



Vol. 4 No. 1 March 2011

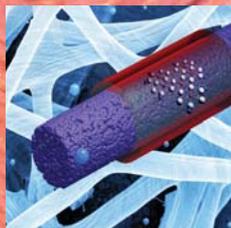
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 English Teaching Robots • *Moon-Sang Kim* Water/Wastewater Purification • *Jaewoo Choi,*  
*Jaesang Lee, Sanghyup Lee* Oncology Kinase Drug Discovery Research • *Taebo Sim*  
 High Activity Pt/Pt-M Alloy Electrocatalysts • *Soo-Kil Kim, Joung Woon Kim, Seung Jun Hwang,*  
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Leading to the world of tomorrow

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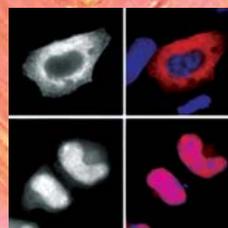
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## Foreword

Ushering in the year 2011, one critical question comes to mind: How do we envision what the future will hold? One of the most important virtues a scientist must possess is the wisdom and ability to look ahead into the future. I have no doubt that when the founding fathers of KIST established the institute back in 1966 their vision was that KIST would be the cornerstone for science and technology in Korea, determining the future of the nation.

With the remarkable economic growth Korea has experienced, largely in part to KIST's significant role in advancing Korea's science and technology, KIST has successfully lived up to this founding vision. This has only been possible due to the efforts, hard work and passion of its researchers. But while our achievements are commendable, there is no time to rest on our laurels.

KIST is now set to pave the way for a brighter future by equipping itself with keen insight and renewed passion, in spite of the challenges and obstacles that lie ahead. This edition of KISToday features many of KIST's recent activities and accomplishments. I hope it will provide you with a clear snapshot of what we have in mind as we strive to make new history in science and technology in the years to come.

President **Kil-Choo Moon**

# Electrochemical Capacitors Using RuO<sub>2</sub> Nanofibers with an Ionically-Conducting Hydrous Layer



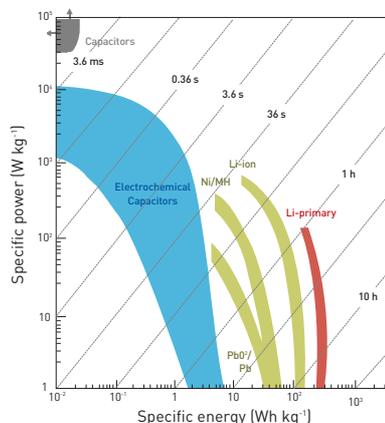
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Recently, environmental pollution and an exhaustion of energy resources have led to active research for the development of environment-friendly alternative energy sources. In spite of the development of batteries or fuel cells with high energy density, there are still limitations when using these technologies. A supercapacitor, which has been shown to have superior power density characteristics to lithium secondary batteries, has attracted attention as a device which can not only satisfy the power density required for hybrid electric vehicles (HEVs) or satellite communications, but also shows superior performance in reducing the size of an energy system by distributing the energy of a battery or fuel cell, as shown in Fig. 1.

Supercapacitors, also called electrochemical capacitors, store energy achieved by virtue of ion absorption (electrochemical double layer capacitors or electric double layer capacitors known as EDLCs) or fast surface redox reaction, i.e., oxidation-reduction reaction on a surface of a material (pseudo-capacitors). Research in EDLCs has focused on improved materials including graphene, activated carbon, and carbon nanotubes that offer higher usable surface areas. More recently, pseudo-capacitors utilizing transition metal oxides have attracted an increasing amount of attention as potential key energy storage devices due to their high capacitance (200 ~ 1300 F/g) as compared to that of EDLCs (50 ~ 150 F/g)<sup>1</sup>. Charge storage of the transition metal oxides is achieved mainly through a pseudocapacitive process involving the use of faradaic redox reactions in conjunction with an electric double layer capacitive (EDLC) process in the interface between the electrode and the electrolyte. Thus far, several promising electrode materi-



**FIGURE 1.** Ragone chart showing energy density vs. power density for various energy-storage devices. Times shown are the time constants of the devices, obtained by dividing the energy density by the power. Copyright: Nature Publishing Groups

als for electrochemical capacitors, e.g., RuO<sub>2</sub>,<sup>2</sup> MnOx,<sup>3-5</sup> NiO,<sup>6</sup> CoO,<sup>7</sup> Fe<sub>3</sub>O<sub>4</sub>,<sup>8</sup> and VOx<sup>9</sup>, have been proposed.

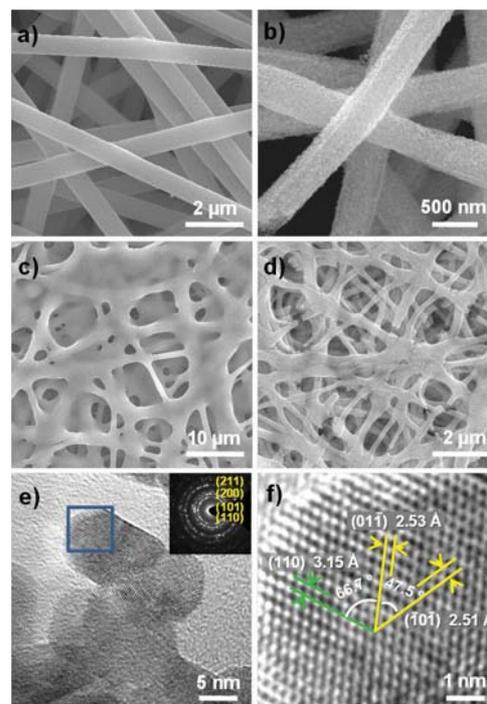
Among the pseudocapacitive materials, many studies on the use of ruthenium oxide (RuO<sub>2</sub>), which has superior specific capacitance as an electrode, have been done, but the high price of ruthenium oxide nanoparticles makes it difficult to mass produce on a cost-effective basis. The ruthenium oxide exhibits very different properties in an amorphous structure and in a crystalline structure. The crystalline ruthenium oxide is known for its high electrical conductivity (specific resistance: 35 μΩ-cm), whereas the amorphous ruthenium oxide is known for its superior hydrogen ion (proton, H<sup>+</sup>) conductivity. Of particular note is that the hydrated ruthenium oxide (RuO<sub>2</sub>-xH<sub>2</sub>O) obtained through a low-temperature fabrication process has a high specific capacitance value due to its high ion conductive properties.

However, hydrated ruthenium oxide is limited when applied to high-speed supercapacitors due to its relatively low electrical conductivity as compared to crystalline ruthenium oxide which has high electrical conductivity.

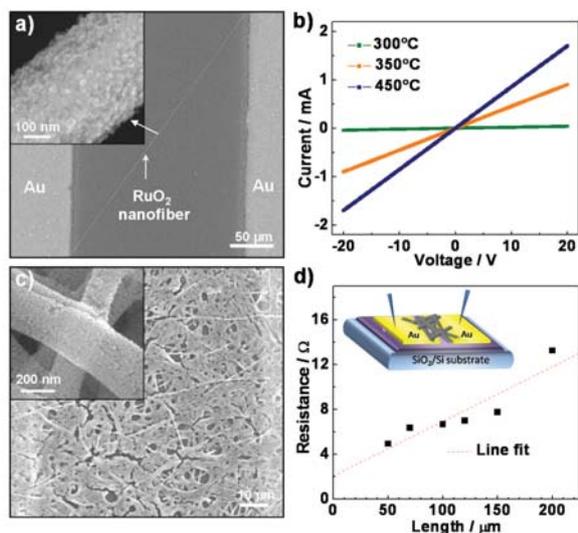
Accordingly, a new composition of materials using less ruthenium oxide is needed which can lower the material costs associated with ruthenium oxide but maintain high electrical conductivity while increasing ion conductivity. In particular, the development of a composite composition having a high specific capacitance value is required. Also, the development of an electrode with a nanostructure having both crystalline and amorphous properties is important for fabricating a supercapacitor with a high power and high energy density. In this regard, multiple nanofiber networks which include fast electronic conducting pathways can afford a high surface area and fast electron/electrolyte diffusion paths for charge storage and delivery, making it one of the most suitable electrode types of architecture for high-power electrochemical capacitor applications. The challenge is to combine electrically conductive nanostructures with hydrous  $\text{RuO}_2$  overlayers in order to obtain simultaneously fast electron and proton conductivity.

Researchers at KIST have introduced an electrospinning method for producing multiple conducting nanofiber mats. To the best of our knowledge, there have been no reports on the electrochemical properties of hydrate  $\text{RuO}_2 \cdot n\text{H}_2\text{O}$  overlayers coated on electrically conductive  $\text{RuO}_2$  nanofibers via electrospinning. Electrospun  $\text{RuO}_2$  fiber mats, calcined at  $400^\circ\text{C}$ , exhibited highly porous morphologies composed of crystalline  $\text{RuO}_2$  nano-particles with an average particle size of 10 nm (See Fig. 2). FE-SEM images in Figs. 2a-f show the morphology and microstructure evolution of  $\text{RuO}_2$  nanofiber mats during each process step. The as-spun  $\text{RuO}_2$  precursor/PVAc composite nanofibers exhibit a range of diameters from 700 to 800 nm, as shown in Fig. 2a. Randomly-oriented fibers in the form of nonwoven mats were obtained as a result of the chaotic motion (bending instability) of the  $\text{RuO}_2$  precursor/PVAc jet ejected through the orifice. After calcination at  $400^\circ\text{C}$  in air for 30 min, the  $\text{RuO}_2$  fibers exhibited a regular structure composed of 400-500 nm diameter cores (See Fig. 2b). However, when spun onto the Ti substrate and Au (150 nm)/Ti (50 nm)/ $\text{SiO}_2$  electrodes arrays respectively, the  $\text{RuO}_2$  fiber mats exhibited poor adhesion to the substrates. After calcination at  $400^\circ\text{C}$ , the  $\text{RuO}_2$  fiber mats tended to peel off from the substrates due to large mat volume shrinkage of 60%. In order to solve the adhesion problems, we introduced a hot-pressing step to drive partial melting of the PVAc (its glass transition temperature is  $28 - 30^\circ\text{C}$ ) before the calcination step. In contrast to unpressed fiber mats, the hot-pressed ( $50^\circ\text{C}$  for 60 sec)  $\text{RuO}_2$  fiber mats did not peel off of the substrate during handling and testing. The

hot-pressed  $\text{RuO}_2$  precursor/PVAc composite nanofiber mats showed an interconnected morphology resulting from partial melting of the matrix polymer, i.e., PVAc, as shown in Fig. 2c. Subsequent calcination at  $400^\circ\text{C}$  for 30 min resulted in highly porous nanofiber mats comprised of crystalline  $\text{RuO}_2$  nano-particles (see Figs. 2d and e). This morphology provides high-porosity for efficient permeability of the electrolyte into the inner structure while maintaining a high surface area for enhanced surface activity. HR-TEM analysis was carried out in order to investigate the microstructure of individual  $\text{RuO}_2$  nanofibers. As shown in the TEM image of Figs. 2e-f, the  $\text{RuO}_2$  nanofibers calcined at  $400^\circ\text{C}$  for 30 min consist of nano-crystals with a size distribution of approximately 5 - 15 nm. Lattice images are clearly visible, indicating that the  $\text{RuO}_2$  nano-particles are highly crystalline.



**FIGURE 2.** a) SEM image of as-spun  $\text{RuO}_2$  precursor/PVAc composite nanofiber mats prepared by electrospinning; b) SEM image of  $\text{RuO}_2$  nanofiber mats calcined at  $400^\circ\text{C}$ ; c) SEM image of  $\text{RuO}_2$  precursor/PVAc composite nanofiber mats after thermo-compressing at  $50^\circ\text{C}$  for 60 sec; d) SEM image of thermocompressed[AC1]  $\text{RuO}_2$  nanofiber mats calcined at  $400^\circ\text{C}$ ; e) HR-TEM micrographs of  $\text{RuO}_2$  nanograins. The inset shows a selected area electron diffraction pattern of  $\text{RuO}_2$  nanograins; f) Lattice image of a single crystalline  $\text{RuO}_2$  grain magnifying the selected area in Fig. 1e.



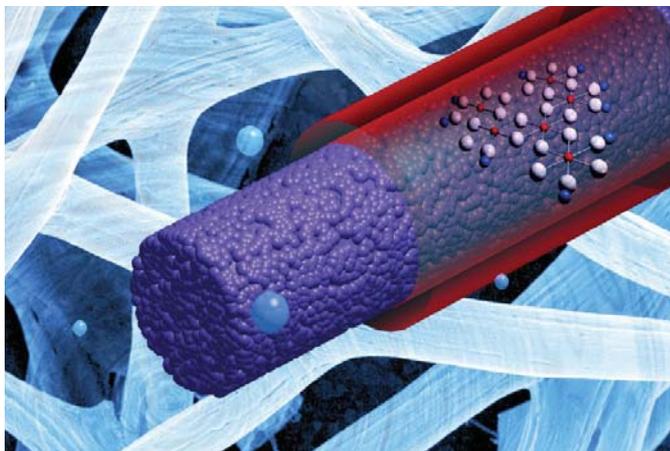
**FIGURE 3.** a) SEM image of a single RuO<sub>2</sub> nanofiber on Au electrodes patterned on top of a SiO<sub>2</sub>/Si substrate. The inset shows a single RuO<sub>2</sub> nanofiber composed of nanograins; b) I-V curves of single RuO<sub>2</sub> nanofibers calcined at 300, 350, and 450 °C. c) SEM image of RuO<sub>2</sub> nanofiber mats prepared on Au electrodes patterned on top of SiO<sub>2</sub>/Si substrate. The inset shows the magnified RuO<sub>2</sub> nanofiber mats; d) I-V curve of RuO<sub>2</sub> nanofiber mats calcined at 400 °C. The inset shows a schematic diagram of the RuO<sub>2</sub> nanofiber mats prepared on the Au electrode patterned on top of the SiO<sub>2</sub>/Si substrate.

In order to investigate the electrical conductivity of single RuO<sub>2</sub> nanofibers and multiple RuO<sub>2</sub> nanofiber mats, Au electrodes were patterned on top of SiO<sub>2</sub>/Si substrates with the aid of a shadow mask. The line width of each Au electrode was 2000 μm spaced 50 ~ 200 μm apart, as shown in the SEM micrograph of Figs. 3a and 3c. Figure 3b shows I-V profiles of single RuO<sub>2</sub> nanofiber, measured at room temperature, and prepared under different annealing conditions. The observed linear relationship between current and voltage for the single RuO<sub>2</sub> nanofiber confirms ohmic behavior between the RuO<sub>2</sub> nanofiber and Au electrodes. The conductivity values of single RuO<sub>2</sub> nanofibers calcined at 350 °C and 450 °C were measured to be  $4.85 \times 10^2$  and  $1.56 \times 10^3$  S cm<sup>-1</sup>, respectively. This is approximately one to two orders of magnitude smaller than the bulk conductivity of RuO<sub>2</sub> ( $2.86 \times 10^4$  S cm<sup>-1</sup>). The lower effective electrical conductivity of one-dimensional RuO<sub>2</sub> nanofibers is likely due to a combination of nano-particle induced scattering in the nanoscale fibers and reduced effective cross-section due to porosity. Similar electrical behavior was observed with multiple RuO<sub>2</sub> nanofiber mats, as shown in Fig. 3d. The insets of Figs. 3a and 3c emphasize the polycrystalline nature of RuO<sub>2</sub> nanofibers. The resistivity of RuO<sub>2</sub> nanofiber mats calcined at 400 °C was  $3.47 \times 10^{-3}$  Ω cm (conductivity:  $2.88 \times 10^2$  S cm<sup>-1</sup>), comparable with

that of the single RuO<sub>2</sub> nanofiber.

In order to investigate electrochemical properties, we carried out supercapacitive characteristics. Electrochemical measurements were performed with a three electrode system, composed of the hydrous RuO<sub>2</sub> coated crystalline RuO<sub>2</sub> fiber mats as the working electrode, a Pt counter electrode, and an Ag/AgCl reference electrode with saturated KCl solution. Cyclic voltammetry was performed using a Potentiostat/Galvanostat/EIS (VSP, BioLogic) in aqueous 1 M H<sub>2</sub>SO<sub>4</sub> sulfuric acid solution at room temperature for the characterization of electrochemical and cycling properties. The cyclic voltammograms of the electrodes were recorded at a scan rate of 10 to 2000 mV sec<sup>-1</sup> and in a voltage range of 0 -1 V.

The pristine RuO<sub>2</sub> nanofiber mats calcined at 400 °C exhibited a capacitive behavior with a nearly rectangular-shaped voltammogram when measured with Ti substrates acting as current collectors at a scan rate of 10 mV sec<sup>-1</sup>. However, the average specific capacitances were low (29.8 F g<sup>-1</sup>), as calculated by the following equation:  $C_{sp} = i/vw$ , where  $i$ ,  $v$ , and  $w$  are the average current, scan rate, and mass of the RuO<sub>2</sub> nanofiber mats (for our sample: 0.42 mg), respectively. This is mainly due to the dense crystalline lattice structure of the pristine RuO<sub>2</sub> nanofiber mats, which often limits the transport of protons (H<sup>+</sup>). In order to improve the charge storage capability, we introduced a thin hydrous RuO<sub>2</sub> overlayer onto the crystalline RuO<sub>2</sub> nanofiber mats using cyclic voltammetric (C-V) deposition. This hybrid strategy can provide facile transport of electrons and protons through the crystalline RuO<sub>2</sub> nanofibers with high conductivity and the hydrous RuO<sub>2</sub> coating layer, respectively. This advantageous feature could be further combined with facile penetration of the electrolyte into multiple nanofiber mats with bimodal pore distributions. [See Fig. 4]



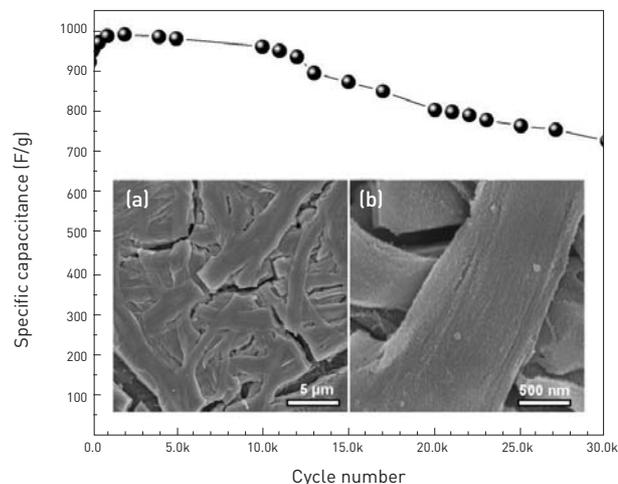
**FIGURE 4.** Schematic image illustrating hydrous RuO<sub>2</sub> coated on pristine RuO<sub>2</sub> nanofibers. [Journal of Materials Chemistry Vol. 20, 8972, 2010, Front Cover Image]

*This result demonstrates that superior long-term electrochemical stability can be achieved with a hybrid electrode, i.e., composed of a crystalline RuO<sub>2</sub> core/hydrous RuO<sub>2</sub> shell.*

The highly conducting ( $\sigma = 288 \text{ S/cm}$ ) fiber mats were used as the basis of a hybrid electrochemical capacitor in which the fiber mats served as the conducting core for electrochemically deposited hydrate  $\text{RuO}_2 \cdot n\text{H}_2\text{O}$  over-layers. These electrochemical capacitors exhibited superior characteristics: a high specific capacitance of  $\sim 886.9 \text{ F g}^{-1}$  (based on the mass of the hydrous  $\text{RuO}_2$  coating layer) at a scan rate of  $10 \text{ mV/sec}$  and high rate capability with a capacity loss of only 30% from 10 to 2000  $\text{mV/sec}$ . In particular, after 20,000 and 30,000 cycles of operation, the hybrid electrode of crystalline  $\text{RuO}_2$  core/hydrous  $\text{RuO}_2$  shell maintained 87.2% and 78.9% of its original capacitance, respectively. No significant difference of the electrode morphology before or after cycling was obtained in the case of hydrous  $\text{RuO}_2$  coated  $\text{RuO}_2$  fiber electrodes while the diameter of fibers was increased [see Fig. 5]. This result demonstrates that superior long-term electrochemical stability can be achieved with a hybrid electrode, i.e., composed of a crystalline  $\text{RuO}_2$  core/hydrous  $\text{RuO}_2$  shell. This is attributed to the superior electron transport pathways provided by the fiber mat core to the upper ionically-conducting hydrous  $\text{RuO}_2$  coating layer. From the present findings, potential contributions of these metallic  $\text{RuO}_2$  nanofibers to applications in electrochemical capacitors can be envisioned.

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**FIGURE 5.** Specific capacitance as a function of cycle number for hydrous  $\text{RuO}_2$  coated  $\text{RuO}_2$  fiber mats (scan rate  $\sim 300 \text{ mVs}^{-1}$ ). The inset shows morphological evolution after 33,000 cycling test

# T

## he World Focuses on KIST-Developed Robots



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*In its November 22, 2010, issue, TIME magazine selected the English Teaching Robot, developed by KIST's Center for Intelligent Robotics, as one of the 50 Best Inventions of 2010. The following article describes not only how the English Teaching Robot attracted world-wide attention, as evidenced by its inclusion in TIME, but also our experience to date in running R-learning classes. This article will also highlight another robotic model developed by KIST, designed to help humans in various ways, particularly the elderly.*

*KIST, with the support of the Korean Ministry of Knowledge and Economy, has been working on the development of the English Teaching Robot through a number of pilot projects and continuous assessment. This robot is expected to be a leading product for Korea in the burgeoning robotics business market, and as such, contribute to the future economic growth of the country.*

### Introduction

The English Teaching Robot, developed by the Center for Intelligent Robotics at KIST, was selected as one of the 50 Best Inventions of 2010 by TIME magazine. TIME described the robot by saying,

*Call it the job terminator. South Korea, which employs some 30,000 foreigners to teach English, has plans for a new addition to its language classrooms: the English-speaking robot. Students in a few schools started learning English from the robo-teachers late last year; by the end of this year, the government hopes to have them in 18 more schools. The brightly colored, squat androids are part of an effort to keep South Korean students competitive in English. Not surprisingly, the proposal has worried a few human teachers and with good reason. Experts say the bots could eventually phase out flesh-and-blood foreign English teachers altogether.*

The selection by TIME focused world attention on the Korean-developed English Teaching Robot. Even before then, however, it had been reported on by *The New York Times* as well as CNN. In an article published



FIGURE 1. TIME cover and article



FIGURE 2. Students with English TeachingRobot

### Exacting Teaching Machine Sticks to the Script in South Korea

**By CHOI SANG-HUN**  
 SEOUL, South Korea — Carefully trained by a government lab, she is the latest and perhaps most innovative recruit in South Korea's obsessive drive to teach its children the global language of English.  
 Over the years, this country has imported thousands of American, Canadian, South African and others to supplement local teachers of English. But the program has strained the government's budget, and it is increasingly difficult to get native English speakers to live on islands and other remote areas.  
 Enter Engkey, a teacher with exacting standards and a silicon voice. She is just a little penguin-shaped robot, but both symbolically and practically, she stands for progress, achievement and national pride. What she does not stand for, however, is bad pronunciation.  
 "Not good this time!" Engkey admonished a sixth grader as he snipped awkwardly over her. "You need to focus more on your accent. Let's try again."  
 Engkey, a contraction of English (on its disc jockey), is the great hope of Choi Man-suk, a team leader at the Korea Institute of Science and Technology's Center for Intelligent Robotics. "In three to five years, Engkey will mature enough to replace native speakers," he said.  
 Dr. Choi's team recently demonstrated Engkey's interactions with four sixth graders from Seoul who had met the robot. Engkey tracked a student around the room, wheeled to a step a few away, and extended a greeting in a synthesized female voice. (Although a male voice is also available, Dr. Choi says the female model seems more effective in teaching.) She then led the boy to a shelf stacked with plastic fruit.  
 "How can I help you today?" Engkey said.  
 "Do you have any fruits on sale?" the student said.  
 "Now? Very good!" Engkey exhibited. She sounded a fanfare, spun and raised her left arm for a high-five. A screen on her chest showed stars grading the student.  
 The students were amazed.  
 "It's cool — a machine hearing and responding to me," said Yang Ui-ryeol.  
 "There seems to be a life inside it."  
 Still, Engkey has a long way to go to fulfill her creators' dream. The robot can help students practice only scripted conversations and is at a loss if a student veers off script, as Yang did during the demonstration.  
 "I love you," the boy said to appease Engkey after he was chastised for a bad pronunciation. Engkey would have none of it; it was not in her programmed script.  
 "You need to work on your accent," the robot repeated.  
 When Yang said, "I don't like apples" instead of "I love apples," as he was supposed to, Engkey froze. The boy pointed her and said, "Hello, are you alive or dead?"  
 The trials and errors at the Korea Institute, a wooded top-security compound for the country's best scientific minds, represent South Korea's ambitious robotic dreams.  
 Last month, it announced a trial service for 11 types of intelligent robots this year. They include "kiosk robots" in room amusement parks selling tickets, and "robo soldiers" that will meet part of the 135-mile border with North Korea with a never-sleeping camera eye, night vision and lethal fire power.  
 But the most notable step was this country's plans to use robots as teaching aids. In February, the Education Ministry began deploying hundreds of them as part of a plan to equip all the nation's 8,600 kindergartens with robots by 2015.  
 One type of robot, toddler-size with a domed head and hoolie body on wheels, takes attendance, reads fairy tales and sings songs with children. A smaller puppy robot helps hands gymnastics and flashes red eyes if touched too roughly.  
 Even though they are little more than fancy toys, experts say, these robots prepare children for a fast-upgrading robotic future.  
 Early this year, when the institute did an experimental run of Engkey in Masan on the south coast, there was a mad rush among children to be selected for the program, said Kim Bo-yeong, an English teacher.  
 "They all loved robots. They get shy before a foreign native speaker, afraid to make mistakes," Mr. Kim said. "But they find robots much easier to talk to."  
 An independent evaluator of the trial noted that Engkey required the constant presence of a technical operator. "Engkey has a long way to go if it wants to avoid becoming an expensive yet ignored heap of scrap metal at the corner of the classroom," said Kim Jaechan, an education professor at Chungnam National University.  
 Dr. Choi knows the challenge. After tests in more schools this winter, he hopes to commercialize Engkey and to reduce the price, currently \$20,000 to \$32,000, to below \$8,000.  
 Dr. Choi said his team was racing to improve the robot's ability to recognize students and to discern and respond to a student's voice and noise. It is also cranking Engkey's more conversational features.  
 For now, though, Engkey's limits quickly become apparent. Hana Yoo, who participated in the recent demonstration, said, "Engkey is fun. But she is not human. Repeating the same dialogue is what she does. I wish she would become more expressive and responsive, like a human teacher."



FIGURE 3. Article from NYT



FIGURE 4. Article from CNN

on July 10, 2010, and devoted exclusively to KIST's teaching robot, *The New York Times* described its use in the actual classroom. The coverage was similar to that of other teaching robots developed at other top-class robotic research institutes worldwide such as the University of California-San Diego, Georgia Tech and the University of Southern California.

In its reporting, CNN covered details of robotic teaching in Korea, which resulted in further foreign press coverage of the Korean robot. These foreign press reports subsequently led to the selection of KIST's teaching robot by TIME.

After a public demonstration of the English Teaching Robot and its selection as one of the 50 Best Inventions of 2010, the international press continued its coverage. Table 1 lists the main articles published by the foreign press.

### 2. English Teaching Robot

KIST's English Teaching Robot is designed to teach various curricula. The idea for utilizing a robot as a practical method for education stemmed from policies developed by the Korean Ministry of Knowledge and Economy and Ministry of Education, Science and Technology. These policies were based on the promotion of public education and the need to reduce the English education gap among different regions in Korea. It was thought that the English Teaching Robot could serve as a substitute for native teachers at schools where it is difficult to attract native teachers because the schools are located far from metropolitan areas. In fact, there are few native teachers in the provinces as compared to metropolitan areas.

There are certain advantages in applying a robot to actual English education. For example, the robot allows students to hear native speech (especially pronunciation) and can also increase student interest and focus in English class since it can seem more friendly to students who are sometimes afraid of interacting with a native teacher.

As to content associated with R-learning, we are trying to find ways to cover the whole gamut of English curricula, including instruction geared to the TOEIC and TOEFL exams, individualized instruction through private lessons or telecommunication with a native teacher via a robot channel for Koreans worldwide who would like to learn English.

The goals of the English Teaching Robot project are threefold. The first goal is to realize a telepresence-type robot which can be controlled remotely by native teachers in English-speaking countries and reach eight students in a classroom at a time. This is like having a native teacher actually present in the classroom because he or she can provide students with the

- S.Korea schools get robot English teachers [AFP   Dec. 27, 2010]
- "S.Korea trials remote-controlled teaching robots" [ABC Online   Dec. 28, 2010]
- Hello, Mr Chips: Bots Teaching English in Korean Schools [AOL, US   Dec. 28, 2010]
- Robots teach South Korean school children [ABC Radio, Australia   Dec. 29, 2010]
- Hi, I'm Robo-teacher: Droids with human faces wheeled into class to teach English [Daily News, British   Dec. 28, 2010]

TABLE 1. Main articles from foreign press

English lesson in real time by controlling the robot even though he or she is actually far from Korea. Our intention is that students at some schools who have had no experience with native teachers will benefit from this type of “direct” contact with a native speaker. In the near future this robotically-enhanced communication can narrow the gaps in English education between metropolitan areas and provinces in Korea, and has the additional benefit of providing a new product for the global robotics market.

To achieve this goal, we need to make sure there is a unity between the native teacher and the robot so that students can concentrate and be fully immersed in the teaching process. We are attempting to achieve this unity by developing easy and real-time control of the robot’s various activities and expressions by a native teacher as if the robot were the teacher’s avatar. If successful, Korean R-learning in business and industry will ensure that Korea is technologically competitive on a global scale. A telepresence robot can also cut the cost of telecommunication with native speakers and systematize the entire installation process of the robot, infrastructure and environment.

The second goal of this project is to develop a robot which can respond to, direct expression and even move toward a recognized student by means of HR-i (Human-Robot Interaction) and situation-recognition. This goal revolves around the development of core robotic technologies which would be crucial for any robot whose role is to assist humans. In order to develop a kind of avatar robot for the native teacher, interaction should be possible between them; for example, the robot must be able to express the native teacher’s emotion in real-time and handle the situation by responding and moving freely by swift command-recognition given by the native teacher. Also, the robot needs to appropriately respond to students in the classroom by recognizing them and the environment.

Our final goal is to develop an assistant robot for a Korean English teacher. Obviously, this final goal overlaps to a considerable degree with our previous efforts. A robot assistant can supplement educational content in an interesting way through conversation, practice with pronunciation, songs and games. Korean English teachers usually provide students with these activities, but the robot can improve learning effectiveness, particularly in pronunciation and conversation, because these are areas in which Korean English teachers are often less adept. For this goal it is also important to develop specialized English learning content adapted to R-learning.

### **3. Types of Teaching Robot**

There are two types of teaching robot currently envisioned. The first one is the telepresence type in which a native instructor teaches a remote class by controlling the robot. The second is the autonomous type in which the robot supports a Korean English teacher by providing students with English-language activities such as conversation practice, vocabulary and sentence building, learning songs and rhymes, and working on puzzles.

- Conversation practice (Role Playing): For example, in an imaginary supermarket the robot plays a clerk and the student plays a customer and they talk to each other with a conversational scenario related to buying and selling.
- Practice with vocabulary and sentence building: The robot first lets students hear a word or sentence and has them repeat it. The robot then gives marks on a student’s pronunciation after accurate voice-recognition.
- Songs and rhymes: The robot makes students memorize an English song or rhyme and sing or recite repeatedly.
- English puzzle game: This is for practice with words and sentences where a student inserts an appropriate

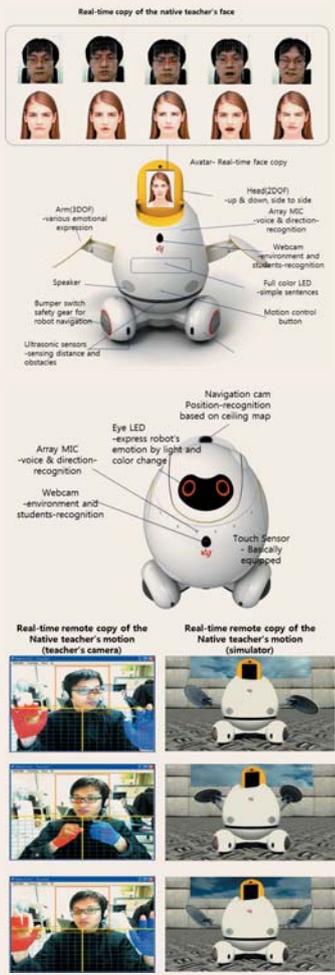


FIGURE 5. Main functions and specifications of ENGKEY

word in the sentence.

In the case of a telepresence-type robot, there is a camera on the front of the robot's body which enables the native teacher to recognize students and the environment of the classroom. The native teacher is provided with an interface screen which can control the robot and enable it to move where the native teacher wants. A capture and follow program is installed which enables the native teacher's motions, gestures and even lip movements to be mimicked by the robot in real time as if the native teacher and robot were working together in one body.

The autonomous-type robot needs to incorporate a lot of core technologies, especially human-robot interaction. This involves accurate location-recognition, human-tracking technology to enable the robot to move in front of a student after recognizing him/her (vision, voice-recognition, sound ranging, etc.), voice-recognition for a student's pronunciation exam, technology for reflecting a robot's emotional expression, and so on. The technologies enabling the autonomous-type robot to perform its tasks have already been developed to some degree and are already bringing competitive success to Korea in global markets. Further refinements are underway at KIST as well as other institutes and universities in Korea. These technologies are also being applied to industrial fields like the automotive, mobile phone and electrical appliance industries.

Figure 5 illustrates the main functions and core technologies applied to the teaching robot

4. Pilot projects in schools

A pilot project testing the English Teaching Robot is currently in progress, the second of its kind. Since the beginning of this project on Dec. 27, 2010, a total of 29 robots have been in use at 29 English classrooms in 21 primary schools in Daegu city. The pilot project is scheduled to last about 3 months, ending by March. 31, 2011.

The pilot project classes consist of two types: those testing the telepresence type (main class) and those testing the autonomous type (review class). Curricula and the detailed contents of the classes are indicated on Table 2, while Table 3 reflects the timetable of the R-learning based English Class.

It was decided to introduce the English Teaching Robots to the public for the first time in December of 2009. At that time, the Center for Intelligent Robotics at KIST was working on the world's first English teaching robot project under the joint auspices of the Ministry of Knowledge and Economy and Changwon city, and supplied a total of four robots to Happo Primary School and Hogye Primary School in Changwon city. The primary objective of this project from the standpoint of Korean government policy was to promote

TABLE 2. Curricula

Frequency/ Capacity	3 hours a day X 2 classes (Basic 8 students, Intermediate 8 students) / Total 48 students
Class type	<ul style="list-style-type: none"> <li>■ <b>Telepresence-type class (Main): 3 times a week (Mon. Tue. Fri)</b> <ul style="list-style-type: none"> <li>- Remote lesson by a native teacher using the avatar robot</li> <li>- Textbook provided, Basic/ Intermediate (8 students for each class)</li> </ul> </li> <li>■ <b>Autonomous-type class (Review): 1 time a week (Wed. Thu)</b> <ul style="list-style-type: none"> <li>- Practice pronunciation, role-playing (dialogues), songs &amp; rhymes, English puzzle game</li> <li>- Basic/ Intermediate (4 students in each class)</li> </ul> </li> </ul> <p>* 8 students in main class are grouped into 2 groups consisting of 4 students each; each group can select Wed or Thu for their review lesson</p>



**ENGKEY (Old version)** Autonomous Type



**MERO** Preparation and pronunciation practice



**TELEPRESENCE TYPE** Remote Video with Native Teacher

**FIGURE 6.** Robots used in the 1<sup>st</sup> pilot project

**TABLE 3.** Timetable

Hour	Mon [Telepresence]	Tue [Telepresence]	Wed [Autonomous]	Thu [Autonomous]	Fri [Telepresence]
1 <sup>st</sup>	Basic (8 students) Intermediate (8 students)	Basic (8 students) Intermediate (8 students)	A Group (4 Students)	B Group (4 Students)	Basic (8 students) Intermediate (8 students)
2 <sup>nd</sup>	Basic (8 students) Intermediate (8 students)	Basic (8 students) Intermediate (8 students)	A Group (4 Students)	B Group (4 Students)	Basic (8 students) Intermediate (8 students)
3 <sup>rd</sup>	Basic (8 students) Intermediate (8 students)	Basic (8 students) Intermediate (8 students)	A Group (4 Students)	B Group (4 Students)	Basic (8 students) Intermediate (8 students)
Content	Unit 1	Unit 2	Review Lesson: Pronunciation practice (15 min.) / Role- playing (10min.) / Songs (10min.) / English Puzzle Game (15min.)		Special Lesson

public education and improve the effectiveness of English classes using robots in place of native teachers. The project continued for eight weeks and received favorable reviews from students, parents and Korean English teachers at the schools who actually used the robots as assistants in English classes. Reaction was so favorable that a second project was conceived for testing the English Teaching Robot.

In the first pilot project three types of R-learning based classes were used. The first one used an autonomous-type of robot in the main class, but for review classes which involved practicing words and sentences, a face robot named “MERO” was used. The final class used a telepresence-type of robot in the main class in which a native teacher, whose face showed up in the LCD screen on the robot’s head, controlled the robot remotely.

Careful analysis of the first project resulted in certain refinements when the second pilot project in Daegu city was planned. The telepresence type was found to be more effective and interesting to students during the first pilot project; therefore, this type of robot was used in the main class while the autonomous type was applied to the review class. Another significant change was that one robot platform was used for both types of robots.

The three types of robots are shown in Figure 6. The face robot MERO was featured in the TIME article.

### 5. Silver-Mate Robot

The English Teaching Robot can be modified to perform various types of human assistant functions. KIST’s Center for Intelligent Robotics has already developed the Silver-Mate Robot, a friendly robot to assist the elderly. To date, however, the Silver-Mate Robot has not captured media attention the way the English Teaching Robot has.

We have already successfully completed the first pilot project involving the Silver-Mate Robot at an elderly care center in Changwon city, and we plan on running a second project with the Korean Ministry of Health and Welfare. True to its name, the Silver-Mate Robot is designed to assist the elderly as a supportive companion would, offering cognitive stimulation through games and other means to improve memory and awareness and providing important information for daily living such as weather alerts, appointment reminders, financial and health information, etc.

In many countries, governments are struggling with issues related to rapidly aging populations. This is particularly true in Korea where the government is actively preparing for future public welfare. The Silver-Mate Robot is seen as one solution for coping with the needs of an aging population. It is equipped with informative programs for keeping track of practical and health information which will be very beneficial in nursing homes and elderly care centers. It also provides elderly people with a variety of lessons and cognitive games that may help prevent Alzheimer's disease and other forms of dementia by strengthening memory and awareness.

## 6. Conclusion

The robots developed at KIST are highly adaptable as human assistants in the areas of education, elderly care, guidance, home service, etc. As we continue to undertake pilot projects, such as the second project involving the Silver-Mate Robot scheduled for this year, further refinements and adaptations are expected to demonstrate beyond a doubt the usefulness of robotic human assistants in many situations. Plans are in place for the Center for Intelligent Robotics to supply English Teaching Robots to 100 schools and private institutions in Korea, and discussions are already underway with a number of foreign countries with rapidly aging populations to supply robots to assist in this area. Work will continue as well to refine the capacity of robotic assistants to serve as smart and informative guides at public sites. The range of helpful functions that could be within the capacity of human assistant robots will continue to expand with our ongoing research and promises to be a particularly exciting prospect for the future.

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**FIGURE 7.** First pilot project for Silver-Mate Robot in Changwon city, May, 2010



Opening Ceremony



Cognitive Game with MERO



English Lesson by ENGKEY

# A pplications of Nano- and Meso-scale Materials for Water/Wastewater Purification



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## Introduction

Human activities such as industrial manufacturing processes, fossil fuel combustion in power plants, and use of household chemicals (e.g., detergents, plastics, and garden pesticides) have caused contamination in aquatic environments when wastewaters associated with these activities, consisting of various organic and inorganic substances, are released. Some organic compounds in wastewater, including chlorinated and aromatic hydrocarbons, are very persistent in natural and artificial chemical/biological processes, thereby posing severe threats to human and environmental health. Heavy metals present in the effluents also induce adverse biological effects in natural waters because they cannot be metabolized in the human body and therefore, become more hazardous as they bio-accumulate. The anthropogenic generation of some inorganic chemical species, such as nitrates and phosphates, can lead to deterioration of water quality by causing an excessive increase of phytoplankton in a water body, i.e. eutrophication.

Since conventional technologies have failed to effectively mitigate emerging aquatic pollution caused by organic/inorganic chemicals, efforts have continued to develop alternative technologies which address degradation/detoxification issues, provide excellent versatility in application media, and exhibit cost-effectiveness. As potential strategies to remediate aquatic environments contaminated with recalcitrant chemicals, we here suggest environmental applications of new organic/inorganic nano- and meso-structured materials, which include use of a renewable organic nanocatalyst for selective BTEX (benzene, toluene, ethylbenzene, and xylene) trapping, mesoporous functionalized silica and titania for phosphorous removal and recovery, and a (modified) titania photocatalyst for chlorinated organic pollutants.

## 1. Renewable organic nano-catalyst particles for selective trapping of BTEX

A variety of approaches, including adsorption, biodegradation, chemical oxidation, incineration, and membrane filtration, have been extensively explored to achieve efficient removal of potential organic pollutants in water. Among such remediation technologies, adsorption processes using activated carbons, synthetic zeolites, and natural minerals (1) have been considered more effective strategies in terms of practical application and cost-effectiveness. Due to its extraordinary adsorptivity for toxic organics and facile chemical modification to improve adsorption efficacy, activated carbon has been widely used as an adsorbent in water treatment processes. However, powdered activated carbons are hard to separate from treated effluents (2). Chemical and thermal treatments for regeneration of exhausted carbon adsorbents are expensive and entail loss of carbons in considerable amounts. On the other hand, polymer materials have demonstrated superiority as adsorbents in water remediation processes in that they are readily regenerated through washing with chemical solutions (e.g., acid and alkali) under ambi-

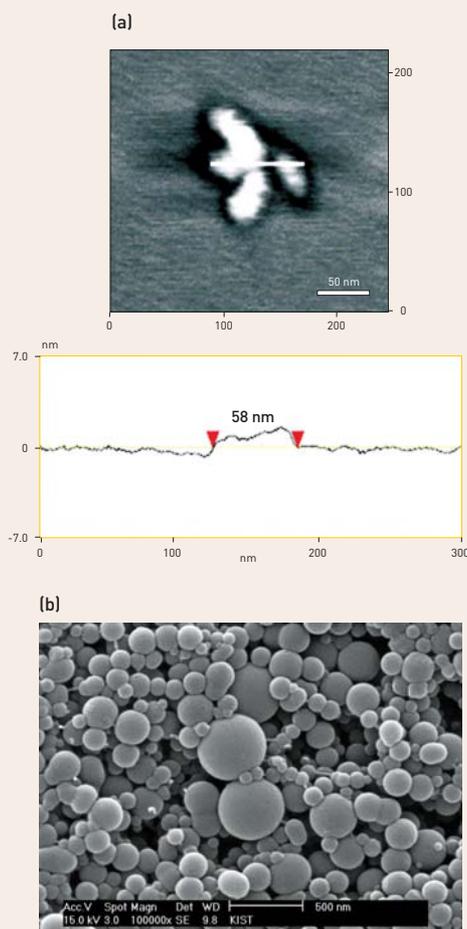


FIGURE 1. (a) AFM height images of the BK core PNIPAM grafted star polymers, (b) porphyrin-CTA (Initiator) with photosensitizer

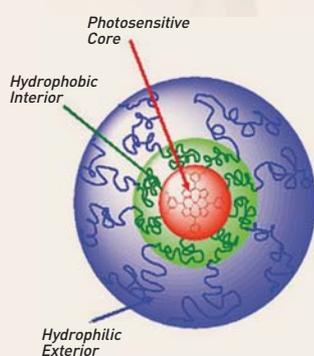


FIGURE 2. Schematic diagram of star polymer

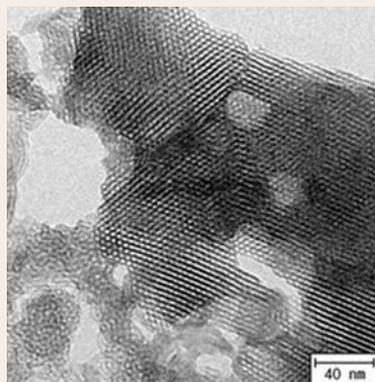


FIGURE 3. Transmission microscopic image of functionalized meso-porous silica

ent conditions [3].

In research at KIST, we synthesized polystyrene-block-poly (N-isopropylacrylamide) (PSN), which contains the structure of a hydrophobic core and hydrophilic shell, and applied it as an adsorbent for BTEX (benzene, toluene, ethylbenzene, and xylenes) pollutants in an aquatic environment (Figure 1). This novel adsorbent takes the form of a micelle as a unit molecule when discharged into aqueous media. The core-organic complexes offer hydrophobic binding sites for adsorption of organic pollutants, suggesting a promising application of PSN for adsorption processes.

In addition, we have synthesized star polymer using an “arm first” approach in which linear polymer arms are first grown to the desired length, being crosslinked together on adding a difunctional monomer to the polymerization mixture. Use of a singlet oxygen ( $^1O_2$ ) photosensitizer as the core of the star polymer enables encapsulation of organic pollutants in the star polymer and subsequent in situ photochemical oxidation in the interior phase (Figure 2). As a candidate material for the core, metalloporphyrins (with Pt or Pd as a central metal) at a ground state readily excite to the singlet state under visible light irradiation, subsequently converting to the triplet state via intersystem crossing. The photo-excited triplet state transfers excess photon energy to triplet-state oxygen, leading to production of singlet oxygen as a strong oxidant. The high quantum yield for intersystem crossing and long lifetime of the triplet state combined are responsible for the excellent activity of the porphyrins for photosensitized  $^1O_2$  production. We modified the photoactive metalloporphyrins by chemically introducing multiple functional groups at the periphery. The resultant derivatives were readily incorporated in the core of star polymer. The synthesized metalloporphyrin incorporated to make the star polymer was found effective for photochemical oxidation of organic pollutants in the vicinity of the photosensitizer, which were first captured and concentrated in the interior of the polymer.

## 2. Removal and recovery of phosphorus in wastewater using mesoporous materials

Phosphorous (P) is a key component of cell membranes, thereby functioning as an essential element for all living cells. Phosphorous is mainly used in the production of fertilizer for agricultural activities, but also in the syntheses of explosives, pesticides, and detergents. The high reactivity renders phosphorous not found as a free and mobile form, but incorporated in other chemical substances in diverse forms. Although inorganic forms of phosphorous have no toxicity, the presence of phosphorous at high concentration in natural water causes serious eutrophication in lakes, bays, and inland seas [4], eventually aggravating water pollution and inducing hazardous effects on human and environmental health.

Current technologies for phosphorous removal, which aim to alleviate eutrophication in

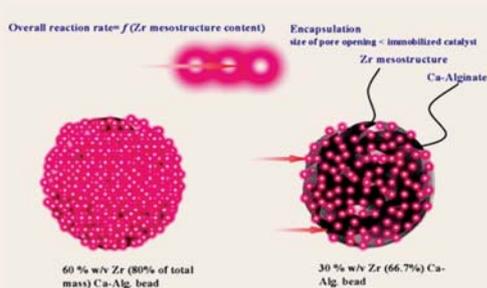
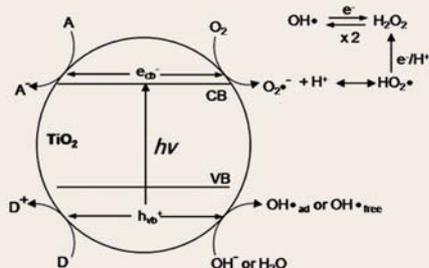


FIGURE 4. Immobilization of mesostructure in alginate beads for removal of phosphorous



SCHEME 1. Photo-induced redox reactions and generation of reactive oxygen species occurring on the surface of  $\text{TiO}_2$  photocatalyst

aquatic environments, include physical processes (e.g., settling, filtration), chemical precipitation (using aluminium, calcium, and iron) (5), and biological processes (using bacteria and algae) (6). Chemical precipitation is not a cost-effective process and generates sludge in large quantities. Biological processes require a very careful operation. On the other hand, adsorption processes offer superior strategies for phosphorous removal due to their operative simplicity, reduced sludge production, phosphorous recovery potential, and cost-effectiveness. A variety of adsorbents have been developed for the removal of phosphorous, including aluminum oxide, zirconium oxide, hydrotalcite, ion exchange resins, clay minerals, and activated alumina (7).

Kresge et al first discovered ordered mesostructure materials in 1992 (8). Meso-structured materials prepared through molecular self-assembly of surfactants have various applications due to their unique pore characteristics. Initial efforts to create mesoporous inorganic materials were mainly focused on fabrication of mesoporous silica, which provided the fundamental basis for a variety of approaches to synthesize meso-structured metal oxides afterwards. Inorganic mesoporous materials, recently developed by Mobil Oil Corporation, have been utilized as adsorbent materials with high adsorption capacity (9).

The physical and chemical properties of silica-based mesoporous materials have been recently improved via surface modification with organic functional groups, resulting in greater multi-functionality and expanded relevant applications. The chemical anchoring of such groups to mesoporous materials is carried out via post-synthetic grafting or co-condensation. The functionalized mesoporous inorganic materials have been found to be superior as adsorbent materials due to their highly ordered hexagonal structure, thermal stability, and dense walls, compared with MCM-41 materials (Figure 3).

Our studies found that a zirconium mesostructure with high surface area showed several times higher performance in phosphorous adsorption than other commercial adsorbents (Figure 4). However, a zirconium-based mesostructure is not likely appropriate for practical use because of its high cost. However, functionalized silica and titania displayed the identical chemical affinity toward phosphorous as zirconium, indicating their potential as a proxy for zirconium adsorbent. Functionalized silica and titania, which are more cost-effective materials, also offered better meso-structured networks than zirconium as measured by durability, chemical stability, and wall density.

### 3. Use of $\text{TiO}_2$ -based photocatalysts for dye bleaching and oxidation of chlorinated pollutants

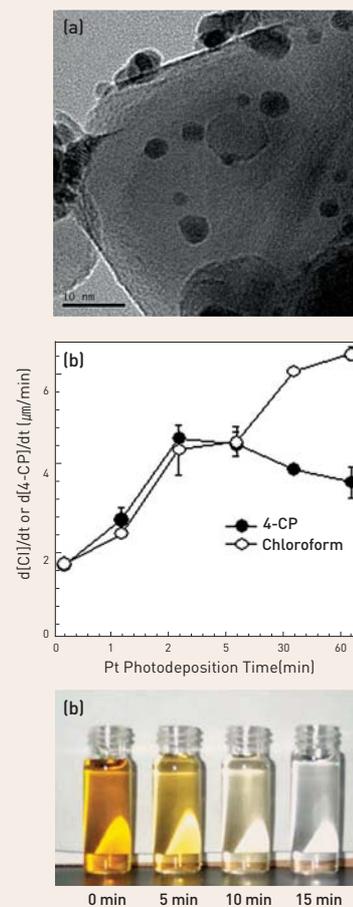
The photocatalytic activity of  $\text{TiO}_2$  has increasingly attracted scientific attention in diverse science and engineering sectors due to its capability in converting (solar) photon energy to induce a variety of reduction and oxidation (redox) reactions (10-12). On absorbing incident photonic energy which exceeds the band-gap energy (3.2 eV),  $\text{TiO}_2$  excites to produce a pair of conduction band electron and valence band holes. In parallel with the recombination process in which the charge carriers recombine with heat release, the electron-hole pair migrates to the surface and undergoes interfacial charge transfer, eventually causing a variety of redox reactions on the surface. Of particular note is that such photo-induced charge formation and subsequent chemical redox reactions initiating on the  $\text{TiO}_2$  surface result in reductive and oxidative degradation of

organic contaminants, reductive detoxification of heavy metals, and ROS (reactive oxygen species)-induced bacterial/virus inactivation [11, 12].

Scheme 1 shows TiO<sub>2</sub>-mediated redox reaction pathways and the mechanisms for photochemical ROS production occurring on the surface of TiO<sub>2</sub>. A CB electron migrated to the surface has mild reducing power to convert heavy metals to low oxidation states and degrade highly chlorinated pollutants and nitroaromatics in a reductive way. In order to maintain the electroneutrality of TiO<sub>2</sub>, a VB hole concurrently drives oxidative degradation of organic contaminants (less vulnerable to H abstraction) via direct charge transfer on the surface of TiO<sub>2</sub>. Due to the strong oxidation potential, VB holes can oxidize surface hydroxyl groups and adsorbed water molecules to surface-bound and freely mobile OH radicals, which play a critical role in non-selective and kinetically diffusion-limited oxidation of organic contaminants in water. The consecutive transfer of CB electrons to dissolved oxygen offers an alternative pathway to generate OH radicals with collateral formation of superoxide radical (O<sub>2</sub><sup>•-</sup>) and hydrogen peroxide. The TiO<sub>2</sub> photocatalysis capable of effective production of OH radicals is classified as one of the promising advanced oxidation processes (AOPs) which are environmental remediation strategies to achieve decontamination via in situ ROS generation within the polluted environmental matrices.

As an effective strategy for degrading emerging contaminants in water, we have carried out photocatalytic degradation of endocrine disruptors (e.g., pentachlorophenol) and pharmaceuticals (e.g., ranitidine, propranolol) in aqueous TiO<sub>2</sub> suspensions under artificial UV and natural solar light irradiations. To explore the mechanisms for oxidative degradation of emerging contaminants, mass spectroscopic techniques such as LC/MS were used to identify the photogenerated intermediates and products. Toxicity tests with treated water showed that TiO<sub>2</sub> photocatalysis achieves both pollutant degradation and detoxification in an oxidative way. In particular, compared to homogeneous AOPs, it is expected that TiO<sub>2</sub>-mediated photocatalytic oxidation favors mineralization of emerging contaminants having aromatic moieties to CO<sub>2</sub> and H<sub>2</sub>O. In an effort to enable kinetic enhancement in TiO<sub>2</sub>-mediated photocatalytic degradation, we plan to employ a variety of TiO<sub>2</sub> surface modification techniques which include metallization, silica-loading, and fluorination. In order to improve efficacy in photo-induced oxidation of pharmaceuticals, we are currently focused on the platinumized TiO<sub>2</sub> photocatalyst among surface-modified ones. Deposition of nanosized platinum particles on a TiO<sub>2</sub> surface (TEM image in Figure 5a) accelerates photocatalytic redox reactions by trapping CB electrons as an electron reservoir (leading to drastic retardation in charge recombination) and facilitating interfacial electron transfer to reducible chemical species. Figure 5b shows that surface platinumization of TiO<sub>2</sub> drastically enhances oxidative degradation of chloroform and 4-chlorophenol under UV-illuminated conditions.

Decolorization of azo dyes, which are known to be recalcitrant toward conventional remediation processes, was successfully achieved using bare TiO<sub>2</sub> with artificial UV-C light. Diverse salts at excess concentration, which remain in dyestuff wastewater effluent released from textile dyeing processes, do not significantly interfere with TiO<sub>2</sub> photocatalytic oxidation of azo dyes. The kinetics for dye decolorization do not vary sensitively depending on the kinds of target dyes, which non-selective reactivity of oxidizing species generated during TiO<sub>2</sub> photocatalysis is responsible for. To save the input energy for TiO<sub>2</sub> photoactivation and create a more cost-effective remediation system, we currently plan to employ a visible-light-responsive photocatalytic



**FIGURE 5.** (a) Nanoscale platinum loaded on TiO<sub>2</sub> photocatalyst via photodeposition method, (b) Initial rates for photocatalytic oxidation of 4-chlorophenol and chlorine evolution as a result of photocatalytic degradation of chloroform

system based on a dye sensitization process in which dyes excite with visible light to inject electrons to the CB of  $\text{TiO}_2$  with dyes themselves oxidized.

#### Closing remarks

Our research so far has been focused on syntheses of various inorganic and organic materials and analysis of their effectiveness for contaminant degradation and removal in aqueous media. As described above, the developed materials have been successfully applied and have demonstrated superior performance compared to conventional adsorbents and (photo)catalysts, thereby confirming the benefits of new nano- and meso-structured materials in environmental remediation. As creation of novel nano- and meso-structured materials continues to make a great impact in diverse science and industry sectors, we are certain that our efforts to develop new materials will open a door to new water remediation technologies capable of effectively addressing emerging concerns about aquatic contamination.

*Our research so far has been focused on syntheses of various inorganic and organic materials and analysis of their effectiveness for contaminant degradation and removal in aqueous media.*

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## Oncology Kinase Drug Discovery Research at KIST



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The protein kinase family enzyme is critical to the proliferation, differentiation, survival, migration, and invasion of a cell and is one of the most important commanders for controlling the signal transduction system within an organism. A protein kinase is responsible for phosphorylating other cellular proteins by chemically transferring a gamma-phosphate group of ATP (Adenosine 5'-triphosphate) to a hydroxyl group positioned in the tyrosine or serine/threonine residue of the protein. This protein phosphorylation event triggers change in protein functions, such as enzyme activity, cellular location, or association with other proteins, and eventually results in cellular signal transduction. 518 kinds of human protein kinases have been identified or proposed so far, which corresponds to about 1.7% of all human genes. Protein kinases can be classified into two categories: tyrosine protein kinase (consisting of over 90 members) and serine/threonine protein kinase. The tyrosine protein kinase can be classified into 20 subfamilies, composed of 58 kinds which are receptor tyrosine kinases, and 10 subfamilies composed of 32 kinds that belong to cytoplasm/non-receptor tyrosine kinases.[1] The extracellular domain of the receptor tyrosine kinases, including EGFR (epidermal growth factor receptor) and VEGFR (vascular endothelial growth factor receptor), can accommodate their ligands, which affect growth, and their kinase domain, located in a cytoplasm, can phosphorylate specific tyrosines. Once a ligand binds to the extracellular domain of a receptor tyrosine kinase, the receptor tyrosine kinase is activated and specific tyrosines in the cytoplasm domain become autophosphorylated. In turn, signaling progresses through the successive phosphorylation of downstream proteins in the cytoplasm and nucleus.

As mentioned above, the protein kinase family of the human genome (kinome) is critical to the regulation of cellular signal transductions. The signal transduction system in a living cell must turn on and off correctly and smoothly in order to maintain homeostasis in an organism. Aberrant activation and dysregulation of certain protein kinases caused by mutation and over-expression have been implicated in a broad spectrum of human diseases such as cancer, inflammation, metabolic disease and brain disorders. Protein kinase inhibitors can suppress increased phosphorylating activity of over-activated protein kinases. Protein kinases are, therefore, one of the most important molecular targets for therapeutic intervention in cancer, inflammatory disease, autoimmune disorders and so forth. Among 518 protein kinases, approximately 30 kinases have been targeted for drug discovery, and over 80 protein kinase inhibitors are known to be undergoing human clinical evaluations. In approaching the conquest of cancer, one of the most effective strategies has been to identify selective and potent small molecule inhibitors against oncogenic protein kinases. Kinomics is an emerging and promising approach for deciphering kinomes. Chemical kinomics is a discipline of chemical genomics that is also referred to as "chemogenomics," which is derived from both chem-

*The protein kinase family enzyme is critical to the proliferation, differentiation, survival, migration, and invasion of a cell and is one of the most important commanders for controlling the signal transduction system within an organism.*



FIGURE 1. IRORI micro-Kan system™



FIGURE 2. Waters FractionLynx™,MassLynx™, AutoPurification system



FIGURE 3. EnVision, HTS Multi-Label Plate Reader

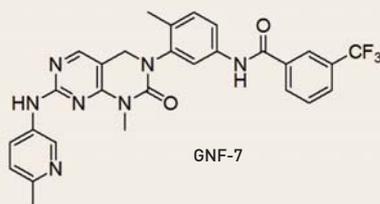


FIGURE 4. Structure of GNF-7

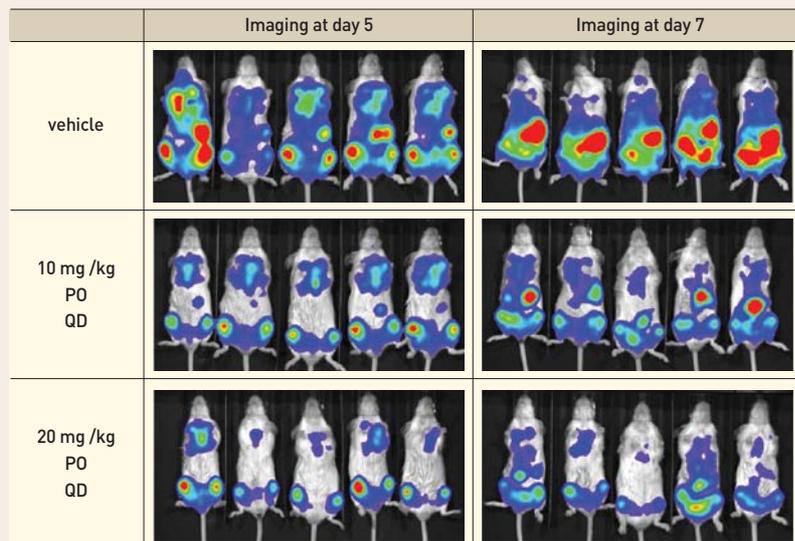
istry and biology. Chemical kinomics has become a powerful approach to decipher complicated phosphorylation-based cellular signaling networks with the aid of small molecules that modulate kinase functions.

My research group has been working on kinase drug discovery and chemical kinomics. Our kinase drug discovery program is focused on the identification of novel small molecule kinase inhibitors, primarily with the help of Computer-Aided Drug Design (CADD). Our goal is to develop oncology kinase drugs. Our chemical kinomics program was established to identify new therapeutic molecular targets, as well as novel functions of known kinases and unique modes of action for given kinase inhibitors. The construction of a kinase-directed focused chemical library and high-throughput screening system (HTS) is necessary for running these kinase drug discovery and chemical kinomics programs. Our laboratory is equipped with an IRORI micro-Kan system™ (Fig. 1) and Waters FractionLynx™,MassLynx™, AutoPurification system for constructing an efficiently focused chemical library (Fig. 2). The IRORI micro-Kan system™ enables Split-and-Pool solid-phase combinatorial chemistry by using radio frequency tags for synthesis tracking, which makes the construction of a chemical library much more efficient compared with conventional and parallel synthesis. The Waters FractionLynx™,MassLynx™, AutoPurification system offers ultra-high throughput isolation and purification capabilities. Moreover, we perform kinase assay in a HTS format (a 384 well plate format) using an EnVision, HTS Multi-Label Plate Reader (Fig. 3).

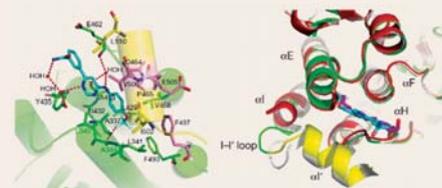
We have recently published two articles [2-3] regarding novel Bcr-Abl kinase inhibitors. These are good examples of our kinase drug discovery programs. Bcr-Abl is a tyrosine kinase and an oncogenic fused protein resulting from the combination of the c-Abl gene with Bcr (the breakpoint cluster region) gene. Bcr-Abl, a 210 kD fusion protein, causes CML (chronic myelogenous leukemia) that is a myeloproliferative disorder disease. The successful development of imatinib, a Bcr-Abl kinase inhibitor for the treatment of CML, has provided a new paradigm for the development of other small molecule kinase inhibitors targeting kinases whose activity becomes deregulated in cancer. One major problem facing imatinib is the emergence of drug resistance caused by point mutations in the Abl kinase domain. A few second-generation Bcr-Abl kinase inhibitors have been developed, including nilotinib, bosutinib, and dasatinib, that are capable of inhibiting most of the known Bcr-Abl point mutants with the exception of the so-called “gatekeeper” mutation T315I-Bcr-Abl that is the most recalcitrant Bcr-Abl point mutant. We have researched and reported on GNF-7, a new Type-II T315I-Bcr-Abl inhibitor (Fig. 4), based upon a 3,4-dihydropyrimido[4,5-d]pyrimidin-2(1H)-one scaffold which occupies the ATP binding site as well as an immediately adjacent hydrophobic pocket of the Abl kinase domain. [2]

In our studies GNF-7 strongly inhibited cellular kinase autophosphorylation of T315I-Bcr-Abl-Ba/F3 with an  $IC_{50}$  of 11 nM as well as T315I-Bcr-Abl enzyme with an  $IC_{50}$  of 61 nM. Furthermore, GNF-7 exhibited a significant *in vivo* efficacy against T315I-Bcr-Abl in the bioluminescent xenograft mouse model using a transformed T315I-Bcr-Abl-Ba/F3 cell line. As depicted in Figure 5, light emission from mice that were administered an oral dose of 10 or 20 mg/kg of GNF-7 once per day was significantly (T/C 38% and 23%, respectively) reduced compared with that from untreated control mice. [2]

Adrian and my colleagues identified a GNF-2 compound (4,6-disubstituted pyrimidine analogue) which was the first allosteric non ATP competitive Bcr-Abl kinase inhibitor. (Adrian et al., Nat. Chem. Biol., 2006, 2, 95.) GNF-2 is capable of strongly inhibiting E255V-Bcr-Abl, a



**FIGURE 5.** Bioluminescent in vivo efficacy study (oral administration, once-daily dosing) for GNF-7 using Ba/F3-T315I-Bcr-Abl cell line that has stable luciferase expression. Mice were imaged at day 5 and 7 after GNF-7 treatment. [2] / Fig. 5 comes from reference [2]

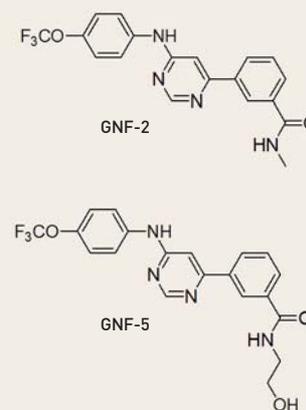


**FIGURE 6.** Crystal structure of GNF-2 bound to the Abl myristoyl pocket. [3] / Fig.6 comes from reference [3]

P-loop point mutant which causes imatinib drug resistance, but unfortunately, does not exhibit significant activity against the T315I-Bcr-Abl "gatekeeper" mutant. [4] Based on HSQC NMR analysis and X-ray crystallography work, it was found that GNF-2 binds to a myristate binding pocket located at the bottom of c-Abl kinase domain, as depicted in Figure 6. [3]

Moreover, it was reported that the combination of GNF-2 or GNF-5 with an ATP-competitive Bcr-Abl kinase inhibitor, including imatinib and nilotinib, exhibited a significant synergistic activity against both a wild-type Bcr-Abl and T315I-Bcr-Abl mutant. GNF-5 is a close GNF-2 analog possessing more improved pharmacokinetic properties compared with GNF-2, as illustrated in Figure 7.

In a T315I-Bcr-Abl bone marrow transduction/transplantation mouse model which resembles human CML disease, the combination of GNF-5 (75 mg/kg) and nilotinib (50 mg/kg) resulted in a normalization of white-blood-cell counts and spleen weights, and also significantly extended survival rates relative to those with either GNF-5 alone or nilotinib alone. [3]



**FIGURE 7.** Structure of GNF-2 and GNF-5

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# H igh Activity Pt / Pt-M Alloy Electrocatalysts for Polymer Electrolyte Membrane Fuel Cells



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*Polymer electrolyte membrane fuel cells (PEMFCs) are promising power sources for electric vehicles due to their high energy density and low pollutant emission*

## Introduction

Polymer electrolyte membrane fuel cells (PEMFCs) are promising power sources for electric vehicles due to their high energy density and low pollutant emission. Electricity is generated through electrochemical reactions at both electrodes of a PEMFC: a very fast hydrogen oxidation at the anode and a very sluggish oxygen reduction reaction (ORR) at the cathode. There are, however, some negative impacts affecting PEMFC performance, including activation overpotentials at the electrodes, ohmic resistance of the cell, and improper management of fluid dynamics of the reactants/products, with activation loss at the cathode accounting for the greatest degree of performance loss. Up to now Pt has been used as an electrocatalyst for ORR, and extensive research has been performed on the development of a high-activity Pt catalyst [1-5]. However, the expense of producing Pt catalysts and their insufficient kinetic activity toward ORR have hindered the commercialization of PEMFC. For example, a 100 kW PEMFC stack is loaded on currently available fuel cell-powered electric SUV vehicles and the stack contains about 40 to 50 g Pt, which costs about \$2,400 to \$3,000. A further restraint is that current annual Pt production can meet only 3% of worldwide vehicle market demands. For this reason, the development of highly active catalysts that can substitute for Pt is considered extremely important.

Current strategies for developing high-activity ORR catalysts are: 1) optimization of Pt catalysts [1-5]; 2) development of Pt-alloy [with transition metal] catalysts [6-12]; and 3) control of the nano shape of pure Pt or Pt alloy catalysts [13-18]. These catalysts have higher activity than the commercially available pure Pt/C catalysts due to either larger surface areas or their more favorable electronic and geometric structures for ORR [18-20]. In terms of surface area, if the Pt particle size is decreased from 3.4 to 1.5 nm, the number of atoms per particle decreases from 1,362 to 117, and the specific surface area increases from 82 to 186 m<sup>2</sup>/g. If Pt is alloyed with transition metals of a smaller atomic size, inter-atomic distance decreases due to the lattice contraction. The lattice contraction provides more favorable sites and energy states for the dissociative adsorption of oxygen species and enhances the kinetics of ORR.

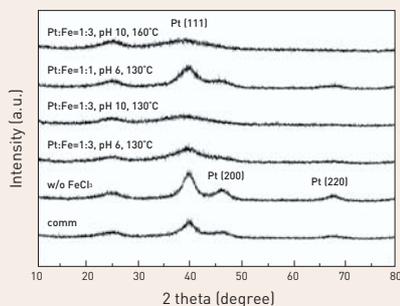


FIGURE 1. XRD analysis of commercial and KIST-made catalysts [5].

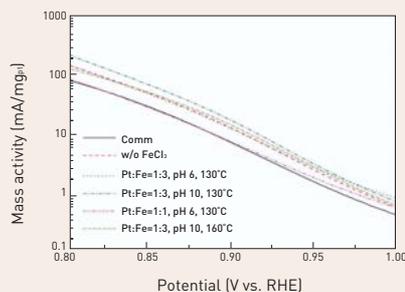


FIGURE 2. Tafel plot of commercial and KIST-made catalysts for ORR.

### Size-Controlled Pt Electrocatalyst

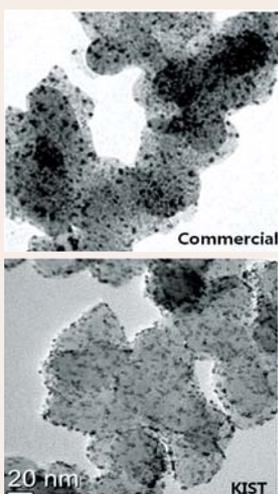
Despite extensive research to improve the ORR activity of catalysts by alloying them with transition metals and by controlling their nanostructures, some efforts are still focused on the optimization of pure Pt catalyst since it is the only commercialized one with reasonable activity and reliability. State-of-the-art technology for the enhancement of the activity of Pt catalyst involves controlling the shape of the nanostructure by using a series of additives to reveal some specific crystal plane highly active to ORR or to increase surface area [18,21].

In a study conducted at KIST, Pt/C catalysts with high activity toward ORR were fabricated in the presence of  $\text{FeCl}_3$  as an additive to control the Pt particle size and distribution [5]. Unlike the conventional method of using surfactants or polymers to control the shape, we only used  $\text{FeCl}_3$  without the polymers since the sophisticated nanostructures formed in the presence of polymers sometimes result in low activity and compromised durability due to the polymer residue on the Pt surface or the thermodynamic/kinetic instability of the complex nanostructures. In our study, a modified polyol-method was used for fabrication of 20 wt% Pt/C catalysts with the aid of  $\text{FeCl}_3$  under different fabrication conditions.

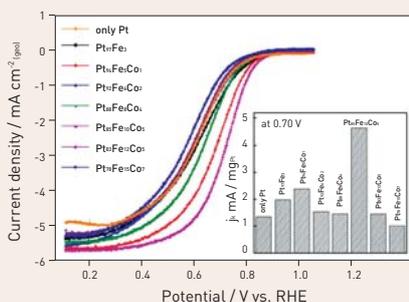
The Pt/C catalyst was prepared by taking the following steps: (i) ultrasonic treatment of Vulcan XC-72R carbon support and ethylene glycol + water mixture; (ii) addition of  $\text{H}_2\text{PtCl}_6$  precursor with 1 hr stirring; (iii) pH adjustment to 10 using NaOH; (iv) heating at 130 °C for 3 h then overnight stirring; (v) filtering and washing, and (vi) drying at 60 °C for 12 h in a dry oven. To observe the effect of  $\text{FeCl}_3$  on the size of the Pt nanoparticles, the amount of  $\text{FeCl}_3$  added (Pt:Fe=1:3 or 1:1), the solution pH (6 or 10), and the heating temperature (130 °C or 160 °C) were varied. For comparative purposes, a commercial 20 wt% Pt/C catalyst was also studied. X-ray diffraction (XRD), a Transmission Electron Microscope (TEM), and inductively coupled plasma (ICP) were used as characterizing tools.

Electrochemical properties were analyzed using linear sweep voltammetry (LSV) in oxygen-saturated  $\text{HClO}_4$  electrolyte by coating the glassy carbon (GC) working electrode with catalyst ink solutions prepared with the fabricated catalyst, water, ethanol, isopropyl alcohol, and Nafion binder. Figure 1 shows the XRD patterns for the commercial and as-prepared homemade Pt/C catalysts [5]. The peak intensity and full width at half maximum of the homemade catalysts are strongly dependent on the synthesis conditions, such as the amount of  $\text{FeCl}_3$ , solution pH, and heating temperature. The Pt/C catalyst without  $\text{FeCl}_3$  exhibited higher peak intensity and narrower peak width than the commercial one, suggesting a larger particle size. However, when  $\text{FeCl}_3$  was added with a stoichiometry of 1:3 (pH6, 130 °C), the peak intensity reduced considerably and the peak width increased. The peak intensity was further reduced when the solution pH was increased to 10. When the amount of  $\text{FeCl}_3$  was reduced to a stoichiometry of 1:1 (pH6, 130 °C), the peak intensities recovered to higher values compared to those observed with a larger amount of  $\text{FeCl}_3$ . When the temperature was increased to 160 °C (1:3, pH10), the XRD peaks were not significantly different from those observed at 130 °C. The average particle size of the  $\text{FeCl}_3$ -added Pt/C catalysts was in the range of 2.0–2.4 nm, which is smaller than that of  $\text{FeCl}_3$ -free (2.6 nm).

Figure 2 is the Tafel plot of the ORR kinetics of the catalysts after limiting current correction. The mass-corrected current densities (mass activity) as a function of the potential at the charge



**FIGURE 3.** TEM images of commercial and KIST-made [by using  $\text{FeCl}_3$ ] 20 wt% Pt/C electrocatalyst.



**FIGURE 4.** Polarization curves for the oxygen reduction on activities of Pt-Fe-Co alloy and pure Pt. The right ordinate plots: mass-specific activities [25].

transfer region reveals that Pt/C fabricated with Pt:Fe=1:3, pH=10, temp.=130 °C appeared to have the best activity owing to the increased surface area of the smallest Pt particles and their better dispersion (see fig. 3). Therefore, the particle size/distribution of the Pt/C catalysts in the presence of  $\text{FeCl}_3$  was effectively controlled by isotropic control of the Pt growth rate by  $\text{FeCl}_3$ .

The control of particle size/distribution by  $\text{FeCl}_3$  might be related to the retardation in the Pt formation rate caused by the  $\text{Fe}^{3+}$  ions. Under the above fabrication conditions,  $\text{Fe}^{3+}$  ions readily form  $\text{Fe}(\text{OH})_3$  with  $\text{OH}^-$  ions from water or the pH adjuster (NaOH). The formed  $\text{Fe}(\text{OH})_3$  alters the system through retardation of Pt particle growth by the inhibition of Pt ion reduction. Li suggested that  $\text{Fe}(\text{OH})_3$  was adsorbed onto metal nanoparticles [22]. In our work, the adsorption of  $\text{Fe}(\text{OH})_3$  onto the Pt seed retarded the surface growth of Pt during synthesis and reduced particle size. The small amounts of Fe observed in ICP analysis are due to the surface residue of  $\text{Fe}(\text{OH})_3$  on the Pt particles and not because of alloy formation.

Figure 3 shows TEM images of the commercial and optimized homemade Pt/C catalysts. The particle size of the catalyst is in good agreement with the XRD results. The presence of  $\text{FeCl}_3$ , significantly reduced the Pt particle size (2.0nm), which played a significant role in the surface area increment.

### Pt-M (M=transition metal) Alloy Electrocatalyst

Previous studies have suggested notable enhancements in ORR activity of Pt-based binary alloys with Cr, Co, and Ni [7,23,24]. However, there have been almost no studies on the ternary alloy electrocatalysts due to difficulties in synthesis, analysis, and separation of the individual component effects.

Introduced herein are our recent studies [25] on the development of ternary Pt<sub>85</sub>Fe<sub>5</sub>Co<sub>10</sub> alloy electrocatalysts and identification of the roles played by Fe and Co in the enhancement of ORR activity. Pt<sub>85</sub>Fe<sub>5</sub>Co<sub>10</sub> alloy electrocatalysts were prepared by electrodeposition on GC films or electrodes from a NaCl electrolyte containing  $\text{H}_2\text{PtCl}_6$ ,  $\text{FeCl}_2$ , and  $\text{CoCl}_2$  for 30 min and 6 min respectively. The Fe and Co composition was controlled by the deposition potential. The electronic and geometric structures of Pt<sub>85</sub>Fe<sub>5</sub>Co<sub>10</sub> alloy electrocatalysts with a change in the composition was investigated using high-resolution X-ray photoelectron spectroscopy (HRXPS) at the Pohang Light Source (PLS).

Electrochemical measurements of ORR kinetics were performed in oxygen-saturated 0.1 M HClO<sub>4</sub> solution at 298 K. A catalyst-deposited GC electrode was used as the working electrode, and a Pt wire was used as the counter electrode.

Figure 4 shows the ORR activities of Pt<sub>85</sub>Fe<sub>5</sub>Co<sub>10</sub> alloys with various compositions obtained using a rotating disc electrode at 1600 rpm. According to the change in composition, the ORR kinetics show dramatic shifts. Particularly in the case of Pt<sub>85</sub>Co<sub>10</sub>Fe<sub>5</sub>, the half wave potential shifted to the positive direction by 120 mV from that of pure Pt, implying a significant improvement in the ORR kinetic. The mass activities calculated from the current densities at 0.7 V vs. RHE are presented as an inset. As clearly shown in the inset figure, most of the Pt-Fe-Co alloy exhibited superior activity as compared to pure Pt catalyst. The mass activity of Pt<sub>85</sub>Co<sub>10</sub>Fe<sub>5</sub>, which showed the greatest shift in ORR

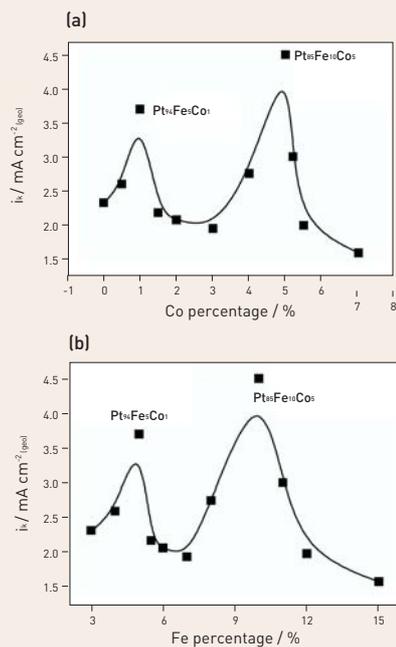


FIGURE 5. Kinetic current densities for ORR at 0.65 V against the concentrations of Co atoms (a) and Fe atoms (b) [25].

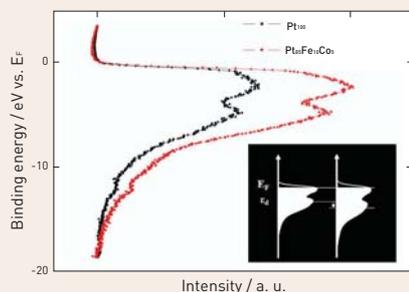


FIGURE 6. Valence level spectra for pure Pt and ternary alloy Pt<sub>85</sub>Fe<sub>10</sub>Co<sub>5</sub> with respect to the Fermi level [25].

polarization, is about 3.5 times higher than that of Pt catalyst. The kinetic current densities were plotted as a function of the alloy composition and are depicted in Figure 5 (a) and (b). Normally the composition-activity curves have volcano behaviors in a binary alloy system [26,27], an outcome which relates to the counterbalance between excessively strong or weak adsorption of oxygen species. The adsorption strength of oxygen species can be controlled by both changing the Pt-Pt bond distance and tuning the electronic structure of Pt (the d-band structure) [28]. As has been stated previously, proper amounts of lattice contraction by alloying with smaller size atoms result in the more favorable Pt-Pt distance to the ORR. The shorter inter-atomic distance also leads to the overlapping of the electrons in the d-band and subsequent down-shift of the d-band center, which also decrease the dissociative adsorption energy of the oxygen species.

However, the curves in figure 5 exhibit double-volcano-type curves according to the composition of either Co or Fe. This is due to the superimposing of different characteristics of Fe and Co, such as the difference in the lattice parameter and electronic structure, which enables the possibility of abnormal activity behavior in the case of ternary alloy catalyst.

In the case of Pt<sub>85</sub>Fe<sub>10</sub>Co<sub>5</sub>, which exhibited the maximum kinetic current density for the ORR, the characterization of the density of states (DOS) near the Fermi edge was conducted using HRXPS and the results are shown in Figure 6. The positions of the d-band center are -4.77 eV in the case of pure Pt and -4.90 eV in the case of Pt<sub>85</sub>Fe<sub>10</sub>Co<sub>5</sub> alloyed electrocatalyst. The downshift of the d-band center by 0.13 eV implies that the binding of O on Pt<sub>85</sub>Fe<sub>10</sub>Co<sub>5</sub> is weaker than that on pure Pt [6,19], which enhances the ORR activity.

## Summary

To improve the commercialization potential of PEMFCs, high-activity Pt-based electrocatalysts for prompting the appropriate oxygen reduction reaction at a cell's cathode have been continuously studied. Most research to date has either been on the optimization of Pt catalyst or on the development of new catalyst, such as Pt-transition metal alloys and nanostructure control of the Pt/Pt alloys. Building on prior research results, we have tried to control the size and distribution of Pt/C catalyst and to develop a new ternary Pt alloy catalyst for use in PEMFCs. Though the results have been encouraging, these catalysts have their own set of drawbacks, in particular, agglomerations between small Pt particles and the leaching out of the transition metals during operation. To overcome these problems, a brand-new catalyst, incorporating a core-shell shape and highly durable supports, is currently under investigation. What is important in the development of a PEMFC catalyst is that we always have to consider both activity and durability. We expect to introduce our cutting-edge results in developing a catalyst with superior qualities in both of these areas in the near future.

## Note

This article was drawn from our recent papers as follows: Int. J. Hydrogen Energy, 36, 706, 2011 [ref. 5] and J. Phy. Chem. C, 115, 2483, 2011 [ref. 25]

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*What is important in the development of a PEMFC catalyst is that we always have to consider both activity and durability.*

# C hannel-Mediated Tonic GABA Release From Glia



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## Introduction

We recently published a research article in the journal *Science* entitled “Channel-mediated tonic GABA release from glia.” This study examines tonic inhibition, a recently discovered and very important form of brain signaling. It is now known that tonic inhibition provides the dominant source of inhibitory drive to cerebellar granule cells, the most abundant type of neuron in the brain, and is also observed in other types of neurons throughout the brain. Although tonic inhibition has been studied in an ever-increasing number of recent publications, the mechanism involved in releasing GABA (gamma aminobutyric acid) tonically as well as the cellular source of this GABA have been impossible to pin down. Our paper tackles both of these questions and provides clear answers to each. Our work provides compelling evidence for a new form of neuron-glia interaction that may have profound implications for our understanding of brain signaling mechanisms and provide novel targets for psychiatric disorders such as depression, epilepsy, sleep disorders, learning disabilities, etc.

## Description of Research

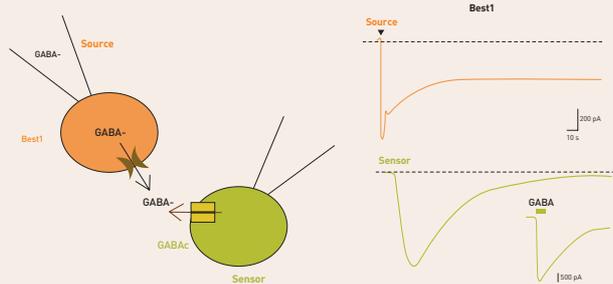
A tonic form of synaptic inhibition that causes sustained activation of GABA receptors in neurons occurs throughout the central nervous system. Because of its sustained nature, tonic inhibition dominates over conventional (phasic) synaptic inhibition in controlling neuronal excitability. Therefore, tonic inhibition plays an important role in neuronal information processing and has been implicated in epilepsy, sleep, memory and cognition. The mechanism underlying the tonic release of GABA and the source of this GABA are poorly understood. We have addressed this question in cerebellar granule cells, which are powerfully restrained by tonic inhibition resulting from GABA released via an unconventional mechanism that is independent of action potentials and does not require vesicular exocytosis.

We hypothesized that tonic inhibition is mediated by GABA permeating through an anion channel, Best1, previously implicated in glutamate release from astrocytes. Best1 has several features that make it attractive as a hypothetical mediator of tonic GABA release. Best1 is an anion channel that is activated by intracellular  $Ca^{2+}$  and by changes in cell volume, though it is tonically active even at resting  $Ca^{2+}$  levels and at normal cell volume. Best1 has unique permeability properties among anion channels, with a significant permeability to  $HCO_3^-$  and a much higher permeability to large anions, such as  $SCN^-$ , than to  $Cl^-$ . This channel is even permeable to gluconate and to the neurotransmitter, glutamate. Thus, Best1 might be permeable to GABA and thereby mediate tonic GABA release.

*Although tonic inhibition has been studied in an ever-increasing number of recent publications, the mechanism involved in releasing GABA (gamma aminobutyric acid) tonically as well as the cellular source of this GABA have been impossible to pin down.*

We found that tonic release of the major inhibitory transmitter, GABA, is due to direct permeation of GABA through the anion channel, Best1, and that this release originates predominantly from glial (non-neural) cells.

The mechanism underlying tonic GABA release has been difficult to clarify because tonic GABA release exhibits several puzzling features that are quite different from those exhibited by conventional, phasic release of GABA. Our proposed mechanism can account for each of these properties: 1) the non-vesicular nature of tonic GABA release is consistent with a channel-mediated mechanism; 2) the independence from neuronal activity can be explained by the glial origins of tonic inhibition; and 3) the apparent lack of dependence on external  $Ca^{2+}$  arises from substantial activation of Best1 at resting levels of intracellular  $Ca^{2+}$ , leading to constitutive release of GABA at such intracellular  $Ca^{2+}$  levels (Fig. 1).

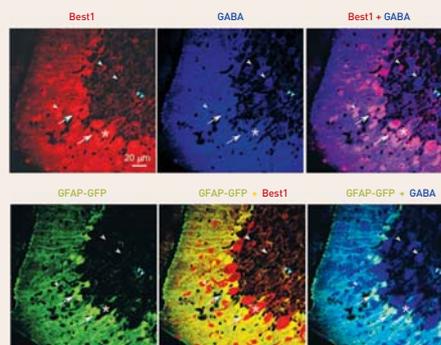


**FIGURE 1.** GABA release through Best1 channel using two cell bio-assay

Our results provide several independent lines of evidence indicating that GABA is permeable through Best1. These include: 1) shifts in current reversal potential when intracellular GABA concentration was varied; 2) current flow when GABA is the only permeant ion; and 3) Best1-dependent release of GABA from one cell onto another. Collectively, these results demonstrate that GABA permeates through Best1. While it has been proposed that Best1 has functions in addition to being an ion channel, our finding that a channel pore mutation blocks GABA release indicates that GABA is released by direct permeation through the Best1 channel pore. We presume that tonic inhibition is caused by GABA; it remains a formal possibility that it is mediated by some other molecule that permeates Best1 and activates GABA receptors, such as taurine.

To cause efflux through the Best1 channel, intracellular GABA concentration in Bergmann glial cells should be high enough to maintain the required electrochemical gradient. Bergmann glial cells show GABA immunoreactivity as intense as that observed in neighboring inhibitory

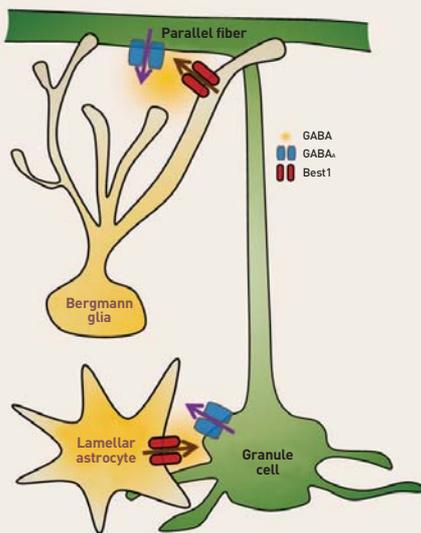
neurons (Fig. 2), suggesting a high GABA content, consistent with the intracellular GABA concentration of 3.5 mM reported in cultured astrocytes. With a submicromolar extracellular concentration of GABA, such high intracellular concentrations yield a positive equilibrium potential for GABA. Given the very negative resting membrane potential of Bergmann glial cells, there is a strong electrochemical gradient to drive GABA efflux through the Best1 channel.



**FIGURE 2.** Presence of both GABA and Best1 in cerebellar glial cells

Our work is consistent with previous indications that glia release GABA. Because Best1 is also volume-sensitive, our results provide a mechanism for the observation that swelling can trigger GABA release from glia. GABA usually is thought to be synthesized, contained, and released exclusively by neurons in the adult brain. However, a handful of reports have suggested that astrocytes contain GABA, and our immunohistochemical data provide further support for this idea. Although our work does not identify the source of GABA in Bergman glia, it is known that GABA can be synthesized in glia via two pathways and can be taken up into glia by GABA transporters.

The spatial organization of cerebellar glial cells is ideally suited to provide ambient GABA for tonic inhibition. In the type II glomerulus, the sheaths of lamellar astrocytes are intimately associated with granule cell dendrites. Such structures could permit the tonic inhibition of granule cell bodies and dendrites. Likewise, Bergmann glial cells tightly wrap around parallel fiber synapses, providing a strategic location for tonic inhibition of parallel fibers. Our findings lead to a model for tonic GABA release (Fig. 3): GABA in Bergmann glia permeates through the Best1 channel to activate GABA receptors on parallel fibers, while the same mechanisms allow lamellar astrocytes to tonically inhibit granule cell bodies and dendrites. By providing a source of GABA and by locating the molecular machinery for tonic GABA release near the granule cell structures, as well as by creating a restricted volume that allows tonic accumulation of GABA, it appears that glial cells are anatomically optimized for controlling electrical signaling in neighboring cerebellar neurons.



**FIGURE 3.** Model for tonic inhibition in cerebellum

In conclusion, we have demonstrated an unprecedented mechanism for tonic GABA release through the bestrophin channel in cerebellar glial cells and propose a novel function for glia in modulating neuronal signaling via tonic inhibition.

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## PUBLICATIONS

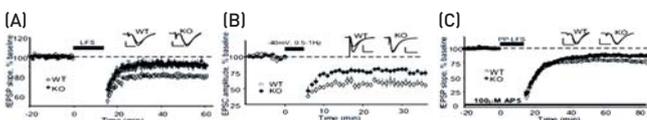
# 1

## Developmental regulation of protein interacting with C kinase 1 (PICK1) function in hippocampal synaptic plasticity and learning

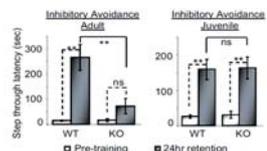
*PNAS Vol. 107 No. 33, 2010, 14857-14862*

Lenora Volk, Chong-Hyun Kim, Kogo Takamiya, Yilin Yu, and Richard L. Huganir

AMPA-type glutamate receptors (AMPA) mediate the majority of fast excitatory neurotransmission in the mammalian central nervous system. Modulation of AMPAR trafficking supports several forms of synaptic plasticity thought to underlie learning and memory. Protein interacting with C kinase 1 (PICK1) is an AMPAR-binding protein shown to regulate both AMPAR trafficking and synaptic plasticity at many distinct synapses. However, studies examining the requirement for PICK1 in maintaining basal synaptic transmission and regulating synaptic plasticity at hippocampal Schaffer collateral-cornu ammonis 1 (SC-CA1) synapses have produced conflicting results. In addition, the effect of PICK1 manipulation on learning and memory has not been investigated. In the present study we analyzed the effect of genetic deletion of PICK1 on basal synaptic transmission and synaptic plasticity at hippocampal Schaffer collateral-CA1 synapses in adult and juvenile mice. Surprisingly, we find that loss of PICK1 has no significant effect on synaptic plasticity in juvenile mice but impairs some forms of long-term potentiation and multiple distinct forms of long-term depression in adult mice. Moreover, inhibitory avoidance learning is impaired only in adult KO mice. These results suggest that PICK1 is selectively required for hippocampal synaptic plasticity and learning in adult rodents.



**FIGURE 1.** Multiple forms of LTD are impaired in adult PICK1-KO mice. (A) LTD induced by LFS (1 Hz, 900 stimuli, 30°C) is significantly reduced in PICK1-KO mice. WT ( $n=8$ ):  $80 \pm 1\%$  at 55-60 min; KO ( $n=9$ ):  $92 \pm 3\%$  at 55-60 min;  $P < 0.01$ . (B) LTD induced by pairing 200-300 pulses at 0.5-1 Hz with -40 mV depolarization (35°C) is reduced in PICK1-KO mice. WT ( $n=10$ ):  $59 \pm 5\%$  at 31-35 min; KO ( $n=11$ ):  $76 \pm 4\%$  at 31-35 min;  $P < 0.05$ . (C) NMDA receptor-independent LTD induced by PP-LFS (50-ms ISI, 30°C) in the NMDAR antagonist  $\alpha$ -AP5 (100  $\mu$ M) is reduced in PICK1-KO mice. WT ( $n=9$ ):  $79 \pm 2\%$  at 75-80 min; KO ( $n=8$ ):  $89 \pm 2\%$  at 75-80 min;  $P < 0.01$ . (Inset scale bars: A and C: 0.5 mV, 5ms; B: 100 pA, 10 ms.)



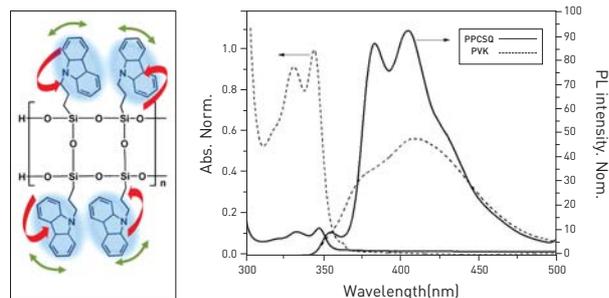
**FIGURE 2.** Hippocampal-dependent learning/memory is impaired in adult but not in juvenile PICK1-KO mice. Adult (2- to 3-mo-old) or juvenile (3-wk-old; postnatal day 20-22) mice were trained on a step-through IA task. Latency to cross over to the dark chamber was measured at training and 24 h later. In adult mice, PICK1-KO results in a dramatically reduced latency 24 h after training (WT:  $n=10$ ; KO:  $n=12$ ). Juvenile PICK1 mice acquire the IA task normally (WT:  $n=7$ ; KO:  $n=9$ ). \*\*  $P < 0.01$ , ns, not significant.

# 2

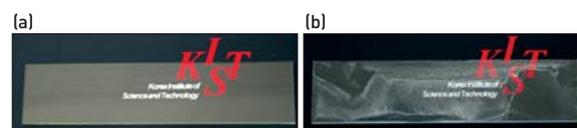
## High photo- and electroluminescence efficiencies of ladder-like structured polysilsesquioxane with carbazole groups

*Journal of Materials Chemistry Vol. 20 No. 44, 2010, 9852-9854*

Seung-Sock Choi, He Seung Lee, Seung Sang Hwang, Dong Hoon Choi, Kyung-Youl Baek



**FIGURE 1.** Ladder-like structured polysilsesquioxane with carbazole groups (PPCSQ) and isolated effect of pendent groups (a), photoluminescence result of synthesized PPCSQ and polyvinylcarbazole (PVK) (b).



**FIGURE 2.** Thin film image on the glass of PPCSQ (a) and conventional poly(octahedral silsesquioxane) after spin coating.

Ladder-like structured polysilsesquioxane with carbazole groups showed unexpected high photo- and electro-luminescence efficiencies both in solution and solid states due to its rigid silicone ladder structures, which efficiently isolated the carbazole groups and thus suppressed their excimer formations by inter- and intra-molecules. Carbazole group functionalized ladder-like structured silsesquioxane with relatively high molecular weight ( $M_w = \sim 10,000$ ) was successfully synthesized by direct hydrolysis and condensation reaction of 9-[3-(trimethoxysilyl)propyl]-9H-carbazole. Obtained PPCSQ showed high photo- and electro-luminescence efficiencies both in solution and in solid states due to its rigid siloxane structure, which effectively isolated the carbazole groups.

## 3 3-D thin-wire FDTD approach for resistively loaded cylindrical antennas fed by coaxial lines

IEEE Transaction on Antennas and Propagation Vol.58 No.12, 2010, 4095-4099

Seung-Yeup Hyun, Se-Yun Kim

For the efficient finite-difference time-domain (FDTD) analysis of electrically thin and resistively loaded cylindrical antennas, the 2-D cylindrical thin-wire approach with circular symmetry is extended to the 3-D Cartesian FDTD with non-cubic cells for asymmetric cases. The axial geometry of the antenna is represented as a set of piecewise-linear lumped resistors. And the near fields around the antenna and the coaxial feed aperture are approximated to the quasi-static fields with the cylindrical behavior. From the cylindrical-to-Cartesian coordinate transformation of the quasi-static fields and the contour-path integration along FDTD unit cells in the vicinity of the antenna and its feed in Fig. 1, the 3-D Cartesian FDTD equations are derived. These equations may correspond to a full coarse-grid FDTD approach with the equivalent corrections. For some numerical examples, the proposed approach provides comparable accuracy to the reference data with fine-grid resolution, as shown in Fig 2. Effects of the cell size and the resistive loading profile are investigated numerically.

FIGURE 1. Dual-grid representation of FDTD unit cells around the  $z$  section of the thin resistive cylinder with outer radius.

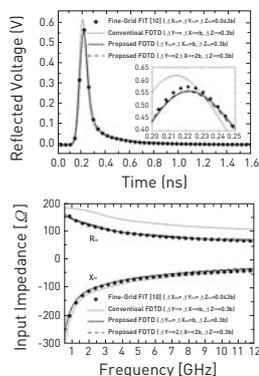
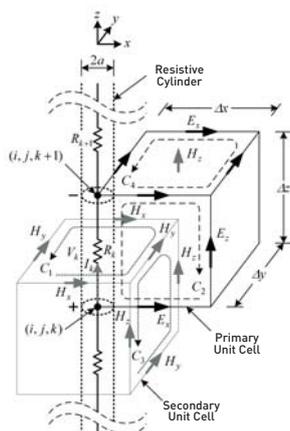


FIGURE 2. Comparison results of the Wu-King (WK) resistively loaded cylindrical monopole antenna in air as a function of the cell size and the near-field correction. The conventional FDTD means the axially equivalent resistor model without the near-field correction of the antenna. In contrast, the proposed FDTD includes the equivalent resistor and the 3-D radial-dependent corrections of the near-field behaviors. (a) The transient reflected feed voltage and (b) the input impedance of the antenna.

## 4 Facile synthesis of highly active and stable Pt-Ir/C electrocatalysts for oxygen reduction and liquid fuel oxidation reaction

Chemical Communications Vol.46 No.44, 2010, 8401-8403

Seung Jun Hwang, Sung Jong Yoo, Tae-Yeol Jeon, Kug-Seung Lee, Tae-Hoon Lim, Yung-Eun Sung and Soo-Kil Kim

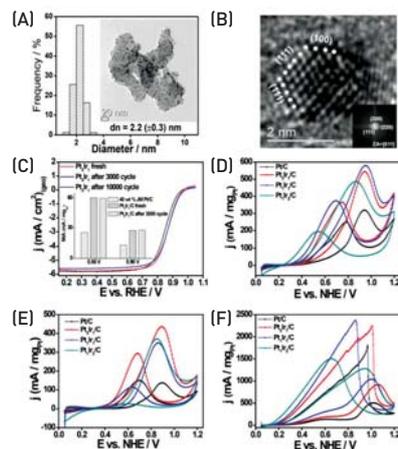


FIGURE 2. (A) Histogram and typical transmission electron microscopy (TEM) micrograph (inset) of a PtIr<sub>1</sub> alloy sample prepared in EtOH and heat treated at 523 K for 2 h. (B) High resolution TEM (HRTEM) image of the prepared PtIr<sub>1</sub> alloy nanoparticle (NP). (C) Oxygen reduction reaction (ORR) polarization curves for fresh PtIr<sub>1</sub> alloy NPs, commercial Pt/C (JM), after 3000 cycles and 10000 cycles of PtIr<sub>1</sub>. (D-F) CV of Pt-Ir electrocatalysts for ethanol (D), methanol (E), and formic acid (F) oxidation measured with 1.0 M ethanol, methanol, and formic acid, respectively, in 0.5 M H<sub>2</sub>SO<sub>4</sub> with a scan rate of 20 mV/s at 298 K.

Power generation utilizing the anodic fuels H<sub>2</sub>, CH<sub>3</sub>OH, C<sub>2</sub>H<sub>5</sub>OH, and HCOOH coupled with an O<sub>2</sub> or air gas is recognized as a promising use of alternative energy sources, especially in the automotive and small mobile device industries. However, the commercialization of low-temperature fuel cells, such as the PEMFC (proton exchange membrane fuel cell) and DLFC (direct liquid fuel cell) is hindered by the slow cathodic oxygen reduction (PEMFC) and anodic fuel oxidation kinetic (DLFC) of these cells. Therefore, discovery of new catalysts with improved oxygen reduction and alcohol oxidation as well as excellent durability is considered a key research objective in this field.

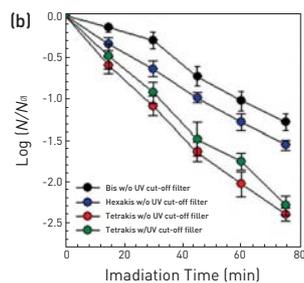
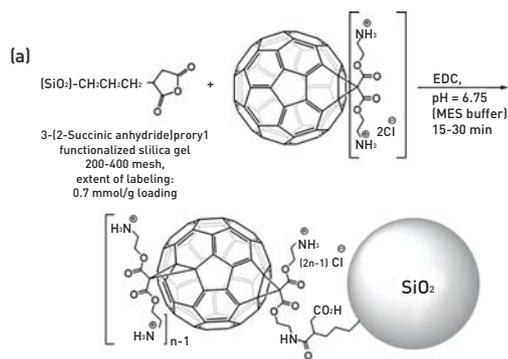
A facile synthesis technique using a CTAB-stabilized NaBH<sub>4</sub> reduction method in anhydrous ethanol media has been developed for carbon-supported highly active and stable Pt-Ir electrocatalysts for applications in low-temperature fuel cells. The mass activity toward oxygen reduction reaction of the prepared PtIr<sub>1</sub> electrocatalyst was 2.4 times higher than that of a commercial Pt/C catalyst, while the durability test showed negligible losses in activity after 3000 potential cycles. In addition, the prepared PtIr<sub>1</sub>, PtIr<sub>2</sub>, and PtIr<sub>3</sub> exhibited the best activities with different alcohol oxidation reactions using methanol, ethanol, and formic acid, respectively, and possessed significant CO tolerance.

## 5 C<sub>60</sub> Aminofullerene Immobilized on Silica as a Visible-Light-Activated Photocatalyst

*Environmental Science & Technology* Vol.44 No.24, 2010, 9488-9495

Jaesang Lee, Yuri Mackeyev, Min Cho, Lon J. Wilson, Jae-Hong Kim, Pedro J. J. Alvarez

We suggest a new strategy to immobilize photoactive C<sub>60</sub> aminofullerene on silica gel (3-[2-succinic anhydride] propyl functionalized silica) via an organic amide linker, which enables facile separation of the photocatalyst from treated water, eventually leading to recycle and repeated use. With no loss in efficacy of visible-light-driven <sup>1</sup>O<sub>2</sub> production plus insignificant chemical modification of the aminoC<sub>60</sub>/silica photocatalyst after multiple cycling, the system offers a promising new visible-light-activated photocatalyst. Under visible-light irradiation, the aminoC<sub>60</sub>/silicaphotocatalyst is capable of effective oxidation of Ranitidine and Cimetidine (pharmaceutical pollutants) and inactivation of MS-2 bacteriophage.

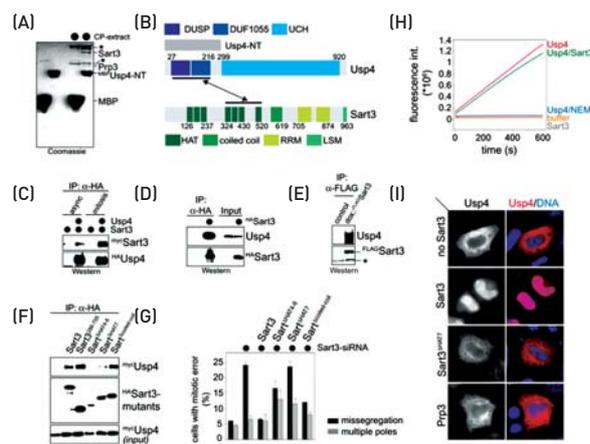


**FIGURE 1.** (a) Strategy for immobilization of water-soluble C<sub>60</sub> aminofullerenes on the functionalized silica gel; and (b) bis-, tetrakis-, and hexakis- aminoC<sub>60</sub>/silica under visible-light irradiated conditions and under commercial fluorescence lamp irradiation

## 6 The Prp19 complex and the Usp4<sup>Sart3</sup> deubiquitinating enzyme control reversible ubiquitination at the spliceosome

*Genes & Development* Vol.24 No13, 2010, 1434-1447

Eun Joo Song, Shannon L. Werner, Jakob Neubauer, Frank Stegmeier, Julie Aspden, Donald Rio, J. Wade Harper, Stephen J. Elledge, Marc W. Kirschner, and Michael Rape



**FIGURE 1.** Sart3 is a targeting factor of Usp4. (A) Identification of Sart3 as a binding partner of Usp4. (B) Schematic overview of Sart3 and its interaction with Usp4. (C) Sart3 binds Usp4 in vivo. (D) Sart3 binds endogenous Usp4. (E) Usp4 and Sart3 interact under physiological conditions. (F) The HAT7 domain of Sart3 is required for the interaction with Usp4. (G) The interaction with Usp4 is required for the role of Sart3 as a cell cycle regulator. (H) Sart3 does not activate Usp4. (I) Sart3 functions as a targeting factor of Usp4.

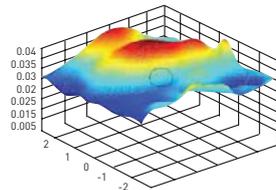
The spliceosome, a dynamic assembly of proteins and RNAs, catalyzes the excision of intron sequences from nascent mRNAs. Recent work has suggested that the activity and composition of the spliceosome are regulated by ubiquitination, but the underlying mechanisms have not been elucidated. Here, we report that the spliceosomal Prp19 complex modifies Prp3, a component of the U4 snRNP, with nonproteolytic K63-linked ubiquitin chains. The K63-linked chains increase the affinity of Prp3 for the U5 snRNP component Prp8, thereby allowing for the stabilization of the U4/U6.U5 snRNP. Prp3 is deubiquitinated by Usp4 and its substrate targeting factor, the U4/U6 recycling protein Sart3, which likely facilitates ejection of U4 proteins from the spliceosome during maturation of its active site. Loss of Usp4 in cells interferes with the accumulation of correctly spliced mRNAs, including those for  $\alpha$ -tubulin and Bub1, and impairs cell cycle progression. We propose that the reversible ubiquitination of spliceosomal proteins, such as Prp3, guides rearrangements in the composition of the spliceosome at distinct steps of the splicing reaction.

# PATENTS

## DIELECTRIC THIN FILM COMPOSITION SHOWING LINEAR DIELECTRIC PROPERTIES

Patent No. 10-0997379 Key Inventor: Choi, Ji-Won (jwchoi@kist.re.kr)

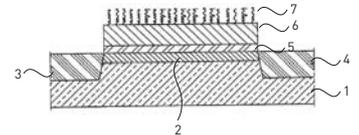
The present invention relates to a dielectric thin film composition showing linear dielectric properties, in which tin oxides (SnO<sub>2</sub>) are introduced into a (Ba,Sr)TiO<sub>3</sub>(BSTO) dielectric thin film in a continuous diffusion gradient manner in composition.



## BIO-SENSOR AND METHOD OF MANUFACTURING THE SAME

Patent No. 10-0998645 Key Inventor: Lee, Wook Seong (wslee@kist.re.kr)

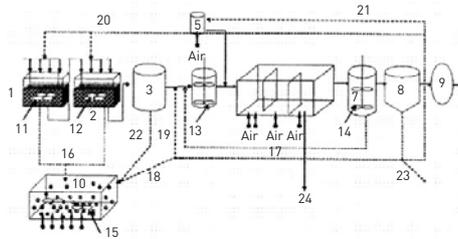
A bio-sensor includes a gate dielectric formed on a silicon semiconductor substrate, a gate electrode of a conductive diamond film formed on the gate dielectric, probe molecules bonded on the gate electrode for detecting biomolecules, and source/drain regions formed on the semiconductor substrate at the sides of the gate electrode. The gate electrode is a comb shape or a lattice shape.



## METHOD FOR COMPOSTING AND TREATING FOOD WASTE BY USING WOOD CHIPS AND APPARATUS THEREOF

Patent No. 10-1000300 Key Inventor: Park, Wan Cheol (wcpark@kist.re.kr)

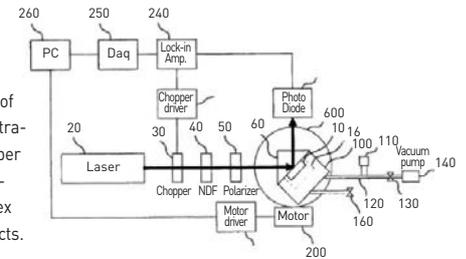
The present invention relates to a method of composting and treating food waste by using wood chips and an apparatus.



## OXYGEN SENSOR USING PRINCIPLE OF SURFACE PLASMON RESONANCE AND OXYGEN TRANSMISSION RATE MEASUREMENT SYSTEM INCLUDING THE SAME

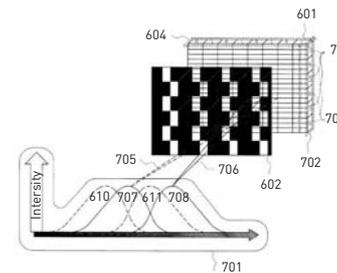
Patent No. 10-996450 Key Inventor: Choi, Ji-Won (jwchoi@kist.re.kr)

An oxygen sensor is provided using the principle of surface plasmon resonance, capable of measuring an oxygen concentration in a measurement chamber by detecting a change in resonance angle or refractive index using field enhancement effects.



## 3D IMAGE DISPLAY DEVICE

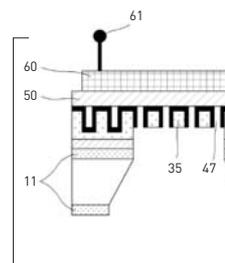
Patent No. 10-1001627 Key Inventor: Kim, Sung Kyu (kkk@kist.re.kr)



The 3D image display device disclosed herein includes an image display panel outputting image signals and a parallax barrier arranged in front of the panel, being spaced at a particular distance, and having a plurality of transparent portions. The transparent portions of the barrier have a plurality of transverse lines, each of which forms one cycle, and the transparent portions that are adjacent to each other in the longitudinal direction in one cycle are arranged to emit images to different fields of view, respectively.

## MICRO FUEL CELL, FABRICATION METHOD THEREOF, AND MICRO FUEL CELL STACK USING THE SAME

Patent No. 10-1002044 Key Inventor: Son, Ji-Won (jwson@kist.re.kr)



A micro cell fuel cell using a nano porous structure according to a thin film process and an anodizing process as a template for implementing a porous structure of an electrode, its fabrication method, and a micro fuel cell stack using the same are disclosed.

#### Chancellor of UC Merced Visits KIST



Chancellor Sung-Mo Steve Kang of University of California, Merced (UC Merced) visited KIST on July 7, 2010.

Chancellor Kang met with KIST's Dr. Kim Myung-soo, Vice President External Affairs, Dr. Yoo Young-sook, Vice President Research, and other directors of research. They discussed personnel exchange and possible measures for research cooperation as a follow up to the MOU between KIST and UC Merced made last month during President Hahn's visit to the U.S.

#### U.S. Ambassador Delivers a Special Lecture at KIST



U.S. Ambassador Kathleen Stephens visited KIST on July 8, 2010, to deliver a special lecture. After meeting with KIST's President for updates on KIST's current R&D activities and future plans, Ambassador Stephens delivered a special lecture on "Science Diplomacy" at the Johnson Auditorium.

During her lecture, Ambassador Stephens shared the history behind the creation of KIST. In the spring of 1965, Korean President Park Chung-hee and U.S. President Lyndon Johnson met to discuss the challenges and opportunities for education and economic development in Korea. There the idea of U.S. support for establishing an industrial research laboratory was suggested, leading to the establishment of KIST in 1966. The creation of KIST, then, was a product of science diplomacy, a reflection of the strong alliance between the United States and the Republic of Korea, and a result of the shared belief that science is essential to the progress of any nation. Ambassador Stephens further explored the role of science in facilitating diplomacy and international collaboration. She explained that science, serving as a common global language, is able to bridge deep political and religious divides. It also benefits from international collaboration due to its global scope, as evidenced by the ITER project, an international effort to harness the power of nuclear fusion as a possible new and viable energy source.

The Ambassador also stressed the importance of scientists and students and their role in science diplomacy. She encouraged the students of KIST's International R&D Academy, who are from all over the world, to make positive contributions to the scientific and economic development of their home countries with the training they receive at KIST.

Looking towards the future of science diplomacy, Ambassador Stephens concluded her lecture by expressing her sense of pride both for the accomplishments of the Korean people and for the U.S.-Korea partnership.

### Nobel Prize Laureate Kurt Wuthrich Visits KIST



On September 7, 2010, Professor Kurt Wuthrich visited the laboratory at KIST which contains a 900 MHz NMR system, and then had a brief meeting with KIST's President. After meeting with the President, he gave a lecture to students and researchers at KIST on "Structural Genomics: Combined Use of NMR and Crystallography with Proteins."

Professor Wuthrich is currently conducting research at the Department of Biophysics at ETH Zurich. He was awarded the Nobel Prize in Chemistry in 2002 for his "development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution."

### Ecuadorian President Rafael Correa Delgado Visits KIST



President Correa met with the President of KIST on September 9, 2010, to discuss KIST's current research activities and personnel training programs. President Correa was also shown the cognitive robot developed by KIST. KIST provided in-depth information on its International R&D Academy to President Correa, describing its advanced degrees in science and technology and the postdoctoral program. Discussions were also held concerning avenues of collaboration between

the two countries in researching natural resources. As a result of President Correa's visit to KIST, more cooperative measures in science and technology research between Ecuador and Korea are expected. Ecuador, an oil-producing country in Latin America, is also one of the seventeen most megadiverse countries in the world.

### KIST-Osaka Prefecture University MOU



The Nano-Materials Center of KIST and the Research Organization for the 21st Century of Osaka Prefecture University (OPU) have agreed to cooperate in the field of nano-materials and nano-technology.

Dr. Woo Kyoung-ja, head of KIST's Nano-Materials Center, met with Professor Masakazu Anpo, Vice President and Director of OPU's Research Organization, on September 27, 2010. They signed an MOU to promote joint research and exchange of technology and personnel. In addition, they agreed to hold a joint symposium in

May 2011 to share research and information on photocatalysts, solar-cell materials, and photo/electronic materials. This cooperation will be a platform for KIST's Nano-Materials Center to globally expand its research in photo/electronic nano-technology.

#### Ethiopian Minister of Science and Technology Visits KIST



Juneydi Saddo, Ethiopian Minister of Science and Technology, visited KIST on September 14, 2010. He met with KIST's President and discussed cooperation measures.

Minister Saddo expressed his belief that many countries in Africa, which are heavily dependent on western countries, should strengthen cooperation with Korea. He also showed great interest in the International R&D Academy (IRDA) and the postdoctoral Research Associateship (RA) program at KIST, as well as in gaining the experience needed to establish a research institute in his own country.

#### KIST-EU High Level Network Meeting



KIST Europe held the 'KIST-EU High Level Network Meeting' on October 25-26, 2010, for the purpose of establishing a Global Open Innovation Network with local German research institutions such as the Leibniz Institute for New Materials, Fraunhofer Institute for Non-Destructive Testing (IZFP), Karlsruhe Institute of Technology, Max Planck Institute for Informatics, and Fraunhofer Institute for Biomedical Engineering (IBMT).

The workshop consisted of four sessions, divided into morning and afternoon sessions. For the first three sessions, a center representative from each research institute presented an overview of their center's respective research fields and discussed future cooperation measures. After the presentations, the participants were given a tour of the KIST Europe facilities.

#### 2010 Seoul S&T Forum Held

The 2010 Seoul S&T Forum was held for two days on November 18-19 at the Shilla Seoul hotel. It was hosted by KRCF, organized by KIST and STEPI, and sponsored by the Ministry of Education, Science and Technology (MEST), Presidential Committee on Green



Growth (PCGG) and the Korea Economic Daily. More than 300 leaders and officials from 71 public research institutes representing 35 countries attended the forum. Under the theme “International Cooperation of Public Research Institutes for Green Growth,” the role of public research institutes and measures for international cooperation concerning the topic of green growth were discussed.

On the first day, presentations and discussions focused on how to position PRIs for global green growth and the potential for PRIs to act as S&T entrepreneurs. The second day focused on ways for global sharing of existing green technologies, developing new technologies through joint efforts, and establishing a global green network of PRIs. All invited participants agreed to and signed the forum statement.

Foreign participants at the forum visited KIST on Saturday, November 20. During the visit, they were presented with KIST’s recent research activities and discussed plans for future cooperation.

#### Dr. Kil-Choo Moon Inaugurated as the 22nd President of KIST



Dr. Kil-Choo Moon was inaugurated as the 22nd President of KIST on November 30, 2010. At the inauguration ceremony, he proposed a new vision for KIST: KIST 50 Years, Global Leading Institute for Future. In order to attain this new vision, he set three key objectives for KIST: (1) to be a future-oriented research institute; (2) to be a global research institute; and (3) to be a coopera-

tive research institute.

Dr. Moon received his Ph.D. degree in mechanical engineering from the University of Minnesota. After gaining experience at a U.S. research institute, he joined KIST as the Manager of the Air Pollution Laboratory in 1991. He then went on to serve as the Director of KIST Gangneung and then as Vice President of KIST. Recently he was also the Director for National Science and Engineering Programs of the National Research Foundation of Korea (NRF).

## Awards

- \* **Dr. Baik Young-joon, Electric Materials Center**
  - Science and Technology Medal (April, 2010)
- \* **Dr. Lee Jung-il, Nano Convergence Device Center**
  - Science and Technology Progress Medal (April, 2010)
- \* **Dr. Lee Yong-bok, Energy Mechanics Center**
  - Presidential Citation (April, 2010)
- \* **Mr. Byun Duk-yong, Senior Administrator in Human Resources Management Team**
  - Award of Minister of Education, Science and Technology (April, 2010)
- \* **Dr. You Bum-jae, Cognitive Robotics Center**
  - Presidential Award (April, 2010)
- \* **Mr. Lee Don-jae, Senior Administrator in Planning and Budgeting Team**
  - Award of Minister of Education, Science and Technology (April, 2010)
- \* **Dr. Seok Hyun-kwang, Functional Materials Center**
  - Award of Minister of Knowledge Economy (May, 2010)
- \* **Dr. Lee Dae-young, Energy Mechanics Center**
  - Award of Minister of Land, Transport and Maritime Affairs (June, 2010)
- \* **Dr. Lee Seock-heon, Water Environment Center**
  - Award of Minister of Land, Transport and Maritime Affairs (June, 2010)
- \* **Dr. Cho Yong-seo, Neuro-Medicine Center**
  - Best Research Advisor Award (University of Science & Technology, July, 2010)
- \* **Dr. Chang Joon-yeon, Nano-Convergence Device Center**
  - KIST Scientist of the Month (August, 2010)
- \* **Dr. Lee So-ha, Biomaterial Center**
  - Best Professor Award (University of Science & Technology, September, 2010)
- \* **Dr. Rhee Jae-seong, Water Environment Center**
  - Award of Minister of Environment (October, 2010)
- \* **Dr. Hong Seong-ahn, Fuel Cell Center**
  - Knowledge Creation Award (MEST, December, 2010)
- \* **Dr. Oh Young-jei, Optoelectronic Materials Center**
  - 2010 Top 100 Best National R&D Performance Award (MEST and KISPI, December, 2010)
- \* **Dr. Lee Joong-kee, Advanced Battery Center**
  - 2010 Top 100 Best National R&D Performance Award (MEST and KISPI, December, 2010)
- \* **Dr. Shin Hee-sup, Neural Science Center**
  - 2010 Top 100 Best National R&D Performance Award (MEST and KISPI, December, 2010)

# A Sign of the Times!

## KIST, A Successful Model for Other Research Institutes

KIST was founded in 1966 as Korea's first multi-disciplinary research institute of Korea and had been a driving force behind national economic development ever since. It has also been instrumental in the formation of other research institutes such as ETRI, KITECH, STEPI, and others, which have subsequently developed into leading research institutes in their own specialized fields.



● 1966



● 1967 ~1980

1976..  
The Korea Research of  
Chemical Technology



1980..  
Korea Institute  
of Energy Research



● 1981 ~1989

1981..  
Korea Institute of  
Machine & Materials



1985..  
Electronics and  
Telecommunications  
Research Institute



1987..  
Korea Food  
Research Institute



1989..  
Korea Industrial  
Technology



● 1989 ~2003

1990..  
Korea Ocean Research  
& Development Institute



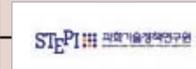
1997..  
Korea Institute of  
Science and Technology  
Information



1999..  
Korea Research  
Institute of Bioscience  
and Biotechnology



Science & Technology  
Policy Institute



Korea Institute of  
Science & Technology  
Evaluation and Planning



THE KIST, Making **New** History



Korea Institute of  
Science and Technology



## Alumni Update

It has been my dream to study abroad with a scholarship since I was in high school. At first, I never imagined that I would continue my studies in Korea because I was thinking of going to an English-speaking country to minimize the language barrier. But what happened was beyond my expectation. Here I am in Korea, not only finishing my master's study in Computer Science, but also now I'm working at Samsung, one of the biggest companies in Korea. Since it is my first job in a company, I feel that my experience studying and researching at KIST gave me a strong foundation to enter working life in Korea. The first time I came to Korea in 2008, I had a lot of worries in my mind since that was my first time out of Indonesia. I thought a lot about how to adapt in the new country, how to adjust to the language barrier and culture differences. But the warm welcome from an Indonesian friend, who picked me up at Incheon airport, reduced some of my worries, as she shared some life experiences at KIST. It is always a relief to meet people from our country when we are abroad.

I was really helped by the orientation which was held before the semester started, especially the intensive Korean class. Through this class, I became more interested in the Korean language because I believed that when I understood more, it would ease my Korean life as well.

During my days at KIST, besides going to lectures, I spent most of my time researching in the lab. One thing that impressed me a lot was the very conducive research atmosphere. I never felt a lack of something while doing my research; everything I needed was there. The hardware, books, resources could be easily found. Seniors and lab mates were there to support me and my supervisor really supported me a lot both for my research as well as my studies. Here I would like to thank my colleagues and extend my deep gratitude to Dr. Park Ji Hyung for his guidance.

Besides the academic life, I enjoyed the cultural and sports activities which were held at KIST, like ICE (International Cultural Exchange), Sports Day, etc. One unforgettable moment was when my senior, Lee Joong-Ho seonbanim, introduced me and my Indonesian lab mate into a "band life" and we performed at two KIST events. It was my first time to be in a band. We might not be a professional one, but I enjoyed each time we gathered to practice.

Another thing that I appreciated about life at KIST was the international community. Meeting people from other countries helped me to be a more open-minded person.

Apart from my KIST life, I managed to do some sight-seeing and travelling around Korea. I believe one of the keys to survival in Korea is to enjoy it. The language which I thought was going to be the biggest barrier, was not a problem when I travelled around. I found out that Koreans are very helpful to people around them, even if you can only speak a little of the language, body language works well ^^ . Korea has many beautiful places to be visited, delicious meals to be tried, and interesting culture to be experienced. Going from place to place is not a problem anymore now that I understand the subway routes. It is especially convenient in Seoul because the subway covers almost all areas. There are many festivals and activities which are offered almost every weekend. Even now, I am still spending my weekends enjoying Korea; I've never gotten bored with it.

My two years at KIST were a precious experience for me, both in terms of academic and non-academic life. I am very proud to be part of the KIST alumni network.



Regards,

Martha Abednego

More informations for IRDA program of KIST.  
<http://irda.kist.re.kr>

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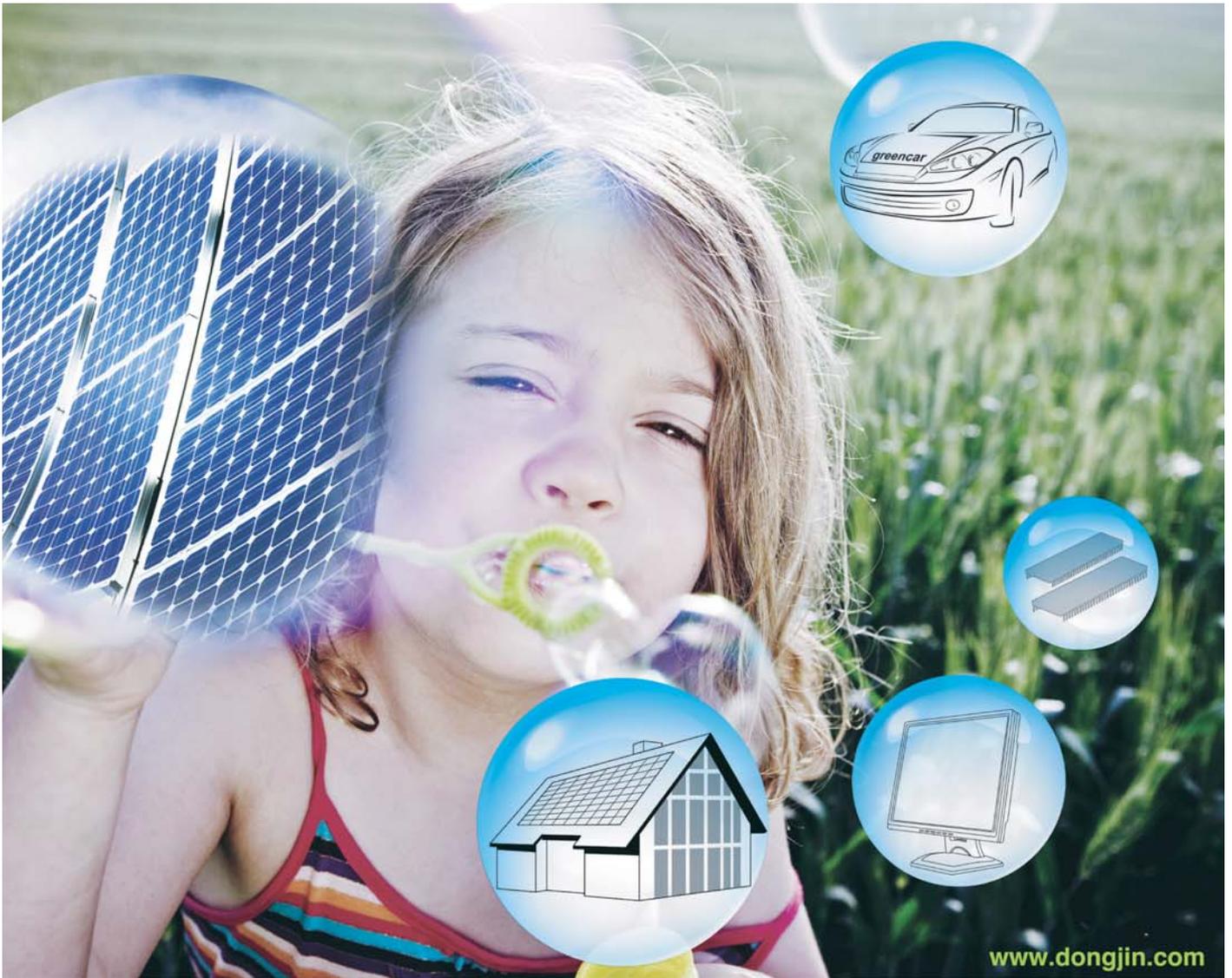
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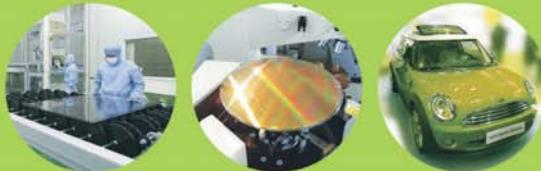
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