ mol m}^{-2} \text{ s}^{-1} \text{ Pa}^{-1}$ ) rather than BTESB membrane ( $0.2 \times 10^{-6} \text{ mol m}^{-2} \text{ s}^{-1} \text{ Pa}^{-1}$ ). These membranes showed approximately the same selectivity for small molecules such as  $H_2/N_2$ ,  $H_2/CH_4$  of 30-70, indicating the created network size was independent of linking unit. On the other hand, a BTESP membrane showed high selectivity for large molecules such as  $N_2/SF_6$ ,  $C_3H_6/C_3H_8$  and  $C_3H_6/i\text{-}C_4H_{10}$ . Since molecular size of hydrocarbon gases (C1-C4) is in between the size of  $N_2$  (0.364 nm) and  $SF_6$  (0.55 nm),  $N_2/SF_6$  permeance ratio is one of the most important factors to fabricate porous membranes for hydrocarbon gases separation with high selectivity.

## Poster080

### Plasma-enhanced chemical vapor deposition of organosilica membranes for gas separation

H. Nagasawa, Y. Yamamoto, M. Kanezashi, T. Yoshioka, T. Tsuru  
Hiroshima University

Silica-based membranes for gas separation were prepared by using plasma-enhanced chemical vapor deposition (PECVD) in vacuum and atmospheric-pressure. The effects of precursor chemical structure and plasma gas composition on gas permeation properties of the membranes were investigated. The membranes prepared using the precursor with higher O/Si ratio showed higher selectivity since the increase in the O/Si atomic ratio of the precursors led to the formation of dense silica-like structure. A sequential plasma-deposition using Ar-PECVD followed by  $O_2$ -PECVD was proposed to enhance the selectivity of PECVD-derived silica membranes. The membrane prepared via the 2-step PECVD exhibited highly efficient gas separation, with permeance ratios for  $He/N_2$  and  $He/SF_6$  of 4500 and 27,000, respectively. Furthermore, we performed the membrane synthesis using a more challenging method that uses atmospheric-pressure non-equilibrium plasma technology. The membranes prepared using atmospheric-pressure plasma were highly permselective for smaller gases over larger ones (e.g.,  $He/N_2 = 200$ ). The use of atmospheric-pressure plasma can significantly increase the potential for a practical large-scale application of PECVD in membrane fabrication.

## Poster081

### Layered hybrid membranes consisting of organosilica and polymer supports for gas and liquid phase separation

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Hiroshima University

A new type of polymer-supported organosilica layered-hybrid membrane was developed. Using 1,2-bis(triethoxysilyl)ethane (BTESE) as a single precursor, a uniform, thin and perm-selective organically bridged silica active layer was successfully deposited onto a porous polysulfone support via a facile and reliable sol-gel process. These new types of organosilica layered-hybrid membranes were then used for the vapor permeation (VP) dehydration of isopropanol-water (90/10 wt%) solutions, and showed a stable water flux of 2.3  $\text{kg}/(\text{m}^2 \text{ h})$  and an improved separation factor of about 2500. Moreover, these layered-hybrid membranes also displayed good stability and reproducibility in the reverse osmosis (RO) desalination of a 2000 ppm NaCl solution process, and showed a stable and high degree of water permeability (approximately  $1.2 \times 10^{-12} \text{ m}^3 \text{ m}^{-2} \text{ s}^{-1} \text{ Pa}^{-1}$ ) with salt rejection that was competitive (96%) with conventional processing. It shows that the separation performances of these polymer-supported organosilica layered-hybrid membranes have been equal to, or even better than, many ceramic-supported membranes.

## Poster082

### Influence of synthesis gel aging period on water permeation performance through SAPO-34 membrane

Masahiro Seshimo, Ataher Ahmed, Masahiko Matsukata  
Waseda University

Membrane separation technologies have been attracted as one of the energy saving technologies. In case of applying membrane separation to distillation process for water/acetic acid mixture separation, it will be able to save energy consumption in chemical industries. Thus, we focused on SAPO-34 having CHA topology for water separation from water/acetic acid mixture. It is considered that SAPO-34 membrane is able to show water permselective performance in water/acetic acid mixture, because SAPO-34 has the micropores of 0.38 nm derived from the CHA crystal structure. We investigated the influence of synthesis gel aging period on water permeation through SAPO-34 membrane. SAPO-34 membranes were prepared by seed-assisted hydrothermal synthesis method on  $\alpha$ -alumina tubular supports. Crystallinity of SAPO-34 membrane was increased with increasing synthesis gel aging period. The membrane, synthesized for 60 h using synthesis a gel after 6 days aging, showed relatively high water permselective performance with the separation factor of 600 and the water permeance of  $2.5 \times 10^{-7} \text{ mol m}^{-2} \text{ s}^{-1} \text{ Pa}^{-1}$  at 453 K.

## Poster083

### Acid Separation through Inorganic Reverse Osmosis Membranes

Ayumi Ikeda, Toshichika Takeuchi, Hiroki Kitao, Mikihiro Nomura  
Shibaura Institute of Technology

Concentration of the acid such as acetic acid or sulfuric acid can be conducted by a distillation method. Water is mainly vaporized in the distillation tower. Removal of water from acid solution before the distillation tower should reduce the heat duty by reducing vaporizing energy of the water. Reverse osmosis (RO) method is one of the effective separation methods. Silica is one of the inorganic materials that is stable in acid solutions. In this study, silica hybrid membranes prepared by a unique chemical vapor deposition (CVD) method have been investigated for the RO membranes. The pore sizes of the silica hybrid membranes were detailed controlled by introducing the organic functional groups to the silica precursors. Phenyltrimethoxysilane and diphenyldimethoxysilane (DPhDMOS) is used as the silica precursors. The RO test of  $10^{-3}$  M  $H_2SO_4$  solution performed at 4.0 MPa. DPhDMOS derived membrane deposited at  $270^\circ C$  showed the  $H_2SO_4$  rejection of 92% with the total flux of  $5.8 \text{ kg m}^{-2} \text{ h}^{-1}$ . The permeation mechanism was investigated thermal decomposition properties of phenyl group and the pore size calculated by the single gas permeances.

## Poster084

### Separation of $CO_2/H_2$ by using amine modified membranes

Yao-De Zeng, Chun-Min Liu, Shu-Yii Wu  
Feng Chia University

Separation of  $H_2$  from biogas is a main issue of biohydrogen application for using hydrogen to power by PEMFC directly. In this study the membrane separation technology was carried out to purify hydrogen for PEMFC to power. The advantages of this membrane purification technology show a higher efficiency to remove carbon dioxide; the processes are simple, easy operation, low cost, and low energy consumption. Two kinds of membrane with amine modification were prepared. First, the bio-cellulose nanofiber (bio-CNF) was immersed in ethylene diamine (EDA) or 1,3-diaminopropane (PDA) in different times. Second, the Poly(phenylene oxide) (PPO) react with EDA or PDA in different weight percentage to prepare the membranes. For permeability and selectivity experiments, the results showed that while mono gas  $CO_2$  or  $H_2$  was introduced, at 3 atm, and room temperature, the membranes present the  $CO_2$  and  $H_2$  permeability are 1446 Barrer and 140 Barrer, and the selectivity of  $CO_2$  and  $H_2$  separation is 0.62 and 0.41 respectively. The composite membranes prepared by combining PPO-PDA 20wt% and Bio-CNF-PDA amine treatment in 15 min. The composite membranes present a low  $CO_2$  gas permeability of 0.26 Barrer in a  $H_2/CO_2$  mixed gases, while in the mono gas  $CO_2$  is 0.57 Barrer, and its selectivity of separation showed almost the same value as the membrane of Bio-CNF-PDA in 15 min treatment, is 0.64 Barrer.

## Poster085

### Characterization of gas diffusible micropores by using multi-probe gas molecules under high temperatures

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A novel characterization method of sub-nano scale microporous structures based on the volumetric gas diffusion technique has been suggested. He, Ne,  $CO_2$ ,  $N_2$ ,  $CH_4$ ,  $CF_4$  and  $SF_6$  were used as probe gases. A significant feature of this method was that the different gas molecules with different molecular size detected different diffusible volumes of pores where each molecule could diffuse as gas state around high temperature. ZSM-5 powder was employed as standard sample with well-known microporous structures and pore size. The diffusible volumes calculated from this model showed good correlation with probe gas molecular size. In addition amorphous silica powder was measured by this method and the difference of adsorptive properties of each probe gas in porous structure was detected.

## Poster087

### Preparation of calcium alginate membrane containing hydrophobic domain and effective diffusion coefficient of water soluble dye

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Mass transfer characterization of calcium alginate membrane containing hydrophobic domain was presented involving with hydrophilic / hydrophobic effect on water soluble dye components. Hydrophilicity of the membrane was regulated with the volumetric fraction of oil in water dispersed phase contained in calcium alginate membrane. Mechanical strength of membrane was examined by maximum stress and maximum strain at membrane rupture. The membrane was exhibited sufficient strength and showed smooth and flat surface. The maximum stress at membrane rupture was slightly decreased with increasing volumetric fraction of hydrophobic domain. The maximum strain was remaining constant. Mechanical strength of calcium alginate membrane containing hydrophobic domain was applicable for practical use. Effective diffusion coefficient was examined on the mass transfer characterization of the membrane. It was evaluated from mass transfer flux of Urea (60Da), Methyl orange, (327Da) Indigo carmine(466Da), Bordeaux S (605Da) and Fast green FCF(808Da). The effective diffusion coefficient in the hydrophobic domain membrane was changed 176-folds even if molecular size only 13.5-folds. It suggested that the size of mass transfer channel was mono-dispersed in our experimental molecular size. In contrast, the effective diffusion coefficient of calcium alginate solo membrane prepared by 'Dry process' was changed steeply with molecular size of components. Calcium alginate membrane containing hydrophobic domain was promising forthcoming selective separation tool based on static diffusion for food, cosmetic and pharmaceutical components.

## Poster089

### Fouling Mechanism of Membrane Distillation in Dairy Process

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The objective of this study is to provide knowledge about the fouling in a direct contact membrane distillation process for whey and to analyze it from the heat and mass transfer perspectives. Experiments to concentrate the whey solution were conducted by membrane distillation using a hydrophobic microporous membrane. In this study, the membrane fouling, flux decline, was observed after the concentration test. The steady state flux depended on the feed concentration and cross flow velocity. Since the permeation flux was recovered after washing, it could be evidenced that the membrane fouling in whey was a reversible process. Based on a heat and mass transfer analyses, the permeation flux decline was attributed to the decreasing water vapor pressure in the fouling layer.

## Poster090

### Molecular simulation study of the valid molecular size and shape in modified gas translation model

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A characterization method of microporous structures of gas separation membranes by analyzing gas permeances based on the modified gas translational (GT) model which employed gas molecules such as He, H<sub>2</sub>, CO<sub>2</sub>, and so on as probe molecules has been proposed. In this method, the values of the probe gas molecular size are very important issue for precise evaluation of micropore size, however, some ordinary kinetic diameters of gas molecules were pointed out to be unsuitable for this purpose. Therefore it is necessary to study effective molecular size for permeation through microporous membranes. In this work, non-equilibrium molecular dynamics simulations of gas permeation were carried out using virtual membranes with a cylindrical pore. In the simulations the influence of size, shape and interaction with membrane of gas molecules on gas permeation characteristics were examined. As the results of MD simulations and analysis, the estimated pore size and membrane porous structures showed good agreement with given characteristics of model membranes. For the case of permeation of linear shaped CO<sub>2</sub> molecule, its minor axis was effective for estimation of small pores on membranes, on the contrary, the major axis was suitable as its kinetic diameter.

## Poster091

### The Enhancement of C-Phycocyanin Purity by Chitosan Nanofiber Membrane

Yu-Ling Lin, Kuei-Hsiang Chen, Zih-Ming Chiou,  
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In this work, the experiments were carried out with chitosan modified membrane to examine the adsorption characteristics of C-phycoerythrin (C-PC) from disrupted *Spirulina platensis*. The influences of NaCl concentration (0.1-1.0 M), adsorption pH (6-8), chitosan concentration (0.1-3.0 %), C-PC concentration (0.05-0.50 mg/ml), and membrane flux ( $6.37 \times 10^{-2}$ - $3.18 \times 10^{-1}$  mL/min-cm<sup>2</sup>) on the adsorption performance of the membrane for CPC were investigated. The results showed that the order of selectivity of the membrane for these proteins was found to be general protein (TP) > APC > C-PC. In this case, TP and APC molecules were more easily adsorbed by the chitosan modified membrane. On the contrary, the C-PC molecules would most easily penetrate the membrane without being adsorbed. Under these circumstances, the filtrate containing C-PC would enhance its purity. The purification factor and total mass flux were found to be 3.3 folds and 66%, respectively in a single step.

## Poster092

### Polyamine Based Nanofiber Membrane for C-Phycocyanin Adsorption

Chien-Yi Lo, Kuei-Hsiang Chen, Jia-Yi Chen,  
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Ming Chi University of Technology

Polyacrylonitrile nanofibrous membrane (P-CN) was prepared by electrospinning technique. The PAN membrane comprises a polyethylene terephthalate (PET) meltblown fabric as a supporting layer. The PAN membrane was directly converted to polyamine membrane by using 50% and 100% (w/w) ethylene diamine (EDA) and 1,6-hexadiazine (HDA), respectively. These polyamine modified membrane modules combined with automatic programmable protein liquid chromatography were used to evaluate the adsorption performance for C-phycoerythrin (C-PC) and allophycocyanin (APC) from disrupted *Spirulina platensis* under different operating conditions. The results showed that the order of dynamic binding capacity, adsorption efficiency and binding selectivity are as follows: (1) modification time: 3 hr > 24 hr, (2) disrupted algae concentration: 0.25% > 1.0%; (3) diamine concentration: 50% > 100%. The adsorption efficiency of polyamine modified membranes for C-PC, APC, and general protein (TP) decreased in the following order: P-EDA > P-HDA ≥ PCN. The polyamine modified membrane with different carbon chain lengths would affect the adsorption performance for C-PC. Moreover, the order of adsorption performance for C-PC, APC and TP onto polyamine modified membranes was C-PC ≥ APC > TP. The polyamine modified membrane may have a high potential for use in the separation of C-PC from complex algae feedstock.

## Poster093

### Tris(hydroxymethyl)aminomethane Affinity Membrane for Adsorption of Lysozyme

Jen-Hong Chang, Kai-Jie Lin, Yu-Kaung Chang  
Ming Chi University of Technology

Polyacrylonitrile (PAN) nanofiber membrane was prepared by electrospinning technique. The PAN membrane used in this work comprises a polyethylene terephthalate (PET) spunbond fabric as a supporting layer with upper and lower PAN nanofiber membrane. After 3 M NaOH and diluted HCl treatments, the weak cationic exchange membrane (i.e., P-COOH) was obtained. The P-COOH membrane was then functionalized with tris(hydroxymethyl)aminomethane as an affinity nanofiber membrane (i.e., P-Tris). In this study, lysozyme was chosen as a model protein. The physical properties of the nanofiber membranes were characterized in terms of fiber diameter, porosity and pore size, specific area of the surface, FTIR and SEM analysis. The adsorption experiments were carried out in a well-mixed system under the various operating conditions (e.g., modification pH, adsorption pH, and the molar ratio of reactants, P-COOH/Tris). The dynamic adsorption characteristics of the P-Tris membranes for lysozyme by membrane chromatography were assessed by measurements of the breakthrough curves. The influences of operating conditions (e.g., adsorption pH, lysozyme concentration, no. of sheet membrane, and flow rate) on the adsorption performance of membrane were investigated in an AKTA prime chromatographic system (GE Healthcare).

## Poster097

### The coordinator's role in the common research and development

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A coordinator regulating the composition between companies plays an important role to create innovation. But it isn't studied so much about coordinator's suited of the common research and development up to now. So by this research, It's defined as the program manager with the close role about the role of the coordinator with a coordinator. The coordinator's importance in the common research and development is made clear. To make it clearer about the attribute of the coordinator who succeeded in commercialization of common research and development. In the common research and development which are private small and medium enterprises by this research. About the role a coordinator is achieving, its importance will be reported. A coordinator has to play its role at each stage of the 3S model of P2M (Scheme model and System model, Service model) as the management studied and developed most suitably jointly. A concept of P2M is indicated first by writing, and the important matter when a coordinator supports innovation activity, is described. Next the role and a skill necessary to a coordinator are described at each stage of the 3S model.

## Poster098

### Decision-making protocol for orchestration under P2M framework

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For companies in an era of high uncertainty, the difficulty of research and development (R&D) to improve business outcomes is a serious problem. To counter this, we propose a "multi-program platform structure," which is a strategic management framework. This structure has three functions: inter-perspective cooperation, hierarchical structure, and dynamic alignment and orchestration. These features harmonize and integrate different perspectives. In this study, two decision-making protocols for orchestration are introduced to implement these functions, and its details are described. Furthermore, to explain the features of these protocols, the Mitsubishi Chemical Corporation is selected as an example.

## Poster099

### Discussion on the Introduction of the Value Creation Process for the Solution of Complex Local Issues

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Local cities are facing labyrinthine issues, including changes in the demographics and depopulation due to the ageing society with fewer children, and abandoned arable lands. In order to solve complex issues, it is necessary to have a system, as well as its specific methodology, to gain the empathy of diversified stakeholders which leads to collaboration. As a system to gain empathy, this study proposes the introduction of the value creation process which consists of the discovery of value, realization of value, and acquisition of value. As a result of case studies, it was found desirable to apply the Boost-Gate method which fosters a value creation mindset as a supplementary function for the value creation process. In addition, the value creation process enabled a pluralistic interpretation of the intention of the Holistic Mission and an expression as a broad value system, enabling the collaboration with existing projects, which in turn contributed to the increase in the value of the whole program.

## Poster101

### Innovative Chemical Reaction Process using Stimulus Response Capsule

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In this study, we propose a novel chemical reaction process using Pluronic micelles as reactant carriers in order to reduce complicated piping. A Pluronic micelle containing the

hydrophobic dye NKX-1595 was prepared by a dialysis method, and the release of the internal dye from the micelle by external stimulation was investigated. In particular, we investigated the effects of the combination of ultrasonic frequency and type of Pluronic on degree of dye release (*DDR*). A low ultrasonic frequency is effective for the release of the internal dye from the micelle and ultrasonic physical effects are an important factor. Furthermore, under a weak ultrasonic physical effect at 490 kHz, the inhibition effect when the internal substance moves to the corona from the micelle core is also important for estimating the retention of the internal substance by the micelle. In addition, we investigated the effects of thermal stimulation on *DDR* at several environmental temperatures. The internal dye was gradually released from the micelle when the environmental temperature was greater than 303 K. Thus, appropriate design of external stimulation enables controlling not only the amount of effluence but also the release rate of the internal dye from the micelle.

## Poster102

### PRODUCTION OF AMMONIA SOLUTION USED AS A FERTILIZER FROM RENEWABLE ENERGY BASED ON THERMOCHEMICAL CYCLE

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The recent growth in food demand is the result of overpopulation. Thus utilizing fertilizers, especially nitrogen-based fertilizer is inevitable to enhance crop yields. However, the ammonia production is now dominantly based on Haber-Bosch process which consumes a lot of fossil fuels and emits a large amount of harmful CO<sub>2</sub> into the atmosphere. Instead of this process, other more sustainable techniques are desired. An alternative method to synthesize low-concentration ammonia at a small scale from renewable energy (air, water, solar energy, etc.) has been proposed at Tokyo University of Agriculture and Technology. Once formed, ammonia solution is supposed to be used directly as a fertilizer, with only 1-5% concentration.

## Poster103

### Supported transition metal oxides as solid acid catalysts for steam reforming of dimethyl ether

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Several supported transition metal oxides ( $X/Y$ ,  $X = \text{WO}_3$ ,  $\text{Nb}_2\text{O}_5$ ,  $Y = \text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{TiO}_2$ ) were investigated as a solid acid catalyst for hydrolysis of dimethyl ether (DME). Among the

transition metal oxides tested,  $\text{Nb}_2\text{O}_5/\text{Al}_2\text{O}_3$  showed the highest catalytic activity because of its unique solid acidity. For the further increase in the hydrolysis activity, the effects of  $\text{Nb}_2\text{O}_5$  loading amount and calcination temperature on catalytic activity were studied. XRD patterns showed  $\text{AlNbO}_4$  phase appeared when the calcination temperature was over 800°C. The BET surface area decreased for the increase in the calcination. The acid amount increased consistently with the  $\text{Nb}_2\text{O}_5$  loading amount up to 25wt%  $\text{Nb}_2\text{O}_5/\text{Al}_2\text{O}_3$ , and it became almost constant for the further increase in the  $\text{Nb}_2\text{O}_5$  loadings. 25wt%  $\text{Nb}_2\text{O}_5/\text{Al}_2\text{O}_3$  catalyst calcined at 500°C exhibited the highest catalytic activity for DME hydrolysis, and consequently steam reforming of DME was carried out over  $\text{Nb}_2\text{O}_5/\text{Al}_2\text{O}_3$  mixed with  $\text{Cu}/\text{ZnO}/\text{Al}_2\text{O}_3$ . It was found that an optimal ratio of  $\text{Cu}/\text{ZnO}/\text{Al}_2\text{O}_3$  and  $\text{Nb}_2\text{O}_5/\text{Al}_2\text{O}_3$  was 1/1, which resulted in higher catalytic activity for DME SR than a mixture of  $\text{Cu}/\text{ZnO}/\text{Al}_2\text{O}_3$  and  $\gamma\text{-Al}_2\text{O}_3$ .

## Poster104

### Wet Chemical Synthesis of Porous Silica from the Acid Extraction of Copper Smelting Slag

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Fukushima College

Copper smelting slag generated during the smelting and refining of copper is currently stored in large quantities worldwide. For this reason, the present study investigated the synthesis of silica-based material via the acid extraction of slag, as a means of chemical recycling. The treatment of copper slag with hydrochloric acid was found to extract the majority of the slag components, including iron, zinc, copper, aluminum, leaving a silica hydrogel. At low acid concentrations (0.50 mol·L<sup>-1</sup> and below), the chemical compositions of the extraction residues were similar to that of the raw slag. In contrast, at higher acid concentrations (above 0.5 mol·L<sup>-1</sup>), the majority of the products were elemental metals. Following the extraction of these metal components, the residual material was transformed into a silica hydrogel due to the gradual aggregation of silica colloids. The dried silica hydrogel exhibited a high specific surface area and hygroscopicity favorable for applications as an adsorbent. In the case of sulfuric acid extraction, similar behavior was observed except that copper was not eluted even at high acid concentrations, although the generation of a silica hydrogel was again observed.

## Poster 105

### A Review of CFD-DEM Application to Heat Transfer in Packed and Fluidized Beds

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Packed and fluidized bed reactors are widely used in various industries, which generally involves complicated multiphase flow, heat transfer and chemical reactions. The performance of these reactors heavily depends on the hydrodynamics and thermal-chemical behavior of particles in interaction with fluid. Understanding and modeling coupled flow and heat transfer in fluid bed reactors at a particle scale is a rapidly developing research area, in connection with the development of discrete

particle simulation techniques and computer technology. The discrete approach based on the discrete element method has been developed for this purpose, and increasingly plays a more significant role in this area. The key advantage of this approach is that it can produce microscopic and dynamic information of particulate systems, which is directly related to the prediction of bed flow and thermal behaviour. In this short review, the development of this approach is briefly discussed, together with its applications to some cases. It is concluded that this particle scale approach is effective for studying the coupled fluid flow and heat transfer in fluid-bed reactors, although further developments are necessary to be generally applied to industrial processes.

## Poster106

### Hydrolysis of lignocellulosic biomass in ionic solution

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Industrial Technology Research Institute

The novel technique of lignocellulose hydrolysis in ionic solution which mixed metal salts with organic acid under mild conditions has been investigated. In this study, the ionic solutions (ITRI-1) are prepared by HCl, ZnCl<sub>2</sub>, and formic acid in different ratios for lignocellulose hydrolysis. In ITRI-1 ionic solution, the total reducing sugar yield of cellulose is great than 90%. Additionally, sugarcane bagasse is used as the main test material for the study of the effects on total reducing sugar yield in various reaction parameters. Under the optimized condition, the reducing sugar yields of sugarcane bagasse which is hydrolyzed in ITRI-1 ionic solution can be great than 90%. Therefore, these results show that ITRI-1 ionic solution is a good medium for the lignocellulose hydrolysis and can accordingly develop new hydrolysis technique for cellulosic sugar production.

## Poster107

### Direct Fabrication of Catalytically Active Fe<sub>x</sub>C Sites by Sol-Gel Autocombustion for Preparing Fischer-Tropsch Synthesis Catalysts without Reduction

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The Fe-based Fischer-Tropsch synthesis (FTS) catalysts, promoted by copper as well as potassium, were directly prepared through a novel modified sol-gel autocombustion without further reduction. It was disclosed that the citric acid contents controlled the reduction/carburization of catalyst, and the performance of FTS reaction was investigated. The citric acid to nitrates molar ratio (denoted as CA/N) played a

noteworthy role in the phase change of the Fe active sites and catalytic performances of the catalysts. Adding CA considerably improved not only the Fe reduction/carburization during the preparation but also the FTS catalytic performance even without reduction process. Enhancement of the CA/N molar ratio resulted in the increasing of the reducibility of catalysts. However, the FTS performance increased first and then decreased because an unnecessary reductant could lead to remaining of the carbonic residual and decreases the catalyst performance for FTS. The FeCuK catalysts prepared using the sol-gel autocombustion method with CA as reductant, could achieve a high FTS performance without further reduction, therefore this method could be widely applied in the designing other metallic nanoparticle catalysts.

## Poster108

### A Non-Drying, Water-Based Process for Fabricating Mixed Matrix Membranes with Outstanding Pervaporation Performance

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In this study, we synthesized nanoporous zeolitic imidazole framework (ZIF-8) nanoparticles with a particle size of 60 nm and a pore size of 0.38 nm in water phase and directly incorporating them into an organic polymer (poly(vinyl alcohol; PVA)) aqueous solution without a drying process, leading to a high-quality ZIF-8/PVA MMM with enhanced performances in ethanol dehydration via pervaporation. The permeability is 3 times as much as that of pristine PVA and the separation factor is nearly 9 times as much as that of the pristine PVA. The significant enhancements in separation performances are attributed to the rises in fractional free volume in membranes which are analyzed by positron annihilation lifetime spectroscopy.