Technologies leading us into the future

Research Organizations

Robotics & Media Institute

- Center for Imaging Media Research
- Center for Intelligent & Interactive Robotics
- Center for Medical Robotics

The Robotics and Media Institute (RMI) is the largest government-sponsored research institute in the areas of robotics and media in Korea. RMI has about 200 researchers working on various projects in advanced media interaction and robotic technologies, such as humanoids, field robots, social robots, soft robots, manipulators, sensors, actuators, AI, big data, IoT, VR/AR/MR, 3D display, facial recognition, and UI/UX, which are essential for the 4th industrial revolution.

RMI consists of 3 research centers (Center for Imaging Media Research, Center for Intelligent & Interactive Robotics, and Center for Medical Robotics) and 2 initiative programs (Lunar Exploration Program and Robot Research Platform Initiative).

KIST
Korea Institute of Science and Technology

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Leading to tomorrow

KISToday

Sodium Battery? A Whimsical Idea Becomes a Game Changer

Research News

- QDSC Blocks Current Loss, Boosts Performance by 47% and Raises Hopes for Next-Generation Solar Cells
- Safe and Clean Water-Sterilized Without Chemicals
- KIST Develops Inexpensive and Efficient Next-Generation Fuel Cell
- Development of High-Quality Perovskite Synthesis Technology without Lead
- Development of Micro-Small Multi-function Brain Chip for Neural Circuits
- Applying Easy Multi-Target Gene Editing Techniques to Open the Way for New Anti-Cancer Immune Cell Therapy

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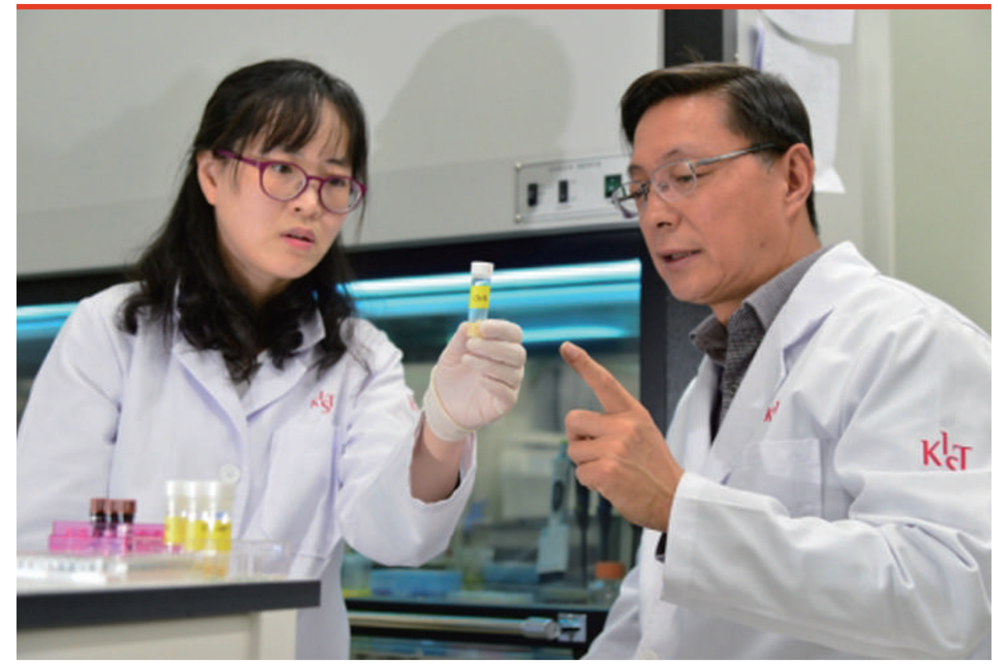
Cover Story

Center for Energy Storage Research of KIST successfully developed new electrode materials for sodium ion secondary batteries using sodium chloride (NaCl)

RNA-based Adjuvant as an Effective Stabilizer to Induce a Humoral Immune Response



As agonists of TLR7/8 (Toll-like receptor), single-stranded RNAs (ssRNAs) are safe and promising adjuvants that do not cause off-target effects or innate immune overactivation; however, low stability prevents them from mounting sufficient immune responses. This study aimed to evaluate the adjuvant effects of ssRNA derived from the cricket paralysis virus intergenic region internal ribosome entry site, formulated as nanoparticles with a coordinative amphiphile, containing a zinc/dipicolylamine complex moiety as a coordinative phosphate binder. We applied our amphiphile system as a stabilizer for RNA-based adjuvants. The nanoformulated ssRNA-based adjuvant was resistant to enzymatic degradation *in vitro* and *in vivo*.

See more details on
https://doi.org/10.1002/anie.202002979
"Nanoformulated Single-Stranded RNA-Based Adjuvant with a Coordinative Amphiphile as an Effective Stabilizer: Inducing Humoral Immune Response by Activation of Antigen-Presenting Cells." *Angewandte Chemie* (2020)

Big Data Analysis Preparing for Post-COVID-19 World

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has caused the global pandemic of the novel coronavirus disease 2019 (COVID-19). Responding to that, there has been a wide outflow of various potential solutions from researchers worldwide. Nearly every research institution is devoting all its efforts to diagnosing and finding treatment for the coronavirus as well as computing its spread rate and/or infection status.

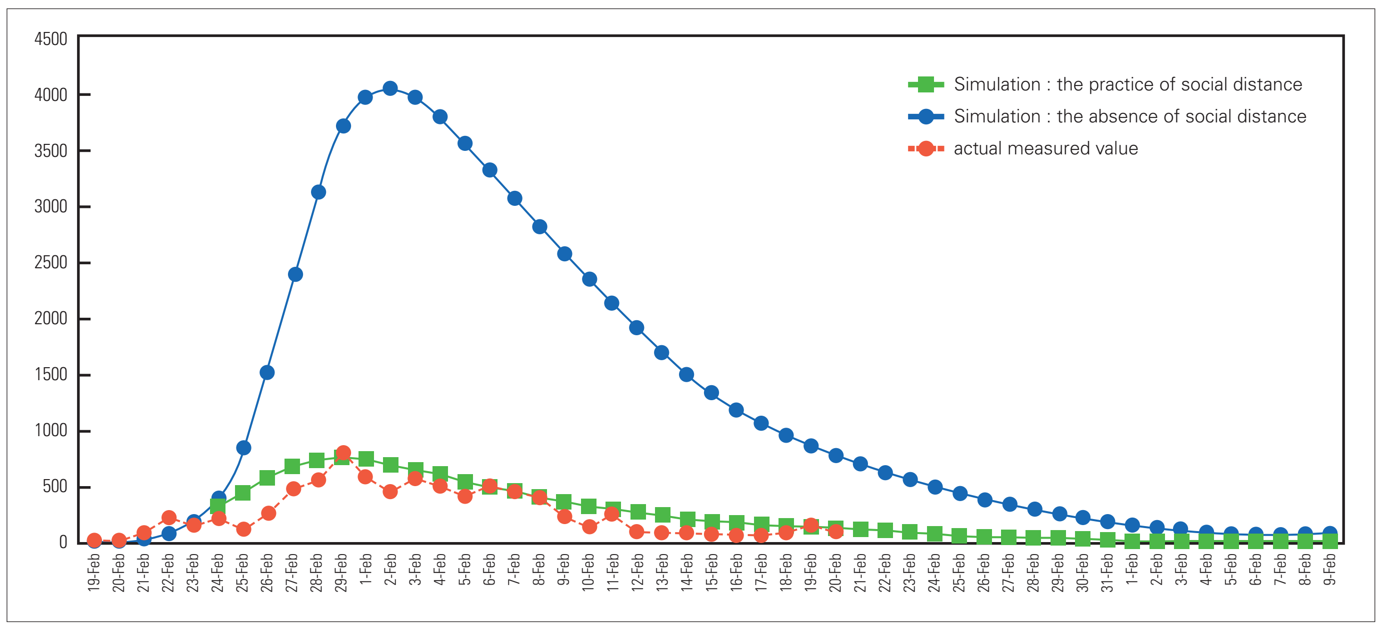
Many experts, however, believe that it will take at least a year to develop a vaccine and cure. This is because while stopping the virus from further spreading is a pressing issue, the process of verifying the impact of a new cure on a human body as well as its safety and effectiveness cannot be done overnight.

Therefore, both long- and short-term approaches to the COVID-19 have gained much attention: the long-term approach being the development of a cure or vaccine and the short-term being the practice of social distancing and daily preventive guidelines to prevent rapid spread and infection.

At the of KIST Computational Science Research Center, Dr. Chansoo Kim's research team developed and has been improving the original simulation toolkit, KIST's Individual-based Simulation for Transfer phenomena (KIST). His group has been focusing on macroscale simulations on the various spread/transfer using the complex system concepts and statistical mechanics, which include individual-based/space-based as well as data-driven approaches.

The KIST toolkit allows to see how individuals' movement can influence the disease spread. Then, the tool is able to deal almost fifty million people in Korea. It is an individual-based simulation computation system, which computes and assesses the spatiotemporal spread of COVID-19 and the significance of various mitigation policies such as social distancing, overseas inflow control and school opening scheduling.

Countries such as the UK are already utilizing such simulation tools to compute the virus's spread and infection rate, develop a mitigation strategy and assess its effect, and use those results to make firm policy decisions based on the science. Similar research had been suggested in Korea, but its progress was hindered by difficulties in accumulating big-data and the lengthy time required to gain results, making it difficult to be used actively in policy decision-making. Nevertheless, KIST and MSIT(Ministry of Science and ICT) had taken the ambitious long-term perspective and has been supporting such research projects and the development of science and technology in applied mathematics and complex systems.



Effect of social distancing: prediction and implementation (x-axis is time, y-axis is number of infections per day)

To analyze the spreading trend of COVID-19, the research team inserted big-data including the gender, age, job, travel route, and others into KIST's own toolkit.

To analyze the spreading trend of COVID-19, the research team inserted big-data including the gender, age, job, travel route, and others into KIST's own toolkit. In cooperation with the with MSIT of Science and ICT, they were was able to make predictions about the disease's spread and assess the effectiveness of a mitigation policy. The team creates 50 million "simulation individuals" using the nationwide data and performs a series of simulations by having them move based on Korea's geographic information inside a supercomputer, which is owned and seriously managed by KIST. They have been focusing on how the disease would spread in a given society, what could be optimal strategies to mitigate it and what changes would occur under those mitigation policies, not on making a "good guess" about when the pandemic would end. Many people including research societies are interested in this right guess, but the team believes that significance of simulations is rather demonstrating the changes, which are born by selected policies.

The "KIST toolkit," which has been developed and improved by the team since 2013, has the intrinsic individual concept for the epidemiology. That is also associated with differential equation model composed of S-(E)-(L)-I-R (Susceptible-Exposed-Latent-Infected-Recovered), which assumes "population mass." Since the toolkit is based on each individual's state, the interaction space is explicitly introduced enabling estimation of infected cases by area throughout simulations.

"Our toolkit allows us to view a social phenomenon that arises from individual behaviors," said Dr. Kim. He added, "We can use this tool to conduct numerical analysis for nonlinear complex systems. Continuous improvements also allow us to use the tool as a valuable test bed to experiment and assess policies to be carried out on individuals." He also emphasized, "The significance of simulations is not in getting a 'correct answer' but in exploring 'what changes' can be created by external factors such as policy."

“Quality, Impacts, and Necessity of Research Prioritized over Possibility of Success”

Byung Gwon Lee, 23rd-24th (2014~2020) President of KIST

“How can we translate national R&D success into innovative growth?”

The most frequently asked question during my time at KIST was “How can we translate national R&D success into innovative growth?” This is probably a different way of phrasing public criticism about “why Korea has failed to create a startup boom like Silicon Valley leveraging national cutting-edge research and development?” The multitude of policy recommendations proposed by the government, national assembly, and academia are not the solution either. I had time to really mull over this question while on a trip to Glasgow, U.K., which is the birthplace of James Watt and the steam engine.

Contrary to popular belief, James Watt was not the first person to come up with the concept of the steam engine. The concept of the steam engine first emerged in ancient Greek physicist Heron’s book “Pneumatica” in the 1st century BC. Then in 1705, Thomas Newcomen invented today’s concept of the steam engine and in 1765, James Watt developed an improved steam engine, which triggered the industrial revolution.

James Watt made history when he innovated Newcomen’s steam engine after being commissioned while working as an engineer at University of Glasgow. The steam engine that had disappeared into history came back to life with efficiency and economic feasibility, bringing out revolutionary changes to factories and transportation. However, R&D in Korea tends to stop at dissertations and patents, which seemingly represent successful testing and research results. Research and development must go beyond that to provide direct benefits that are useful and accessible to everyone in the form of revolutionary technology and innovation.

It is now high time that we create R&D culture by nurturing the countless successful fundamental studies out there so that they can translate into innovation. This begins with changing the way we perceive fundamental research – going a step further from just creating the seeds for growth, by solving the obstacles ahead for the seed to take root and blossom. This requires wide-ranging follow-up and complementary studies that can

It is now high time that we create R&D culture by nurturing the countless successful fundamental studies out there so that they can translate into innovation.

help commercialize basic and fundamental research results, in tandem with an immediate structural overhaul of national R&D projects that are currently siloed, lacking uniformity and without a proper pipeline that connects basic and fundamental research to applied and commercialization research.

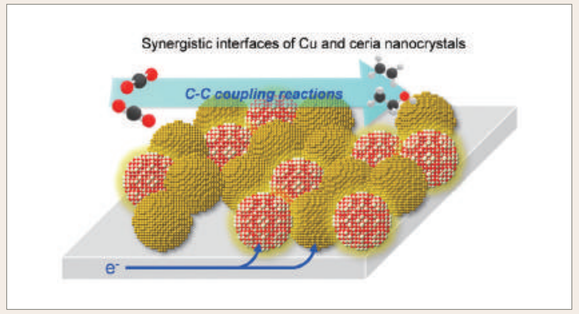
Improvements to the evaluation system for government-funded organizations in order to encourage creative and bold research is critical. The focus should be on quality instead of quantity, and impact and necessity of the research rather than its possibility of success. A telling example of such high-risk, high-return initiatives is K-DARPA, a national innovative defense technology project that represents KIST's effort to encourage new and bold research. K-DARPA's evaluation criteria are mainly related to setting clear targets, assessing potential social impact, etc., which is why researchers dive into studies that can create significant social impact despite the high level of difficulty such studies require.

Improving the evaluation system of government-funded institutes begins with completely changing the way we think about and approach R&D. The idea that cutting edge technological developments in the age of the 4th industrial revolution require a different approach compared to our current trajectory of basic, fundamental, applied, and commercialization research needs to be embedded from the get go at the design phase of policies. In addition, legal and institutional infrastructure need to undergird new technological expansions in society. The Parliament of the United Kingdom played a critical role when it approved an extension on the patent for the steam engine. This provided James Watt with the opportunity to work with renewed vigor on improving the steam engine. Furthermore, this move by the Parliament sent a clear message that U.K. law recognizes and protects the value and hard work that goes into innovation.

In the late 1700s, the Lunar Society, a monthly gathering of prominent intellectuals in the U.K. scheduled on the day of the full moon, was founded. Erasmus Darwin, grandfather of Charles Darwin, Joseph Priestley who discovered oxygen, and James Watt were all members of the Lunar Society. These esteemed figures gathered to talk about different areas of interest of the time and debated how these ideas could be developed into science and technology that improve our daily lives.

Hongneung Research Complex, where KIST is located, is being revamped as platform for bleeding-edge innovation in order to create an innovative ecosystem in which universities, research institutes, and startups work together to translate the latest research results into actual jobs and value. In fact, the district where this complex is located happens to be called Lunar Valley. I look forward to the achievements that the talented individuals here will bring about in Industry 4.0, much like James Watt did back in history and pave the way for innovation as the members of the Lunar Society did dating back centuries.

Taking a Step Further to Electrochemical CO_2 Conversion Technology

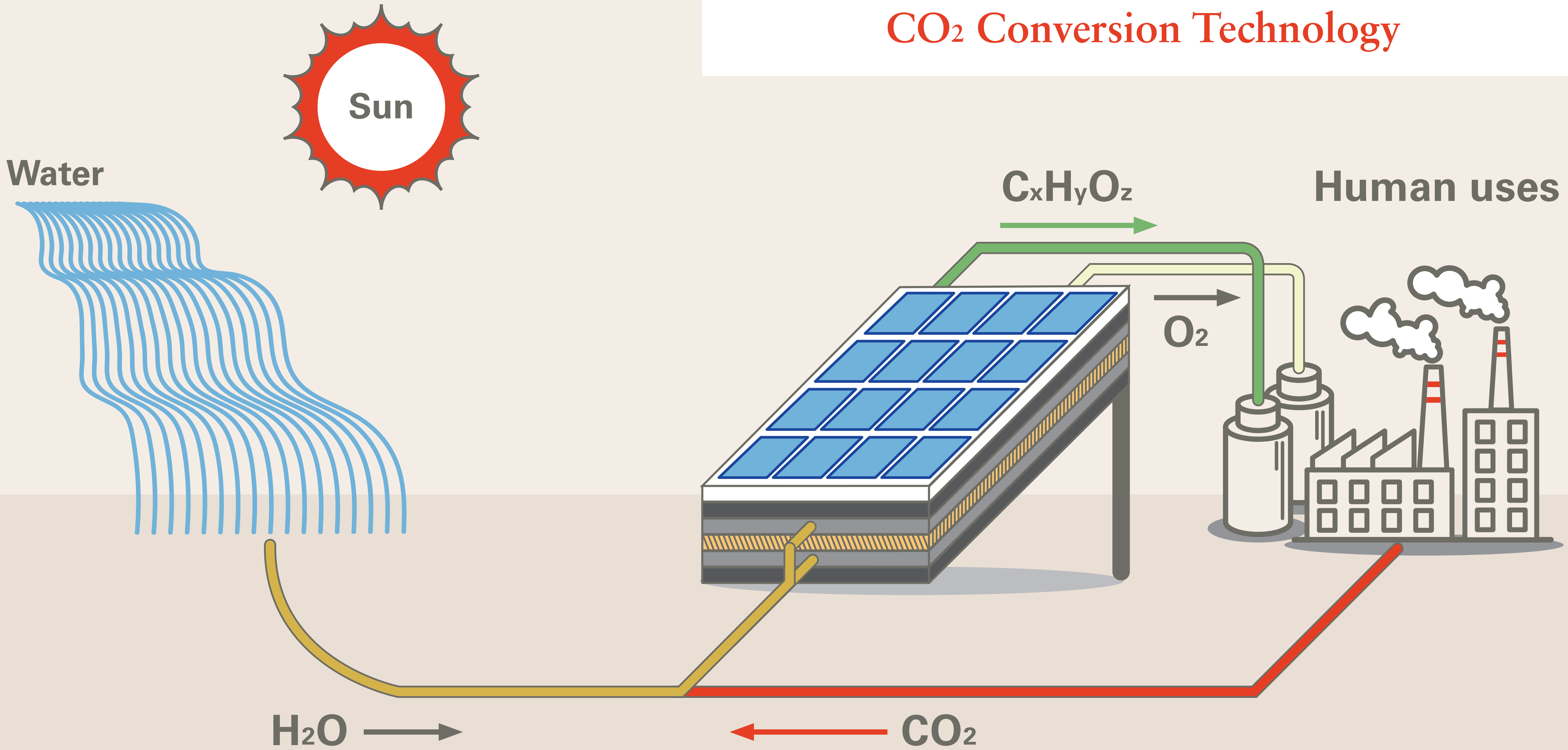


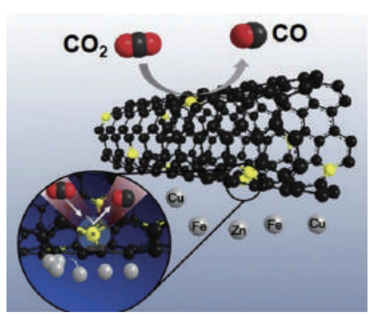
Metal–oxide interfaces provide a new opportunity to improve catalytic activity based on electronic and chemical interactions at the interface. Constructing a high density of interfaces is essential in maximizing synergistic interactions. Here, the research shows that Cu–ceria interfaces made by sintering nanocrystals facilitate C–C coupling reactions in electrochemical reduction of CO_2. The Cu/ceria catalyst enhances the selectivity of ethylene and ethanol production with the suppression of H_2 evolution in comparison with Cu catalysts.

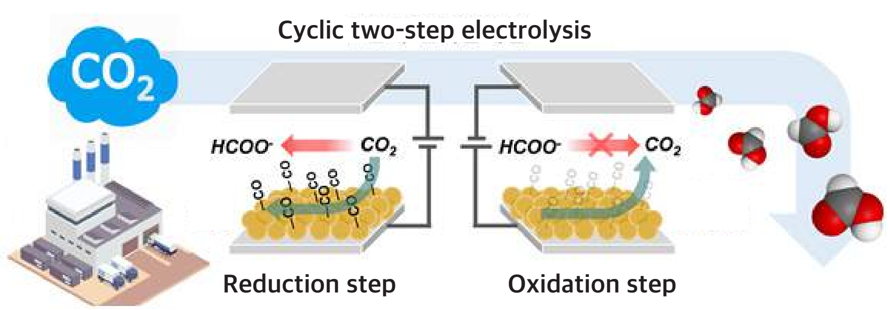
See more details on
https://doi.org/10.1021/acsenergylett.9b01721
"Metal–Oxide Interfaces for Selective Electrochemical C–C Coupling Reactions." *ACS Energy Letters* 4.9 (2019)

In order to achieve practical application of electrochemical CO_2 conversion technologies, the development of durable catalyst in real water matrix is essential because the use of catalysts only showing high performance within a well-refined environment cannot guarantee their feasibility in realistic conditions.

See more details on
https://doi.org/10.1016/j.apcatb.2019.117961
"Achieving tolerant CO2 electro-reduction catalyst in real water matrix." *Applied Catalysis B: Environmental* 258 (2019)







Electrochemical CO_2 reduction combined with renewable energy resources represents one of the promising strategies for not only reducing greenhouse gas emissions, but also storing electrical energy in a value-added chemical form. A key challenge is how to minimize or prevent catalyst degradation caused by CO poisoning.
Here, we demonstrate that cyclic two-step electrolysis, by applying the reduction and oxidation potentials alternately, achieves 100% current density stability and 97.8% selectivity toward $HCOO^-$ production for at least 45 h.

See more details on
https://doi.org/10.1038/s41467-019-11903-5
"Cyclic two-step electrolysis for stable electrochemical conversion of carbon dioxide to formate." *Nature communications* 10.1 (2019)

New Principle to Open the Era of Customized Medical Science

Theragnosis, by combining diagnosis and treatment, is breaking conventional thinking on serious illnesses such as cancer and rheumatism and is using a new principle as it opens a new era of customized medical science.

Rising income levels and better quality of life have led to a growing interest in health and medicine, and today customized medical technology is particularly gaining much attention.

When we are sick, we see the doctor at the hospital and take medicine made in the pharmacy. The medicine, however, is not 100% effective on everyone. The reason behind this is because drugs are made after averaging optimal effectiveness derived from experiments on the amount and timing of drug intake. Thus, individual patients may experience inefficiency when trying to get 100% cured if they go to the hospital and take medicine in general.

As a result, there is an increasing interest in customized medical technology that factors in individual genetic traits or unique health habits. Genetics is particularly known to be an extremely critical and unique individual trait, which is why many people are interested in customized medicine via genetic analysis. The human genome is like a chain of three billion marbles, and genetic analysis interprets the predetermined set of sequence. Since each person inherits different genes from their parents, genetic analysis enables us to better understand individual differences, much like distinctive personalities and looks. Combining such genetic information with personality, age, and eating habits can help us better infer what illness one might have in the future, which drug will be most effective, and what diet works best, taking us closer to “customized medicine”. However, commercializing customized medicine using genetic analysis has its obstacles - namely, the high expense of genetic testing, which still costs around thousands of dollars.

Recently, there has also been a growing interest in theragnosis research, which is different from genetic research yet can carry out customized diagnosis and treatment.

Theragnosis, a term combining therapy and diagnosis, is a technology for the simultaneous process of early detection through fluorescent substance and therapeutics. Based on its vision for future health care that provides simultaneous diagnosis and therapeutics and in order to become a leader for relevant base research, KIST launched the Center for Theragnosis in 2009. With theragnosis, it is possible to visually check changes taking place within a patient’s body after taking drugs, making it possible to diagnose and individually tailor treatment for long-fought diseases such as cancer or rheumatism.

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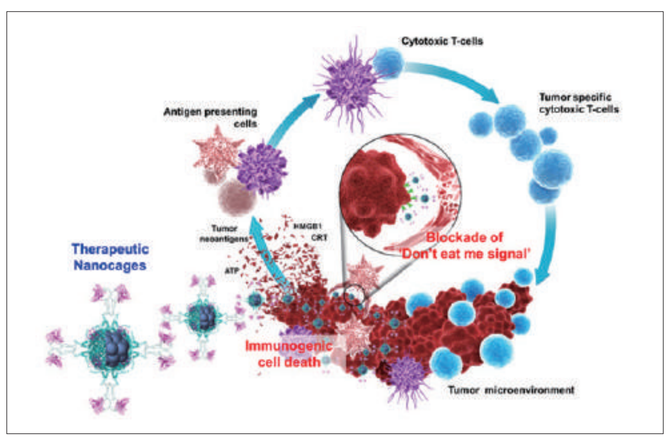
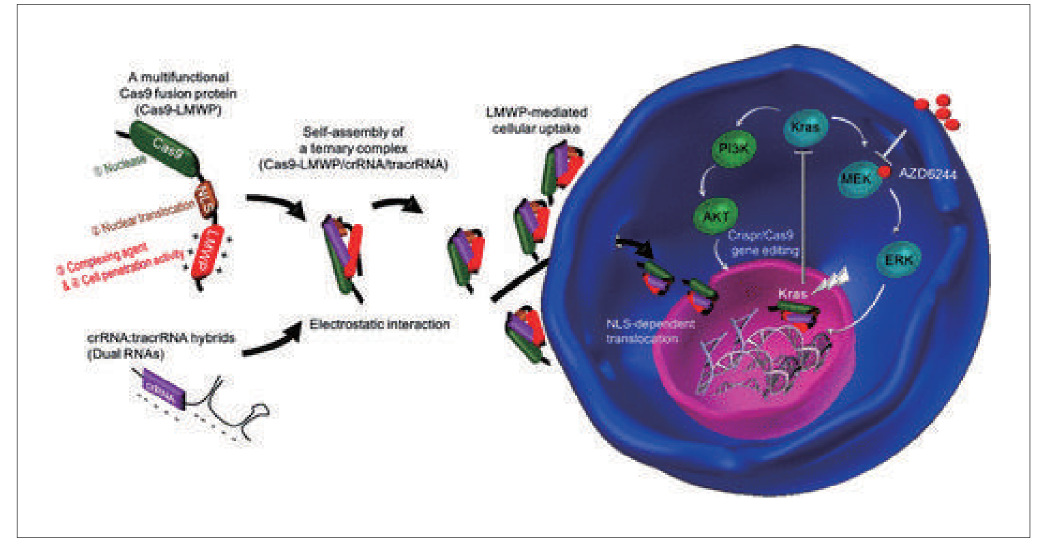


“Nanocage-therapeutics prevailing phagocytosis and immunogenic cell death awakens immunity against cancer.” *Advanced Materials* 30.10 (2018)



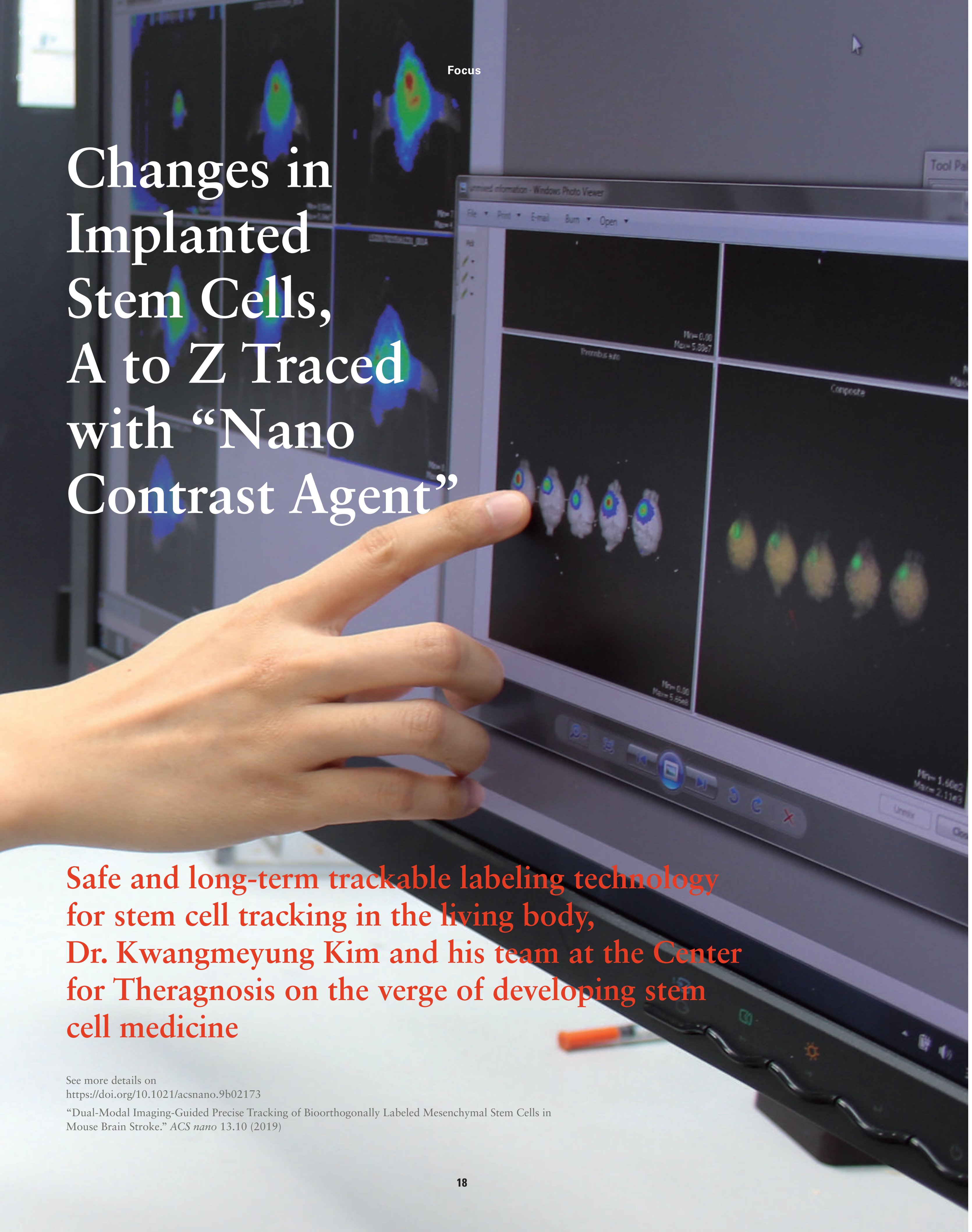
“Simple in vivo gene editing via direct self-assembly of Cas9 ribonucleoprotein complexes for cancer treatment.” *ACS nano* 12.8 (2018)

Take cancer, for example. After drug delivery, doctors use X-ray to detect a decrease in cancer cells and this requires a month of waiting for the cancer cells to drop to a visibly noticeable level. With theragnosis, doctors can visually identify using real-time images how anticancer agent binds to cancer cells and check the level of drug effectiveness. The more active cancer cells are the brighter their fluorescent light is, and it is possible to visually check the light dying after drug delivery, allowing doctors to immediately confirm whether the cancer is being treated. In addition, theragnosis can be useful for cancer surgery as cancer will emit fluorescent light. During cancer surgery, healthy tissues surrounding cancer tissues are also removed, due to concerns that cancer cells may remain. However, such method can be dangerous when dealing with brain tissues, and theragnosis can enable doctors to perform surgery without damaging surrounding tissues because only the cancer tissues will emit fluorescent light.

“It is common to remove surrounding tissues out of fear that cancer cells may be remaining in the body. Such surgical method may not be a problem for gastric cancer, but it is for brain tissues,” explained Dr. Ick Chan Kwon. “But using theragnosis, you notice fluorescent light being emitted only by cancer cells, and so you don't damage surrounding tissues.”

The same goes for rheumatism. Enzyme that melts down cartilage does this slowly, so it is difficult to determine at an early stage whether a patient has rheumatism or arthritis even after testing. It is thus common to see patients with rheumatism coming to the hospital after most of their cartilage has been damaged and impossible to recover. With theragnosis, doctors can identify enzymes via imagery and immediately check whether a drug is blocking enzyme activity, enabling early diagnosis and treatment of the disease.

Theragnosis, by combining diagnosis and treatment, is breaking conventional thinking on serious illnesses such as cancer and rheumatism and is using a new principle as it opens a new era of customized medical science.



Changes in Implanted Stem Cells, A to Z Traced with “Nano Contrast Agent”

Safe and long-term trackable labeling technology for stem cell tracking in the living body, Dr. Kwangmeyung Kim and his team at the Center for Theragnosis on the verge of developing stem cell medicine

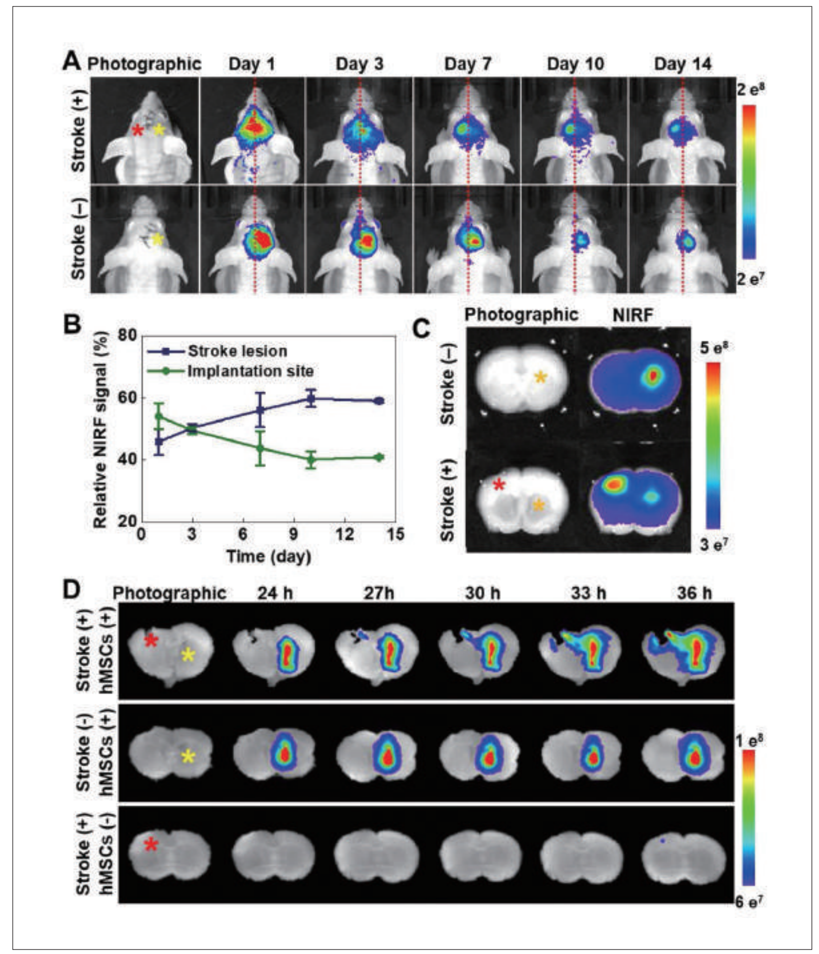
See more details on
https://doi.org/10.1021/acsnano.9b02173
“Dual-Modal Imaging-Guided Precise Tracking of Bioorthogonally Labeled Mesenchymal Stem Cells in Mouse Brain Stroke.” *ACS nano* 13.10 (2019)

Hong Yeol Yoon
Senior Researcher
Center for Theragnosis

Kwangmeyung Kim
Principal Researcher
Center for Theragnosis

Stem cells are pluripotent, which means that they can develop into any type of organ or tissue. In fact, stem cells are what allow our body heal wounds. Theoretically, stem cells are capable of regenerating any type of cell or tissue, including muscles, bones, organs, and our brain. The possible applications of stem cells as treatment agents are significant because stem cells can self-replicate and are pluripotent, which means that they can develop into other tissues that our body needs. This is why research on developing cell therapy using stem cells and a wide array of clinical studies are underway across the world.

Near infrared fluorescence (NIRF)-based *in vivo* real-time tracking of bioorthogonally labeled hMSCs in a mouse PTS model



However, the downside to implanting stem cells in our body is that accurately identifying the stem cell’s fate such as migration, survival and differentiation process is difficult.

KIST successfully developed a nano contrast agent that accentuates the implanted stem cells and used it for imaging. This technology binds highly biocompatible nano particles of contrast agents bound to stem cells to help monitor the implanted stem cells with a combination of long-term fluorescent imaging and magnetic resonance imaging (MRI).

Dr. Kwangmeyung Kim and his team at the Center for Theragnosis and Dr Dong-Eok, Kim and his team from Dongguk University Ilsan Hospital carried out the research. It seems that this study will lay the foundation for developing stem cell treatments for brain disease.

The importance of tracing: preventing side effects and predicting therapeutic efficacy of treatments

“Tracking and observing implanted stem cells with precision helps prevent side effects and predict the therapeutic efficacy of treatments.”

Dr. Kwangmeyung Kim and his team focused their research on developing a nano contrast agent to accentuate implanted stem cells without genetic modification and identifying the optimal condition for labeling stem cells efficiently using this nano contrast agent.

Let’s take a look at how observational studies on the movement and distribution of therapeutic stem cells began. According to Dr. Hong Yeol Yoon, at the Center for Theragnosis, it’s critical in stem cell therapy that stem cells reach the right place and do what they need to do. This is especially the case for stem cells that assist cell and tissue regeneration in order to prevent side effects. Dr. Yoon stated that "biomonitoring is essential because depending on the surrounding environment stem cells can potentially differentiate at the wrong place and time or reduce the efficacy of the therapy."

However, existing contrast agents that help trace stem cells were inefficient at labeling because they are not easily absorbed into stem cells. Furthermore, the additional genetic modification step required to convert the cells to make imaging possible meant that teratoma and safety was always an issue.

In an effort to remedy this problem, the research team turned their attention mainly to "metabolic glycoengineering" and "bioorthogonal copper-free click chemistry".

"Metabolic glycoengineering" is a technique based on glycoprotein synthesis that helps artificially manipulate the amount of chemical reaction of non-totoxic and labelable reactors. "Bioorthogonal copper-free click chemistry" is a phenomenon of specific binding of two molecules without using toxic copper catalysis. This has the advantage of being non-totoxic and faster in response.

The research team successfully combined these two methods to develop a chemoreceptor that can safely label stem cells, along with an iron-oxide- and fluorophore-containing glycol chitosan nano contrast agent that binds specifically. As a result, the team was able to obtain MRI and fluorescence dual images that maximize the imaging signals from stem cells.

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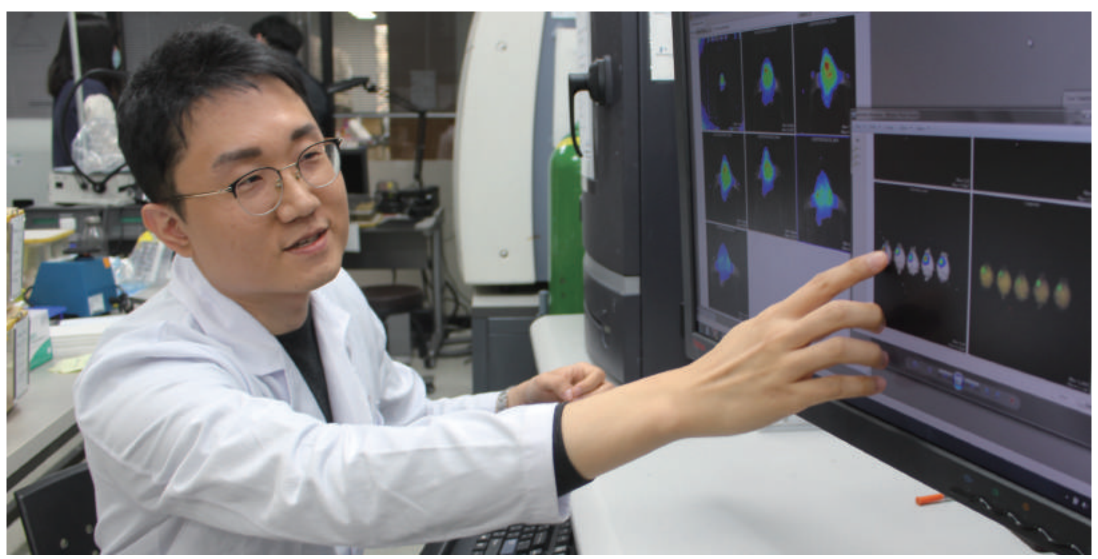
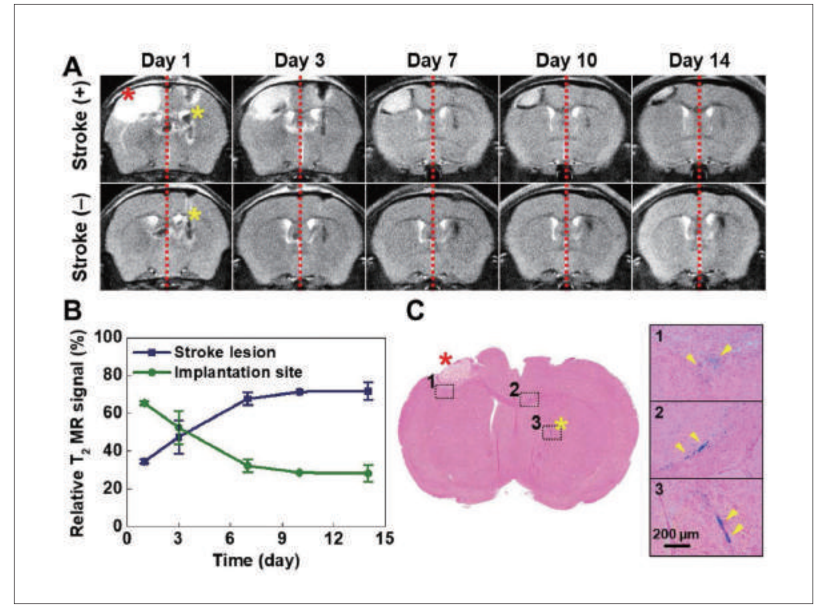




In vivo real-time tracking of bioorthogonally labeled hMSCs in a mouse PTS model using 4.7T MR imaging

Using this technology, the research team was able to use near-infrared fluorescent imaging and MRI imaging to trace stem cells in a mouse brain stroke model for 14 days. Dr. Yoon explains that "long-term tracing was possible because we minimized differentiation capacity loss and cytotoxicity."

Business trips accompanied by a mouse... "wide ranging experiences helped our research"

"My first attempt at growing stem cells was hard. Our research team had to take the lab mouse on business trips back and forth from KIST and KBSI (Korea Basic Science Institute). As a result, these efforts helped to acquire wonderful stem cell images in our research."

It took six months just to get familiar with cultivating stem cells. Dr. Yoon said that he "worked with stem cells in past studies, but it was difficult this time because we did not have the laboratory infrastructure needed to conduct studies on a mouse brain stroke model using stem cells," adding that "stem cells are extremely sensitive, which is why there was a lot of trial and error, but mistakes can cause difficulties in the experiments down the road, so I had to invest about six months so that I could learn the ins and outs of stem cell culture."

The research team also took on new challenges, including obtaining an animal model with clinical disease from an expert. The team also took advice from experts on matters where they did not have experience, such as medical interpretations of MRI data and research settings for a stem cell study.

The most memorable moment was the business trip with the mouse, or animal model to check whether the nano contrast agent was properly labeling.

He says "we had to go to KBSI in Ochang with the mouse we were experimenting with because we didn't have MRI equipment. We went to get MR images in the morning and came back to KIST to get fluorescence images," adding that "MRI takes a long time, but has the upside that you can get an image of the entire tissue, while fluorescence imaging is faster and more accessible. That is why we used both so that they could complement each other."

According to Dr. Yoon, "detailed tracing of the movement and dispersion of stem cells implanted in animals in the research stage can be applied to efficacy assessments of cell therapies and development of new cell therapeutics." Dr. Yoon plans to build on this stem cell labeling and tracking technology and dive into researching new treatments for cancer.

Recruitment

KIST is looking forward to recruit creative and passionate research talent both in Korea and from abroad to continue our move to a position of preeminence in global research.

- **Job openings: Ph.D ○○ openings**
  *Applicant may apply for only one job opening
- **When & How to Apply**
  Please refer to the details after July 24th
  http://www.kist.re.kr
  http://onest-kist.saramin.co.kr

Categories and Specific Areas of Research

Brain Science Institute

- Examine brain function and cause of disease; utilize mapping of functional-structural connection in neural circuits
- Computational neuroscience
- Neural stem cell application
- Microsensors, MEMS, Brain Engineering and Microsystems
- Brain Disease/Neurochemical Imaging and Therapeutics

Biomedical Research Institute

- Analysis and application of medical big data
- Rehabilitation technology for overcoming disabilities
- Electric/optical sensors for implantable devices
- Targeted anticancer agents and cancer immunotherapy

Clean Energy Institute

- Material and system technology for hydride/fuel cell
- Hydrogen storage material and module technology
- Solid state electrochemical thin film process and engineering technology
- Synthesis of advanced secondary cell liquid electrolytes, separators, battery engineering and production, electrode material technology

Post-Silicon Semiconductor Institute

- Quantum Computing, Quantum Communication, Quantum Information Theory
- High speed electronic device/nonlinear photoelectric device, optical data control/analysis/design
- Spin device using nano spin dynamics and spin trajectory
- Neuromorphic semiconducting material/devices/system

Robotics and Media Institute

- Technology and system technology for intelligent robots (control/recognition/human robot interaction, etc.)
- Atmospheric environmental science related to fine dust
- Medical robot system technology
- 2D/3D video and media technology
- AI core technology

Materials and Life Science Research Division

- Photonics materials and devices for optical control
- Biomarker detection technology based on omics and antibody engineering
- Cancer immunotherapy and medicinal chemistry
- Materials for extreme physical properties and extreme environments(energy, environment, structure)
- Multiscale organic-inorganic hybrid catalyst active material

National Agenda Research Division

- Technology and system technology for intelligent robots (control/recognition/human robot interaction, etc.)
- Atmospheric environmental science related to fine dust
- Medical robot system technology
- 2D/3D video and media technology
- AI core technology

KIST Gangneung* (*Must be able to work in Gangneung)

- Identify and verify the efficacy and mechanism of natural substances based on omics data
- Bioinformatics for the application of precision medicine to natural materials
- Analysis of changes in the signal transduction system in vivo induced by natural products (mRNA/protein)
- Smart Farm AI Control and Modeling

KIST Jeonbuk* (*Must be able to work in Wanju)

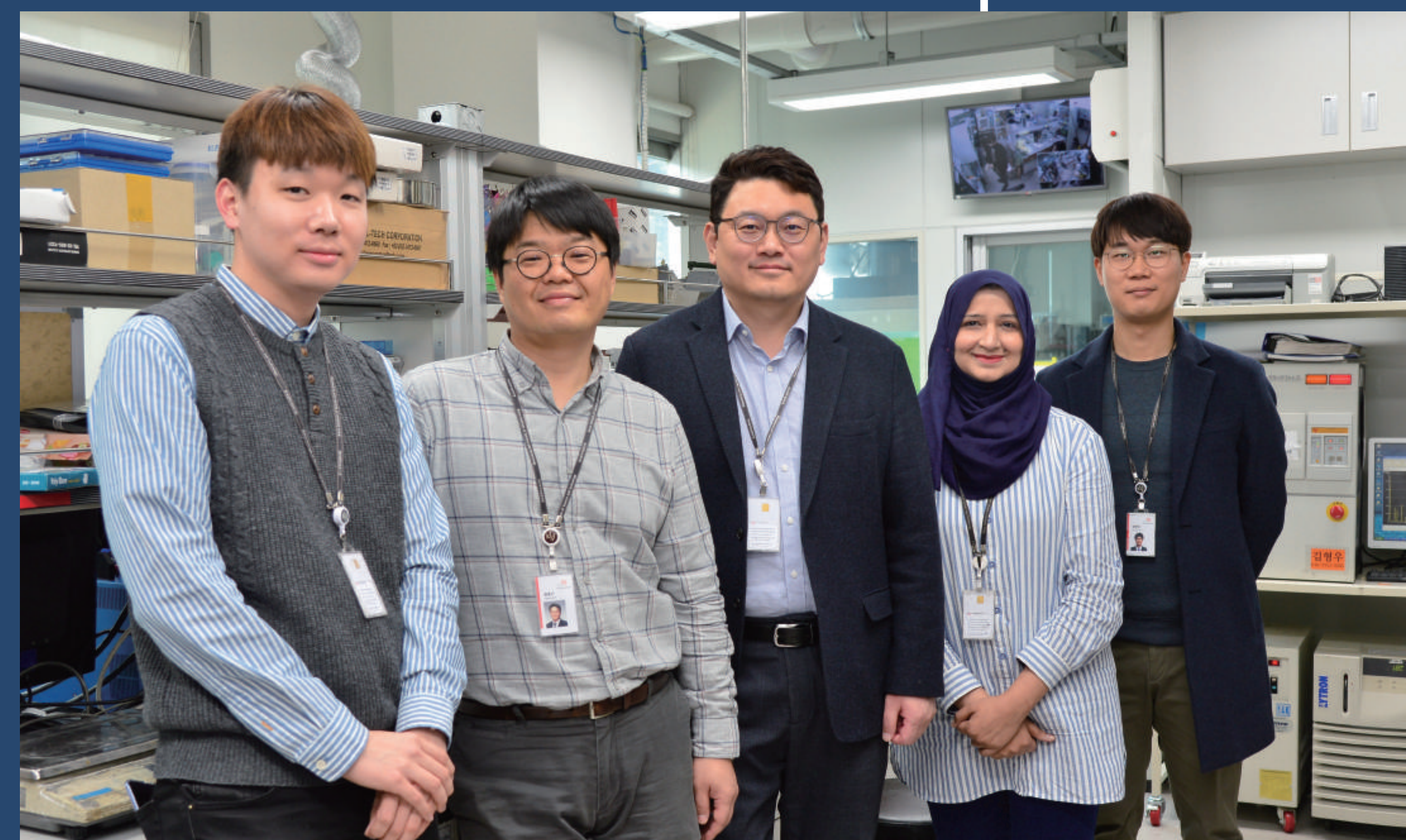
- High temperature carbon composite material manufacturing technology
- Synthesis and mechanical molding/physical analysis of thermoplastic/thermosetting polymer resins
- Polymer synthesis and analysis
- Multi-scale modeling of structural composite materials

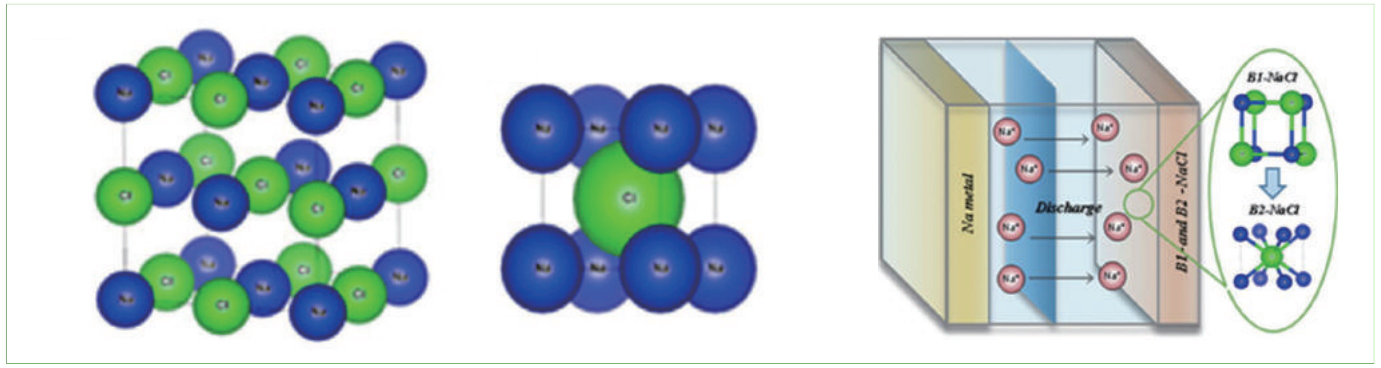
01

Sodium Battery? A Whimsical Idea Becomes a Game Changer

Kyung Yoon Chung
Principal Researcher/Head
Center for Energy Storage Research

See more details on
https://doi.org/10.1021
acsenergylett.9b01118
"Electrochemically Induced Metallization of NaCl: Use of the Main Component of Salt as a Cost-Effective Electrode Material for Sodium-Ion Batteries."
ACS Energy Letters 4.9 (2019)





Crystal structure of B1-NaCl (face centered cubic structure with six fold coordination) and B2-NaCl (like CsCl: body centered cubic structure with eight fold coordination)

The dream of building next-generation batteries has become reality. This is a feat after listening to voices of concern and doubt. Kyung Yoon Chung, Head of the Center for Energy Storage Research spearheaded this research, alongside Hee-Dae Lim, Ph.D. and Ms. Iqra Moeez, Ph.D. student (first author) from Pakistan. The initial idea came from Ms. Iqra Moeez.

Dr. Chung's team successfully developed new electrode materials for sodium ion secondary batteries using sodium chloride (NaCl), which is a major component of salt, through a simple electrochemical tunning process to transform electrochemically inactive sodium chloride into the active phase of electrode material. Salt is abundantly available in ocean water, which can improve pricing and economic competitiveness.

Dr. Chung says that "Ms. Iqra Moeez always loves trying something new. Some people were dubious when she told them about using sodium chloride, but she persisted and found a way."

Concerns and doubt, a lonely battle… changing the properties of sodium chloride

The lithium ion batteries which we generally use in a daily life have superior performances compared to other battery systems. But, the raw materials such as lithium,

The dream of building next-generation batteries has become reality.

cobalt, nickel and others which are used to fabricate the lithium ion battery are relatively rare. Futhermore, these raw materials are produced in only the specific regions of the world, and the its cost is increasing as the demand for the batteries increases. Thus, the demand for the alternative battery system with economic competitiveness has increased and one of the promising candidate is sodium ion battery.

The key factor to achieve next-generation sodium ion secondary batteries is developing efficient electrode materials having actual electrochemical response. However, sodium chloride or "sea salt" - an element that is most readily available in our daily lives – could not be used in rechargeable batteries because it is not electrochemically active. Instead, most of studies have been focused on intercalation-based materials such as NaxMO2, NaMPO4 (M=Fe, Mn, Co, Ni).

But one day in 2016, Ms. Iqra Moeez called on Dr.

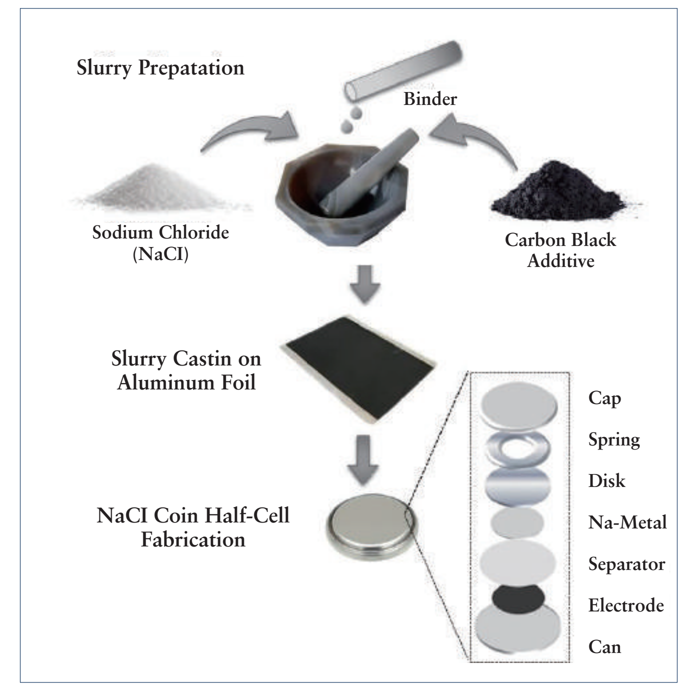
The lithium ion batteries which we generally use in a daily life have superior performances compared to other battery systems. But, the raw materials such as lithium, cobalt, nickel and others which are used to fabricate the lithium ion battery is relatively rare.

Chung, with a proposal to "electrochemically activate sodium chloride and use it in batteries". Since the application of batteries is expanding from small electronic devices to large scale applications such as electric vehicles or energy storage system (ESS), the development of a new battery for large scale applications based on abundant raw materials system would be very important. And, Ms. Moeez's proposal could potentially achieve this.

Ms. Iqra Moeez, who has tried challenging things bravely, proposed a fanciful idea. In the discussion, Dr. Chung said that "The idea and priliminary data were interesting.", adding that "Although we couldn't guarantee the success, it must be worth trying. We went ahead in this study with the belief that attempting various different methods in our research would yield positive results."

So the research had begun, but the progress was slow. Some people would ask Ms. Iqra Moeez "Why are you doing that research?". This caused doubt about the research and we started wondering whether we should scrap the project. But every time Ms. Iqra had difficulties, she discussed the study in depth with Dr. Chung and Dr. Lim.

Three years into the study, Dr. Chung and his team came up with a way to electrochemically activate sodium chloride compounds and presented the possibility of using



Sodium Ion Battery(SIB)

sodium chloride as a material for electrodes. A special electrochemical process was used to transform sodium chloride into a structure that can be used for electrodes. This process made a path in sodium chloride so that sodium ions could move around freely, thus making it possible to use sodium chloride as an electrode material in sodium ion secondary batteries.

Dr. Lim says that "Previous studies about activating sodium chloride involved complicated processes using high temperature and high pressure, which diminished their economic feasibility," adding that "Our process is quite simple and involves none of them, which is why we confirmed its potential application in existing battery manufacturing processes."

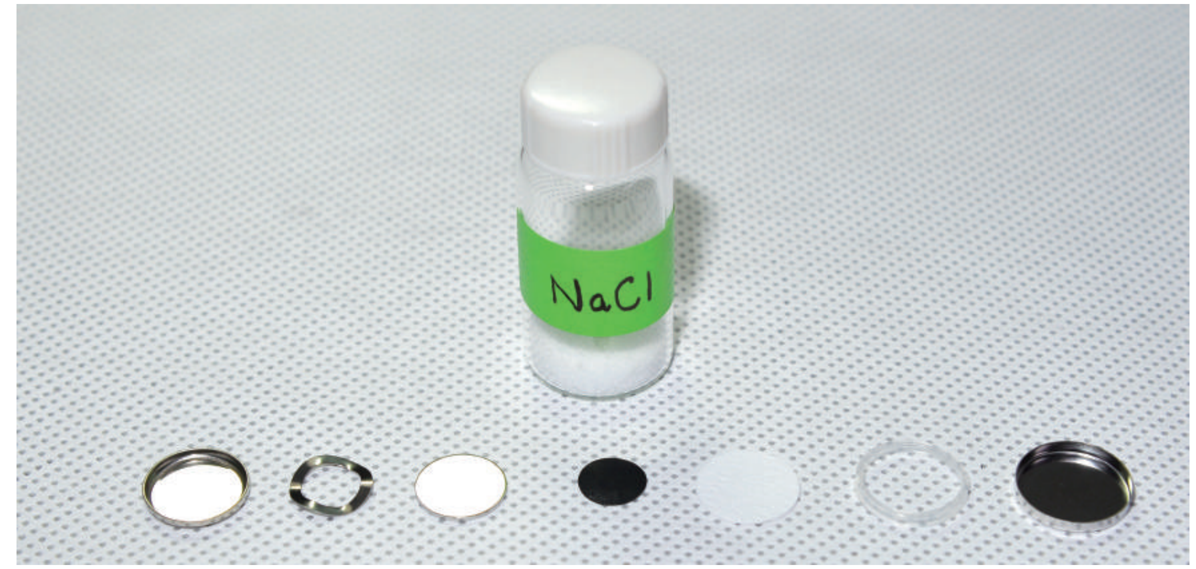
Dr. Chung's team is currently conducting follow-up studies aimed to improve electrochemical performance. They aim to utilize a sugar as a conducting agent in this system. The team is currently researching ways to enhance the performance of sodium chloride by coating with conducting carbon made from sugar. It is also new challenges but they believe it is worth to try.

A bold move slated to become a game changer for batteries

Dr. Chung says that "Why would you make SUVs if sedans are already in the market? It's the same logic with batteries. The battery market will steadily grow with time. The current Lithium ion battery alone is not sufficient to support the fast-growing huge markets. This is the reason why we are developing next-generation batteries." Dr. Kyung Yoon Chung, Head of the Center for Energy Storage Research

Dr. Chung emphasizes that "Importance of developing batteries to build a hyper connected society in the age of the fourth industrial revolution." Miniaturizing mobile devices, autonomous EVs, drones, IoT, and other elements that characterize industry require portable and convenient batteries. Dr. Chung added that "Just as laptops and mobile phones wouldn't have been developed like those we are using without lithium ion batteries, the future will require alternative next-generation batteries."

Iqra Moeez(1st Author) is testing Sodium Battery(SIB) with salt



Decomposition of Sodium Battery(SIB) with salt

The current Lithium ion battery alone is not sufficient to support the fast-growing huge markets. This is the reason why we are developing next-generation batteries.

Moving forward, Dr. Chung's team plans to focus on developing next-generation batteries that will eliminate the current limitations we have with existing batteries.

Dr. Lim states that he wants to take on "new challenges" and build next-generation batteries. According to Dr. Lim, "three scientists were awarded the Nobel Prize last year for developing lithium ion batteries. However, the materials we use today are the same as the ones we used two decades ago, with some minor improvements" and "Those minor improvements are very important, however, it is time to move on the second-stage of batteries with significantly improved quality and performance. Therefore, new materials need to be developed in order to make breakthrough changes in the battery industry."

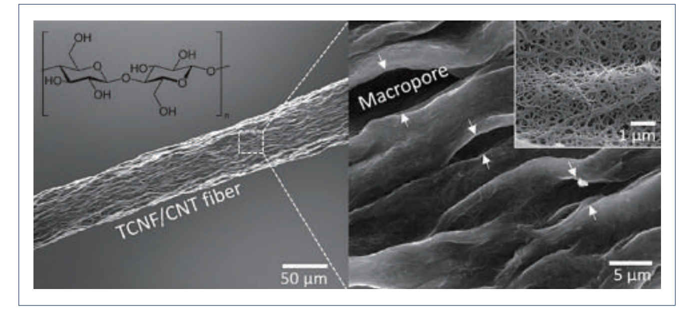
Ms. Iqra Moeez expressed that "Being a part of a developing country like Pakistan, I always think to add significant part through my research in the betterment of the society and humanity as a whole."

Wearing “Sea Tunicate Clothes” to Detect Hazardous Gas, Making Wearable Sensors

See more details on
https://doi.org/10.1021/acsnano.9b03971
“Continuous meter-scale synthesis of weavable tunicate cellulose/carbon nanotube fibers for high-performance wearable sensors.” *ACS nano* 13.8 (2019)

02

Hyeon Su Jeong
Senior Researcher
Materials Architecturing Research Center



Scalable synthesis of the TCNF/CNT fibers and material characterizations

A package arrived at KIST laboratory and inside the heavy and sizeable box, a sharp item was unveiled. Inside this somewhat fishy smelling box was none other than “sea tunicate”.

A laboratory and sea tunicate – this mismatched combination was actually a result of hard work put in by researchers to obtain. Dr. Hyeon Su Jeong and Seoung-Ki Lee’s research team at the Functional Composite Materials Research Center used these sea tunicate to successfully make wearable sensors that detect harmful gas.

The research team used the nanocellulose obtained from sea tunicate and carbon nanotubes to develop composite textile to use as materials for the sensor. This sensor is able to detect harmful nitrogen dioxide. This sensor has immense potential as a next-generation wearable sensor as it can be weaved onto ordinary textiles and is economically feasible as it can be non-postprocessed and continuously mass produced.

Dr. Jeong says that “exposure to high concentrations of nitrogen dioxide can damage a person’s respiratory system and lead to pneumonia,” adding that “this wearable sensor provides us with easy, fast, and accessible real time information about the user’s state or CO_2 in the air. The main advantage is that it is easy to manufacture all the basic materials needed for this sensor all at once.”

The unique pore structure of nanocellulose from sea squirts make them a perfect match for wearable sensors.

Wearable devices that we keep on our bodies collect and provide information about the surrounding environment or personal health status in real time. Wearable sensors in particular come in a slew of different functions and shape depending on the materials that are combined. Textile that can be weaved onto ordinary textiles is the most ideal platform for wearable sensors.

However, existing fiber-based sensor materials were made by combining conductive materials and sensor materials with ordinary textile and coating it, which means that high voltage needed to compensate for the strong resistance. What’s more important is that durability was an issue because of the low adhesiveness of the coating. Reduced graphene oxide materials that are inherently conductive emerged as a solution, but the downside was the high processing and material cost incurred because they required postprocessing and are not as flexible as oridnary textile once they are reduced.

The research team turned their attention towards nanocellulose that can be extracted from sea tunicate and carbon nanotubes that are thrown out. According to Dr. Jeong, nanocellulose is in general mostly extracted from wood, but the density in the structure of nanocellulose extracted from wood increases significantly when turned into fiber. However, nanocellulose derived from sea tunicate form a unique pore structure.

Dr. Jeong made use of this feature. Dr. Jeong says that he came up with the idea of combining nanocellulose extracted from sea tunicates that have a pore structure with conductive materials to make wearable sensors, explaining that the nitrogen dioxide sensor was made by creating a composite fiber out of nanocellulose and carbon nanotubes. In fact, the research team was successful in producing fabric with this composite fiber that detects harmful nitrogen dioxide.

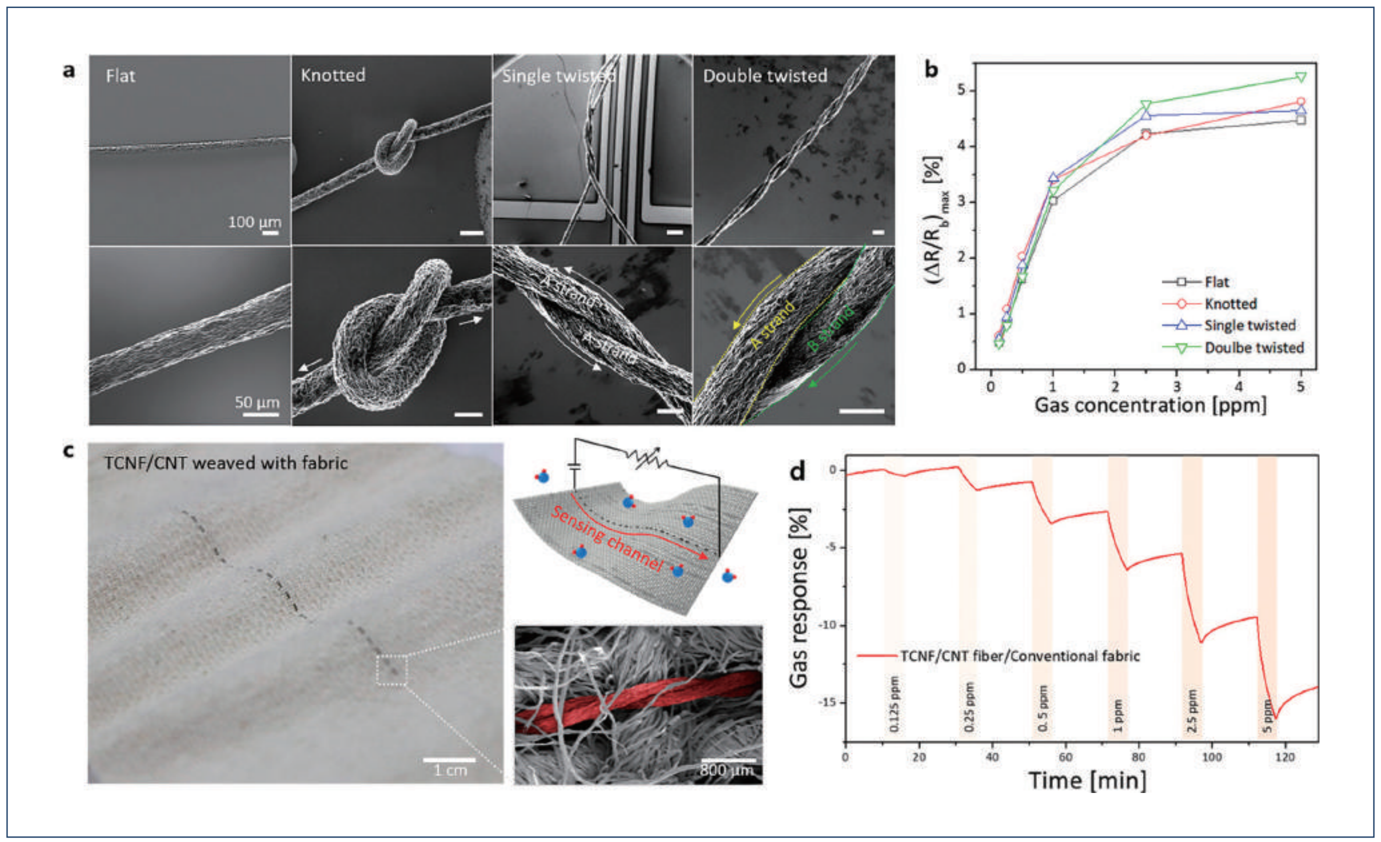
One of the upsides of this study is that it took into consideration commercial viability and used the generic wet spinning method which is already in use at industry The logic was that utilizing existing processes would help commercialize this price-competitive wearable gas sensor. According to the team, the cost of production that includes just the cost of material is less than $0.01 (approximately KRW 10) per meter.

According to Dr. Jeong, "the role and purpose of researchers is to exceed basic research and conduct studies that result in items that can be commercialized and used in people's daily lives. This sense of purpose was rooted in the entire process, beginning with the design phase when we came up with the idea. We focused not only on performance, but also on productivity."

"Follow-up studies for detecting hazardous gases other than nitrogen dioxide will continue"

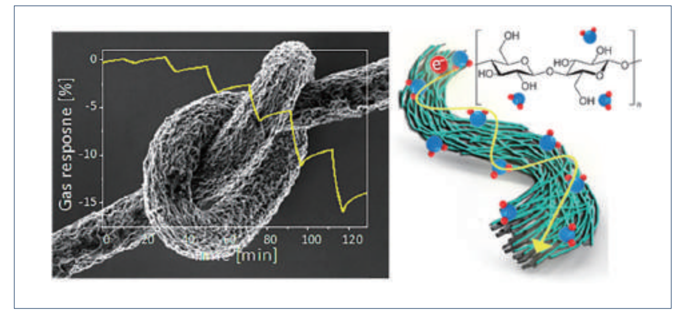
According to Dr. Jeong, this is the first wearable sensor using the unique structure of nanocellulose extracted from sea tunicates, because research is relatively lacking on this matter compared to studies on nanocellulose extracted from wood. Dr. Jeong also stated that the reason for this lack of research is related to food culture involving growing and eating sea tunicates.

However, getting your hands on sea tunicate in Korea is not as easy as one might think. The team asked around at sushi restaurants nearby, but most had already disposed of sea tunicate. Dr. Jeong says that they "uploaded posts on websites for buying and selling (wasted) seafood with student researchers and explained the purpose of their study

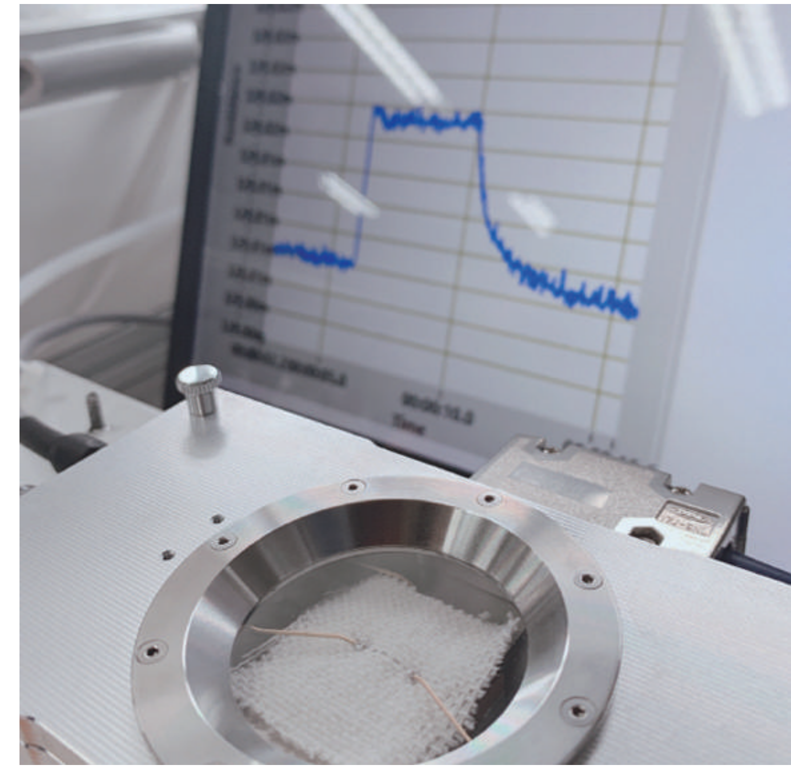


High mechanical flexibilities of the TCNF/CNT fibers for a wearable sensor

Establishing the response mechanism was not easy given that there were no precedents, says Dr. Kim, but he believes that the technology will be commercialized within the next year or two.



The highly sensitive nitrogen dioxide sensing mechanism by -OH group on tunicate in composite fiber



The research team was successful in producing fabric with this composite fiber that detects harmful nitrogen dioxide

and an unexpectedly large number of people thought it was a good idea and sent us sea tunicate they would have otherwise disposed of."

Building on this success, the research team is planning follow-up research on economic wearable materials that can detect other hazardous gases.

According to Dr. Jeong, the team is "creating a database for textile-based gas sensors using sea tunicate nanocellulose as a platform and making preparation to transfer the technology to companies".

In particular, because Korea has the original technology needed for textile-based gas sensors that use carbon nanomaterials unlike existing mainstream sensor materials, Dr. Jeong believes that continued research on this topic could pave the way for Korea to become a leader in this field, armed with original technology and intellectual property.

Dr. Jeong says "given the lack of natural resources in Korea, this is the only weapon our science and technology have to compete on the global stage", adding that "strong research and technological capabilities will not only help Korea withstand uncertainties stemming from the fast changing landscape, but also help it become a global leader, which is why we are committed to producing results that make an impact on people's lives."

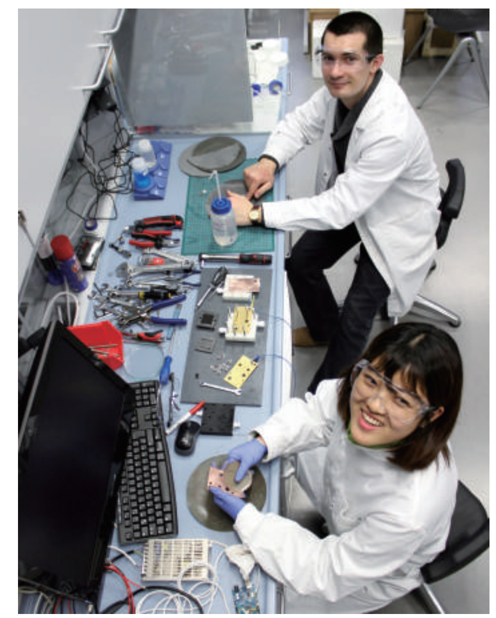
This was a joint study carried out with Professor Hui-tae Jeong's team at KAIST (Korea Advanced Institute of Science and Technology). The results of this study have been published in ACS Nano, an internationally acclaimed journal for materials.

KIST Europe as an Open Research Hub for Joint Research and Technology Exchange

The history of KIST Europe began with an agreement made during Korea's Presidential visit to the EU in 1995. Science and Technology Ministers of Korea and Germany agreed to establish a Korean research institute in Germany, and as a result, an overseas branch of KIST was founded in 1996 in Saarbrücken.

Since then KIST Europe has functioned as an open research hub for joint research and technology exchange between Korea's government funded research institutions and top research centers in Europe. At the same time, as an EU base camp for Korea's private sector, KIST Europe supports Korea's industrial and academic activities in EU and conducts highly requested empirical research.

KIST Europe works on three research areas: Environmental Safety Research Group focuses on toxicity assessment and chemical substance toxicology through non-animal testing, Bio Sensor Research Group develops environmental sensor devices and innovative biochemical, electrochemical technology while Smart Convergence Research Group is devoted to research on predicting toxicity behavior and efficiently providing intelligent information with AI and deep learning applications.



These days, KIST Europe has formed a research consultative group to investigate investigate 'Adverse Outcome Pathway' (AOP) with the European Union Reference Laboratory for Alternatives to Animal Testing (EURL ECVAM). EURL ECVAM is part of the Joint Research Center (JRC) of the European Union and is a verification and assessment agency for non-animal testing methods.

KIST Europe exclusively applied for the identification of a new COVID-19 AOP in the human body at the Organisation for Economic Cooperation and Development (OECD). EURL ECVAM confirmed KIST Europe's application and officially explored the possibility of a joint development, and as a result a joint research project was agreed upon.

AOP of COVID-19 will enable not only the diagnosis of infection but also the development of various treatments to lower phased toxicity and help quantify phased toxicity levels, through which researchers will be able to not only diagnose but also identify infection stage. Hence, COVID-19 patients will be able to receive phased treatment effectively.

Through various non-animal experiments, researchers identify toxic effects of chemical substances on the molecule, organelle, cell, tissue, organ, and individual and group level, and AOP is a map of connections between toxicity effect at different levels. The U.S. and EU considers AOP as the central concept of toxicology and are actively conducting related research. KIST Europe is the only Korean institution in the area of Ecotoxicology to have three AOPs registered in the OECD Work Plan and received recognition for relevant technology.

Dr. Kim, Young Jun, leader of KIST Europe Environmental Safety Research Group, said, "AOP is a new concept in Korea but it is being developed by researchers in Europe and U.S. as it has become established as an alternative to costly and inefficient animal testing for chemical toxicity." Dr. Kim continued, "KIST has been recognized for its AOP development capability, as we can see from the fact that three of our AOP have been selected as OECD Work Plan and was offered a proposal to conduct joint research with Europe's research center."

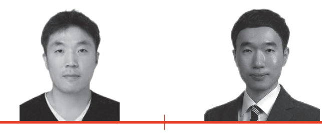
In addition, to strengthen open research cooperation, KIST Europe has built a platform called "Korea-EU Initiative Program" and is conducting precedent research with high demand in Korea and the EU. Currently researchers are working on four areas – smart factory, smart healthcare, brain science/brain disease, and cyber security – and is showing much success in active international research cooperation.

Research News. 01

Energy/Environment

QDSC Blocks Current Loss, Boosts Performance by 47% and Raises Hopes for Next-Generation Solar Cells

See more details on
https://doi.org/10.1002/aenm.201901938
"Suppressing Interfacial Dipoles to Minimize Open-Circuit Voltage Loss in Quantum Dot Photovoltaics." *Advanced Energy Materials* 9.48 (2019)



Jin Young Kim
Principal Researcher
Center for Hydrogen-Fuel Cell Research

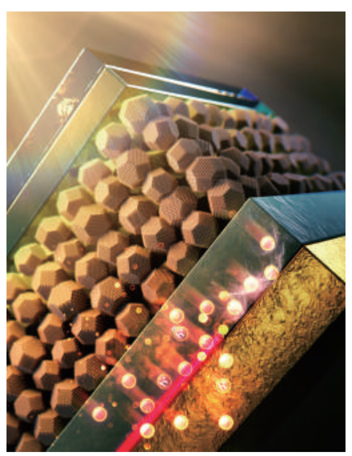
Donghun Kim
Senior Researcher
Computational Science Research Center

KIST announced research findings that brightened the prospect for commercialized quantum dot solar cells (QDSC) by preventing the chronic issue of current loss and raising cell efficiency by 47%. This was a result of joint research by Dr. Jin Young Kim's team at the Center for Hydrogen and Fuel Cell Research, Dr. Donghun Kim's research team at the Computational Science Research Center, and research team led by Prof. Yeon Sik Jung at the Department of Materials Science and Engineering in the KAIST (Korea Advanced Institute of Science and Technology).

Hole transport layer (HTL), a QDSC component, plays a critical role in flowing electric current in the solar cell. During the process of converting light into electric power, a considerable amount of current is lost at this layer, which is why minimizing this loss was key to boosting QDSC performance. To solve this problem, many research teams around the world attempted to develop a new HTL material but failed as each attempt was accompanied by current flow interrupting dipole.

The research team worked to eliminate such dipole by utilizing quantum mechanics theory (density functional theory) where atomic units can be controlled and developed a double layered new HTL material (a-6T/PEDOT:PSS). Using this, the team reduced current loss to 20% compared to previous level, which improved cell efficiency by 47%. They hope this new HTL material will be widely used in the academia and industry. Also, if more research is conducted to further reduce current loss, QDSC can become commercialized as the next-generation solar cell that outperforms its competitors such as silicon or perovskite solar cells.

Dr. Jin Young Kim explained, "We hope our research findings help guide the right direction for various future experiments to increase the energy conversion efficiency of QDSC."



The article were featured on the cover of *Advanced Energy Materials*

A novel photoelectrochemical catalytic process that is capable of efficently disinfecting aquatic bacteria and viruses without usage of chemicals was developed by Dr. Seok Won Hong's research team of Water Cycle Research Center at KIST and a research team led by Prof. Cho, Kangwoo of Environmental Science and Engineering Division at POSTECH (Pohang University of Science and Technology).

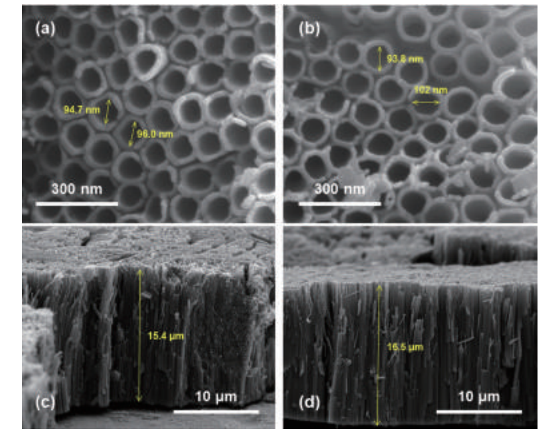
Ever since the humidifier disinfectant scandal few years ago, people paid closer attention to the safe sterilization of their water-using appliances such as water purifiers and humidifiers. The scandal had caused hundreds of deaths, which led to a ban on PHMG (PolyHexaMethylenGuianidine), the key chemical blamed for the deaths, but consumers still felt uneasy.

Existing chemical sterilizers create toxic and carcinogenic materials during sterilization process. To avoid such problems, researchers have been focusing on finding an alternative that can control microbes and decompose toxic pollutants using UV rays or photocatalysts. However, this method had limitations in that it showed relatively slow kinetics and high energy consumption.

KIST research team applied electricity to this material, which enabled them to develop a system that overcomes existing limitations and effectively sterilizes water without chemicals. And they used self-doping technology, which partially adjusts Ti's oxidation state, thereby significantly improving conductivity and ultimately created a nanostructured catalyst.

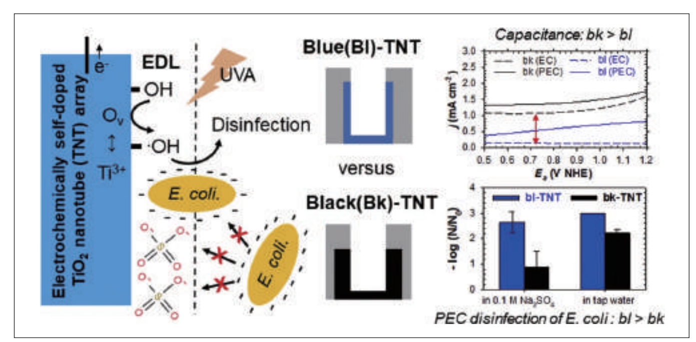
This catalyst uses UV rays for sterilization and produces large amount of sterilizers when electricity is provided, and eliminates over 99.99% of bacteria and viruses within minutes. This system maintained a high level of performance even when operated nonstop for over 20 hours.

Dr. Hong stated, "This chemical-free, eco-friendly sterilizing technology can be applied not only to small household appliances but also to swimming pools, and I expect it to be widely used after academic-industry cooperation."



Horizontal and vertical SEM images for (a,c) blue and (b, d) black -TiO2 nanotubes arrays

Seok Won Hong
Principal Researcher/Head
Water Cycle Research Center



Schematic of disinfection mechanism of the self-doped blue(bl)- and black(bk)-TiO2 nanotube(TNT) arrays and their respective electrochemical characterization results and photoelectrocatalytic disinfection performances

Research News. 02

Energy/Environment

Safe and Clean Water - Sterilized Without Chemicals

See more details on
https://doi.org/10.1016/j.apcatb.2019.117910
"Effects of reactive oxidants generation and capacitance on photoelectrochemical water disinfection with self-doped titanium dioxide nanotube arrays." *Applied Catalysis B: Environmental* 257 (2019)

Research News. 03

Material/Systems

KIST Develops Inexpensive and Efficient Next-Generation Fuel Cell

See more details on
https://doi.org/10.1039/C9EE00381A
"Work function-tailored graphene via transition metal encapsulation as a highly active and durable catalyst for the oxygen reduction reaction." *Energy & Environmental Science* 12.7 (2019)

Hydrogen and Fuel Cell Research team led by Dr. Sung Jong Yoo conducted a joint research with Chungnam National University's Prof. Namgee Jung and recently succeeded in developing a low-cost catalyst that can replace costly platinum catalysts for alkaline fuel cells, which is gaining popularity as the next generation fuel cell.

Oxygen reduction reaction takes place in a fuel cell's electrode. This is a key reaction that determines cell efficiency as it causes slow reaction and hinders cell efficiency. To solve this issue, existing alkaline fuel cells uses platinum-based alloy nanoparticles that have excellent electrochemical activation.

However, platinum catalysts lack durability and are expensive, and much research is being conducted on alternative carbon-based catalysts. The carbon-based catalysts developed so far shows highly active oxygen reduction but had limitations in that its point of activation could not be identified and showed low performance in an alkaline fuel cell.

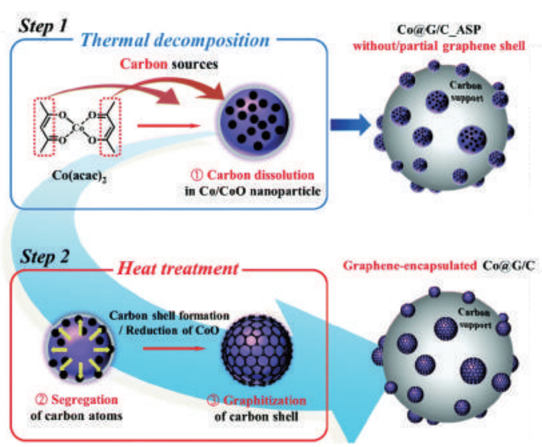
KIST-Chungnam Nat'l Univ team successfully developed a carbon-based catalyst that can replace the costly platinum catalyst while improving both the performance and durability of fuel cell. This was done by developing a core-shell structure catalyst with a cobalt inner core and graphene-structured carbon shell, which is inexpensive and shows great performance and durability. The research team maximized reaction surface area using core-shell structure and formed electrodes similar to platinum catalyst structure. As a result, they succeeded in achieving excellent fuel cell performance.

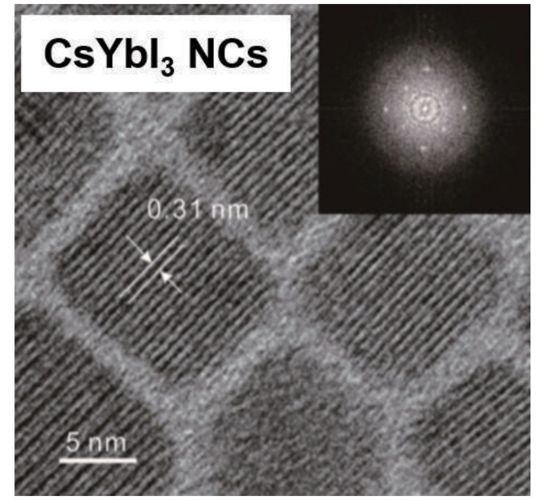
The research team proved through their experiments that when they form graphene shell on a cobalt metal surface, they can induce graphene surface electronic structure that is favorable for oxygen reduction, and used analytic methods to prove that reaction takes place on the graphene surface.

Much research is being conducted on material development for the commercialization of alkaline fuel cells. "This research is significant in that it examined the previously unclear oxygen reduction's active site and provided implications for electrode composition, a core factor for running fuel cells," explained Dr. Yoo.

Sung Jong Yoo
Principal Researcher
Center for Hydrogen-Fuel Cell Research

Schematic illustration of the formation of the graphene shell on cobalt nanoparticles





High-resolution transmission electron microscopy (HR-TEM) image of $CsYbI_3$ NCs

Research News. 04

Material/Systems

Development of High-Quality Perovskite Synthesis Technology without Lead

See more details on
https://doi.org/10.1002/adma.201901716
"Rare-Earth-Element-Ytterbium-Substituted Lead-Free Inorganic Perovskite Nanocrystals for Optoelectronic Applications." *Advanced Materials* 31.33 (2019)

Byung Joon Moon
Researcher
Functional Composite Materials Research Center

The of KIST Functional Composite Materials Research Center team announced that it has developed a synthesis method of perovskite, a nanomaterial that does not use lead harmful to the human body and is spotlighted as a next-generation solar cell material, through joint research with Professor Lee Sang-hyun's research team at Chonnam National University.

Perovskite refers to a semiconductor material with a special structure of a hexagonal body. It is applied to industries such as solid-state lighting and lasers as it has the characteristics of converting light into electricity or electricity into light, and has recently attracted great attention in the solar cell industry. Perovskite, which has a better color reproduction rate than conventional materials due to its superior efficiency and narrow wavelength width, is a relatively simple manufacturing process that can achieve high luminous rates and vivid colors, making it a promising material for future displays.

However, studies so far have used lead(Pb) components to maximize the performance of the synthetic nanostructures of perovskite. Lead components, which are heavy metals, are paying attention to pollution and damage to the human body, and furthermore, restrictions are placed on use, export and entry.

For the commercialization of perovskite, the development of a synthetic method that does not contain lead harmful to the human body and environment was a priority that must be addressed. In response, the KIST research team succeeded in synthesizing high-quality, high-quality Perovskite nanomaterials using Ytterbium (atomic number 70), a rare earth element, instead of harmful lead, and reported the results of producing high-performance photodetector devices.

Research News. 05

Bio/Medical

Development of Micro-Small Multi-function Brain Chip for Neural Circuits

Dr. Il-Joo Cho(KIST) has developed an ultra-small brain chip that can simultaneously measure neural signals from various parts of the brain and stimulate the brain by delivering drugs or light.

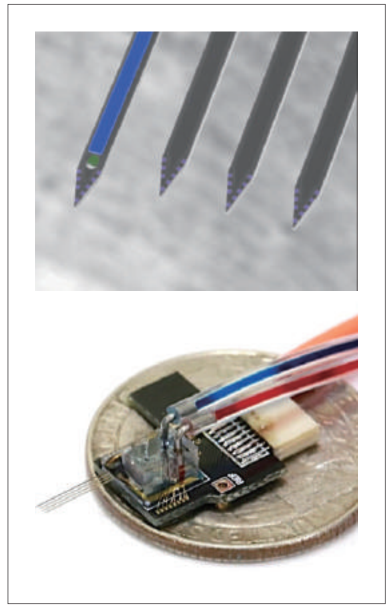
In order to conquer brain diseases through understanding of the brain or to enhance brain function, signals generated by the brain must be measured accurately at cellular level. Therefore, there have been several research activities to insert chips into the brain or measure neural signals with non-invasive imaging technology. It is also a key technology in the brain-machine interface system (BMIs), which reads thoughts through detected neural signals and tries to move machines without movement or language expression, drawing more attention.

Previously, it was possible to identify abnormalities in brain function by reading signals from the brain through brain chips, but on the contrary, much of the bi-directional communication that sends signals to the brain has yet to be studied. Devices for deep brain stimulation are being used for patients with Parkinson's disease to control brain function, but precise stimulation of brain circuits and simultaneous measurement of changes in brain signals have been remained challenging.

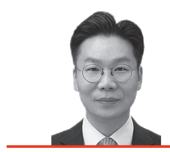
The researchers confirmed that the very thin (40 micrometers thick) brain chips of hair thickness could be developed and inserted into the brain of a living mouse to strengthen or weaken the brain circuit by delivering light and drugs to the hippocampus region which is known to be responsible for the memory of mice.

In particular, outstanding performance was achieved in terms of miniaturization, which is a factor directly related to tissue damage or possibility of infection during implantation of the brain chip. It is integrated with optical waveguide for optical stimulation, microfluidic channel for drug delivery, and electrodes for brain signal measurement. Four small shanks and 32 electrodes, which are nearly 6 to 8 times smaller than the existing ones, are built in to read signals from each nerral cell and deliver drugs or light directly within seconds.

The study was conducted in anesthetized mice, and the researchers plan to study behavior in the future for awake mice. "We have developed a very small system that can precisely control brain function," Dr. Cho said. "We expect to overcome the limitations of existing method for studying brain circuitand suggest ways to control brain function in the future."



Fabricated multifunctional multi-shank MEMS neural probe



Il-Joo Cho
Principal Rese archer/Head
Center for BioMicrosystems

See more details on
https://doi.org/10.1038/s41467-019-11628-5
"Multifunctional multi-shank neural probe for investigating and modulating long-range neural circuits in vivo." *Nature communications* 10.1 (2019)

Research News. 06

Bio/Medical

Applying Easy Multi-Target Gene Editing Techniques to Open the Way for New Anti-Cancer Immune Cell Therapy

See more details on
https://doi.org/10.1016/j.biomaterials.2019.119298
"A carrier-free multiplexed gene editing system applicable for suspension cells." *Biomaterials* 217 (2019)

Mihue Jang
Senior Researcher
Center for Theragnosis

Dr. Mihue Jang of the Center for Theragnosis and Professor Hong Seok-man of Sejong University announced that they have developed a new gene scissors technology that can treat cancer immunization by simultaneously suppressing proteins that interfere with the immune system that are expressed on the surface of "blood cancer cells."

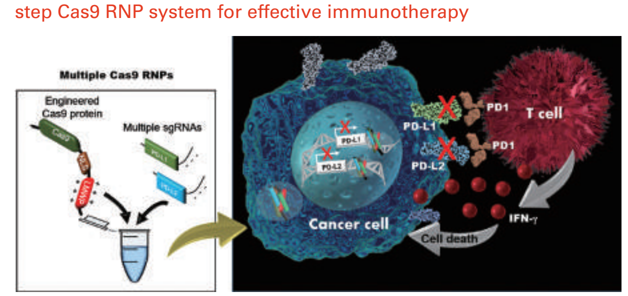
Genetic scissors technology is a technique that can be cured by removing certain genes or by editing genes to make them function normally. In particular, CRISPR gene scissor technology, one of the gene scissors techniques, has recently been in the spotlight as an immunotherapy treatment that induces immune cells to selectively attack cancer cells only by selectively correcting genes in immune cells.

There were various types of genes that controlled immune activity, and there was still a lack of technology to induce immunotherapy safely and easily. Dr. Mihue Jang team at KIST and a joint research team at Sejong University have developed a technology that can deliver genes to blood cancer cells without external transporters while improving the CRISPR gene scissors one more time to efficiently correct multiple genes at the same time.

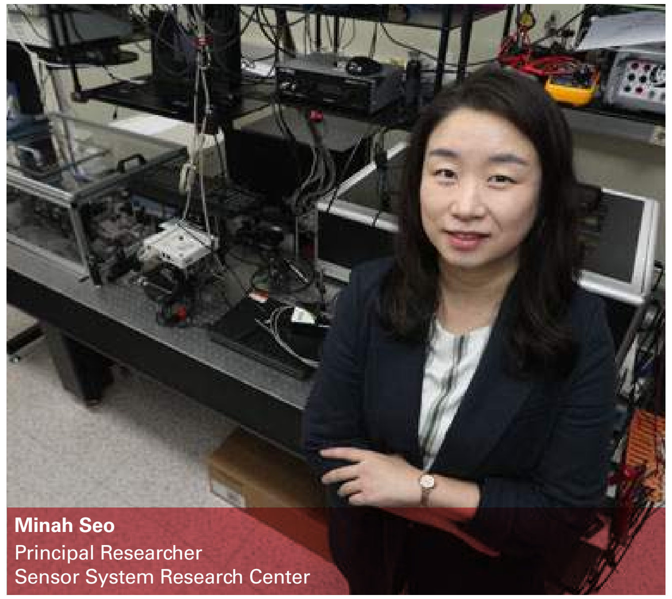
The existing gene scissors technology mainly used virus or electric shock therapy to transfer genes within blood cancer cells such as 'T cells' among immune cells. Virus-based methods often induce unwanted immune responses and are more likely to misinsert genes in the genome sequence, not targets. In addition, the electric shock method requires separate expensive equipment, and the disadvantage is that it is difficult to calibrate large amounts of cells at once due to electrical stimulation and cell viability is also low.

Dr. Jang said, "Because the newly developed gene scissors technology is applicable to various immune cells, it is expected to be applicable to the development of various diseases such as autoimmune diseases and inflammatory diseases as well as cancer."

Scheme of a multiple gene editing strategy using a simplified one-step Cas9 RNP system for effective immunotherapy



Unraveling the Principle of Convergence between Science and Art



Minah Seo
Principal Researcher
Sensor System Research Center

Photo by Seung-Hwan Lee at Maeil Business Newspaper

Meet KIST Dr. Seo Minah. During the week, she is a physicist devoted to her research in ultrafast optics and nanoscience. Her current research is on developing a sensing platform for quick diagnosis using light to examine protein structural change or virus. On weekends? Don't be surprised to see her as an artist holding a paintbrush.

Optics play an important role in paintings. It has long given inspiration to artists. Georges Seurat, a famous French painter, studied chromatics and optical theory and developed pointillism, drawing paintings that display division of pure color and color contrast. Claude Monet drew haystacks, which look different by seasons. Monet expressed how haystacks, with their porous yet large surface area, are viewed differently under varied sunlight. Many well-known painters, in their attempt to express objects onto the canvas, experimented with light whether they were aware of it or not.

The Lycurgus Cup is a 4th century Roman glass cup ornamented with a sculpted mythical King. Normally a green hue, the cup turns red when light passes from the inside. This effect is caused because the scattering of light changes depending on the size and shape of metal nanoparticles. The skill to grind gold and silver into nanoparticles became the underlying technology of stained glass, which spread across Europe after the 12th century. Color change using metal particles is used in various areas in science and technology including biosensors.

Dr. Seo's book published early this year, "A Physicist in the Art Museum", reveals the world of physics found in art. "Artists are the true experimenters and scientists," says Dr. Seo.

As the title implies, the book is an artbook written from a physicist's point of view. With each turning page readers are met by artwork after artwork, with atomic model, photo of the sun's black spot, and sound wave graph in between. Dr. Seo, who makes sure to visit art museums whenever she travels abroad for research or a conference, realized that artists' inspirational muse turned out to be physics, especially since 17th century. With this book, she hoped to unravel how that science converges with art.

Through drawing, I developed a skill of giving form to numbers inside my head. It is important to visualize your research to help people understand it.

<Albuquerque international balloon fiesta, acrylic on canvas, 24.4x33.5cm>
Dr. Seo recalled the unique scenery of New Mexico, where she stayed as a postdoctoral fellow for three years

<A drawing 'Sky view of Delft', Watercolor on paper, 29.7 x 45.0 cm>
Dr. Seo painted while studying in the Netherlands in 2008

Take the two paintings of La Grenouillère, for example. Comparing the same scenery drawn by Renoir and Monet during the same period, you can understand how surface tension and gravity creates waves on water surface, and the book explains how waves are made and the movement of medium when wave travels, and why this happens. René Magritte's 'The Treachery of Images' unfolds the wonders of quantum mechanics, a main pillar of modern physics, while Vincent van Gogh's 'Agostina Segatori Sitting in the Café du Tambourin' shows us another image hidden in the background, investigated by various wavelength of light.

Dr. Seo draws cover images for her research paper whenever possible. In graduate school she was well known for her image-producing skills. Even now Dr. Seo continues to paint. She sends drawings for her friends' wedding invitations, published a children's picture book, and submits artwork for her art club's group exhibitions. She also drew the image for the cover paper published in Advanced Optical Materials last February. These have led to her writing a book introducing core concepts and principles of physics in art masterpieces

Dr. Seo said, "The experiment data we see every day is boring numbers, not images. Through drawing, I developed a skill of giving form to numbers inside my head. It is important to visualize your research to help people understand it. I hope this book will be helpful in adding a stroke of thoughtfulness when visualizing study findings to exchange ideas with experts in other fields."

Even as she continues to paint, Dr. Seo plans to focus more on her career as a researcher. "I recently had success with KIST Virus Research Team on virus measurement and cell observation research using THz light. Bio research is a completely new field for a physicist like myself, but I want to use this experience as a chance to develop medical equipment that is useful in our daily lives in the near future," says Dr. Seo.

1,000 Innovative Tech Companies within 10 years, for Development and Growth of the Bio-health Industy

Seok Hyun Kwang
Principal Researcher/
Director-General
Biomedical Research
Institute

Creating new industries and achieving growth is important as it is directly linked to employment. Aging societies, diseases, and other challenges that modern society face indicate that bio-health could be a promising industry.

China, the World's Factory is on a sharp downhill slide. Increase of minimum wage, capital movement restrictions, technological and IP policies that fall dismally behind international standards, increased trade conflicts with the U.S., among other factors are dismantling China's status and charm as world's factory. Although this may be a crisis for China, it could be an opportune moment for Korea's industries to bounce back. South Korea's traditionally strong industries could enhance their competitiveness, while new industries could be created to serve as growth engines.

Creating new industries and achieving growth is important as it is directly linked to employment. Aging societies, diseases, and other challenges that modern society face indicate that bio health could be a promising industry. Developed countries are already jockeying for position in the market, in expectation of its immense growth potential. However, Korea's bio health industry growth lags behind that of such developed countries.

Translational research – research that translates various original technologies into biomedical technologies that can be used in the clinical setting (the market) - is considered as one of the most critical step in development and growth of the bio-health industry. Translational research must be conducted for the commercialization of outstanding laboratory experimental results.

In 2013, the Biomedical Research Institute at KIST began pilot projects for translational research with Samsung Medical Center, Asan Medical Center, Korea University Medicine, and Kyung Hee University Hospital, among others. KIST committed to investing approximately 1 billion KRW annually, with partnering hospitals committing to the same amount. In 2019, after roughly five years of dedicated research efforts, this project has produced four startups, four technology transfers, and one clinical trial that has been recognized by the National Assembly for its contributions.

Although some of the government agencies are currently pursuing translational research support projects, it is far more effective for institutions and clusters that are rich in original technologies and capable of clinical linkage to promote translational research independently. This is because communication between researchers and clinical physicians is crucial during the initial stage of the research for successful translation of the technology. They need to be in constant communication throughout the entire research process and research institutes or local clusters provides open channels and environment for such exchanges.

Educating researchers participating in the translational research about licensing and approval, clinical studies, bio-ethics, patient care, and safety needs to be systematically implemented as well. Such process is called "reverse translational research", which has the advantage of partnering with startup and technology commercialization support programs provided by research institutes or local clusters at the right time since the technology will have been verified throughout the maturing process.

If we take a look at one of the leading countries in biomedical research, there are 63 translational research support projects that are ongoing in the U.S including the CATALYST program at Harvard University sponsored by NIH (National Institute of Health), which has attracted significant investment in the bio health industry.

At this moment, we imagine a future full of challenging spirit to create "1,000 innovative tech companies within 10 years". While government agencies and local governments carry out distinctive translational research support projects, the startup and technology commercialization infrastructure of research institutes that have wide range of original technology and direct partnerships with hospitals must be utilized. This will spur growth in the bio health industry so that we can reach our goal of creating at least 1,000 startups and commercialization of new biotechnologies within the next five to ten years. It goes without saying that this requires businesses, academia, research institutes, and government to come together and commit to achieving the same goal.

Translational research must be conducted for the commercialization of outstanding laboratory experimental results.

First Steps of the New Northern Policy, VKIST Laboratory Opens in Gangneung

On the morning of the September 27, 2019, KIST and Vietnam-Korea Institute of Science and Technology (VKIST) jointly hosted the opening ceremony for the VKIST lab at KIST Gangneung Institute of Natural Products.

The establishment of VKIST supports early research. Moving forward, researchers at VKIST and KIST Gangneung Institute will conduct joint and cooperative research in an effort to utilize research know-how and cutting-edge equipment and tools to strengthen VKIST's research capabilities.

VKIST in Gangneung will focus on utilizing Vietnam's natural resources to develop substances and new drug candidates that can be commercialized. In particular, VKIST will serve as a research hub for science and technology, leveraging extraction techniques and component analysis on Vietnam's natural resources .

The Vietnam-Korea Institute of Science and Technology Project was selected by the Vietnamese government as a strategy to promote science and technology with the aim of building an advanced industrial nation. The project began with an official request submitted to the Korean government in 2012 to build a science and technology institute like KIST that drives economic growth. Afterwards, former KIST President Dong-hwa Geum was appointed as the first President of VKIST (May, 2017), and finally, the groundbreaking ceremony was held on March 2018 with President Moon Jae-in in attendance.

The goal of VKIST is to become an industrial technology research institute that keeps pace with the trend, using applied research to develop technologies that can help reduce lead time. In this vein, VKIST aims to become a future-oriented world-class institute of science and technology that can help spearhead industrialization in Vietnam and further national development.

The 7th S&T Forum was held under the theme of "Innovation Clusters Leading Global Inclusivity and Innovative Growth"

The Seoul S&T (Science and Technology) Forum was held at The Plaza Hotel in Seoul for two days from November 6th to 7th, 2019.

Now in its 7th year, this Forum was first hosted in line with the G20 Summit hosted in Seoul in 2010 and has become a venue for spirited debate among international experts in science and technological research policies, officers from international organizations and government on the topic of resolving the challenges of our time using science and technology.

This year, the theme of the forum was “Innovation Clusters Leading Global Inclusivity and Innovative Growth”, focusing on finding ways for R&D zones to become world-class innovation clusters. A total of approximately 200 specialists in the field of science and technology and columnists in relevant fields participated from 29 countries.

In particular, world’s leading innovation cluster experts and representatives from Korea’s most renowned innovation clusters such as Daedok Science Complex and KBIO Health joined in discussions based on case presentations from innovation clusters from home and abroad to analyze the success factors and review takeaways with the aim of building growth engines for the future.

The keynote speech at the opening ceremony focused on public-private partnerships in policies, R&D, and commercialization, pursued by the Ministry of Science and ICT since 2018 to successfully build small yet strong R&D zones.

Chairperson Kwang-yun Wohn of NST stated in his welcoming remarks that “now is the time public research organizations step up and display leadership in science and technology to create growth engines for the future”, adding that “creating an environment conducive to facilitating sustainable exchange and collaboration by building clusters is important and this forum will prove useful in strengthening the link among industry, academia, and research institutes and breathing new life into clusters.”

Building a Foundation for Technological Collaboration for Korea’s Air Force and National Defense

KIST announced an MOU with Air Force Headquarters for a partnership in Air Force development and R&D.

In response to public demand for scientific development in national defense, the two organizations signed this MOU in recognition of the importance of joint efforts to prepare for a future in which the landscape of war will change. Moving forward, KIST plans to support Air Force efforts to identify needs in force development and provide technological support, while the Air Force will fully cooperate with and support military-related research.

This MOU is expected to strengthen military and civilian technological cooperation alongside government-funded institutes and provide a model case for military and civilian cooperation aimed at enhancing public safety and public interest.

Meanwhile, ever since its founding, KIST has been committed to national defense research, including studies on fire arms, radio transceivers, high-speed boats used by the navy, removing explosives, and robots.

In addition, research and development on the “new metal fuel cell”, a spare cell for next-generation military-use transceivers was completed in April 2017 and become the world’s first salt water-magnesium cell for military-use. This fuel cell will be deployed for military use once the corresponding radio transceiver is developed later on.

Furthermore, KIST commenced with K-DARPA (KIST, Demand-based Aim-oriented Research for Public Agenda) a fully self-funded empirical and application project spanning seven different fields, including national defense and security, and disaster and safety. This project will develop additional technologies, based on which KIST will supply the military with prototypes that can be commercialized.

Future Innovative Technologies at CES

The Consumer Electronics Show (CES), the world’s largest home appliances and IT product exhibition was hosted in Las Vegas for four days from January 7th to January 10th, 2020.

KIST will showcase an independent exhibition spanning eight booths. Throughout the years, researchers have participated as exhibition-goers and have held individual exhibitions, but government-funded research institutes have yet to participate at an organizational level. KIST’s exhibition will be located at Eureka Park, which is a space dedicated to showcasing new technologies and products of 2020, focusing on startups and is also an active hub for buyers and users to provide feedback on new products released by startups, universities, and research institutes.

The KIST exhibition hall will showcase not only successful technologies developed at KIST, but also technologies owned by two members among the group at K-Club, launched by KIST to support small and medium enterprises.

At CES 2020, KIST will unveil exoskeleton robots that disabled persons can use just by thinking to assist in walking (Principal Researcher Laehyun Kim), 4K-level high-resolution smart AR glasses that use 5G and AI-based deep learning technology (Min-Chul Park), 3D composite technology and aging technologies utilizing face recognition and 3D analysis modeling (Ig Jae Kim), the world’s first precision in-door location recognition and monitoring system using RF signals (Taekjin Lee).

A 4D+SNS Platform Based on Coexistent Reality

A platform that crosses over between reality and virtual reality, transcending social media services was developed.
The Ministry of Science and ICT (MSIT) announced that the Center of Human-centered Interaction for Coexistence (CHIC) developed a (tentatively named) 4D+SNS platform where multiple users can share and communicate using spaces and sensations.

CHIC has developed a remote interactive software framework, a hand motion capture device, and avatar modeling technology backed by global frontier project support and has used this platform to combine research results into a single service.

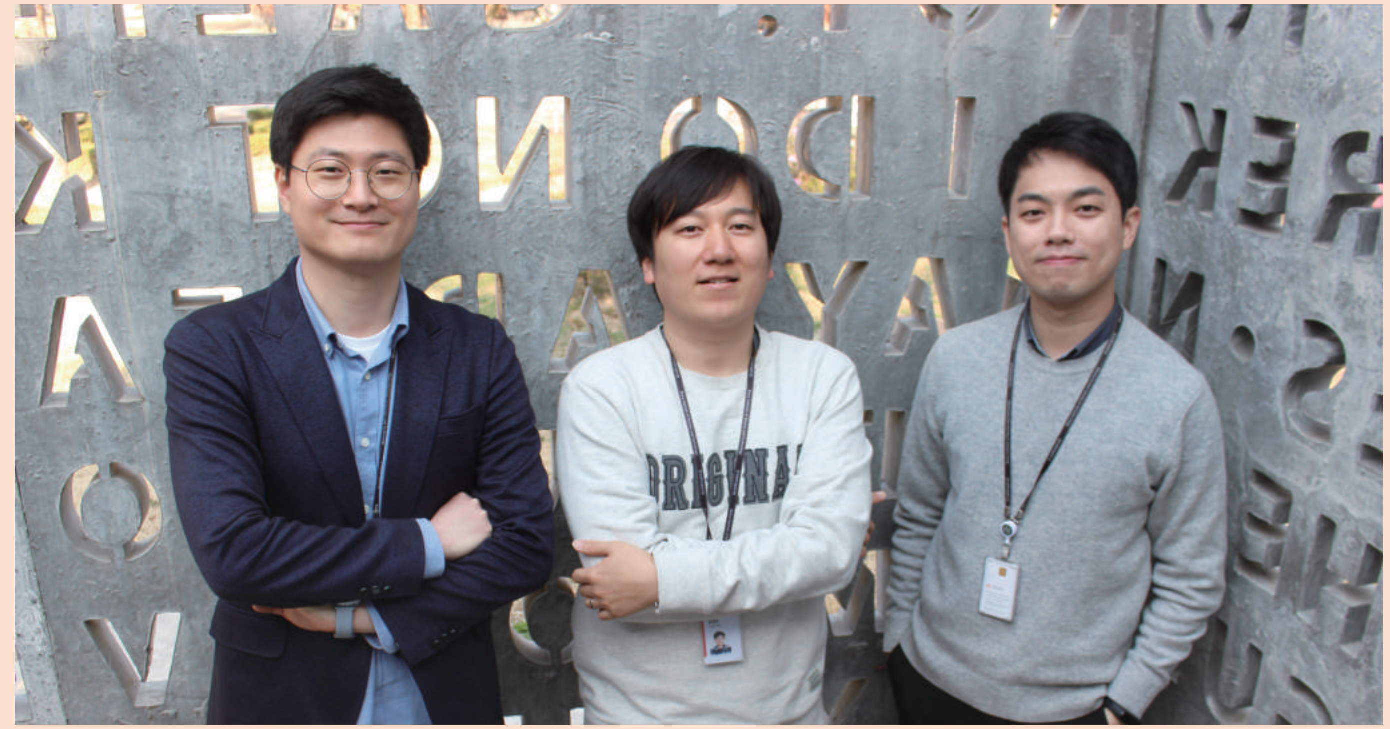
Users can share text, images, and videos on Kakao Talk, Facebook, and other social media platforms, but sharing spaces and sensations are difficult. Existing virtual reality services offer personal experiences with limitations to simultaneously sharing experiences with other users.

In comparison, CHIC's 4D+ SNS allows multiple users to share and communicate spatial and sensational information in a coexistent reality, providing users access to different collaborative contents so that users can participate in remote conferences, and enjoy virtual shopping and mini games. Users express themselves as avatars and can interact and cooperate with avatars of users connected to the network in different locations.

Head of CHIC Bum-jae Yoo stated that "the results of this research carries significant meaning in that it presented a completely new concept of social media platforms, including two-way communication services, and virtual and combined reality services which are functions provided by Killer Apps in the age of 5G", adding that CHIC "plans to help make inroads into the new 4D virtual communication service market by going full-out to commercialize the platform."

Introducing KIST's Youngest Researchers

Dr. Ansoo Lee (Center for Neuro-Medicine), Dr Jungho Yoon (Center for Electronic Materials), Dr. Seon Joon Kim (Materials Architecturing Research Center)



Dr. Ansoo Lee (Center for Neuro-Medicine), Dr Jungho Yoon (Center for Electronic Materials), Dr. Seon Joon Kim (Materials Architecturing Research Center)

Today we're going to introduce you the youngest group of researchers with an average age of 31 have come aboard KIST. These are people who dreamt of becoming scientists early on and perfected their abilities at research institutions home and abroad. These three people have dreamt of coming to KIST for years. Although they joined KIST at different times and studied different majors, they had the same dream: "to become a scientist that contributes to society and their country".

Twins who dreamt of becoming scientists, "my goal is to develop treatments for degenerative brain diseases"

"My goal is to develop an effective treatment for patients suffering from degenerative brain diseases."

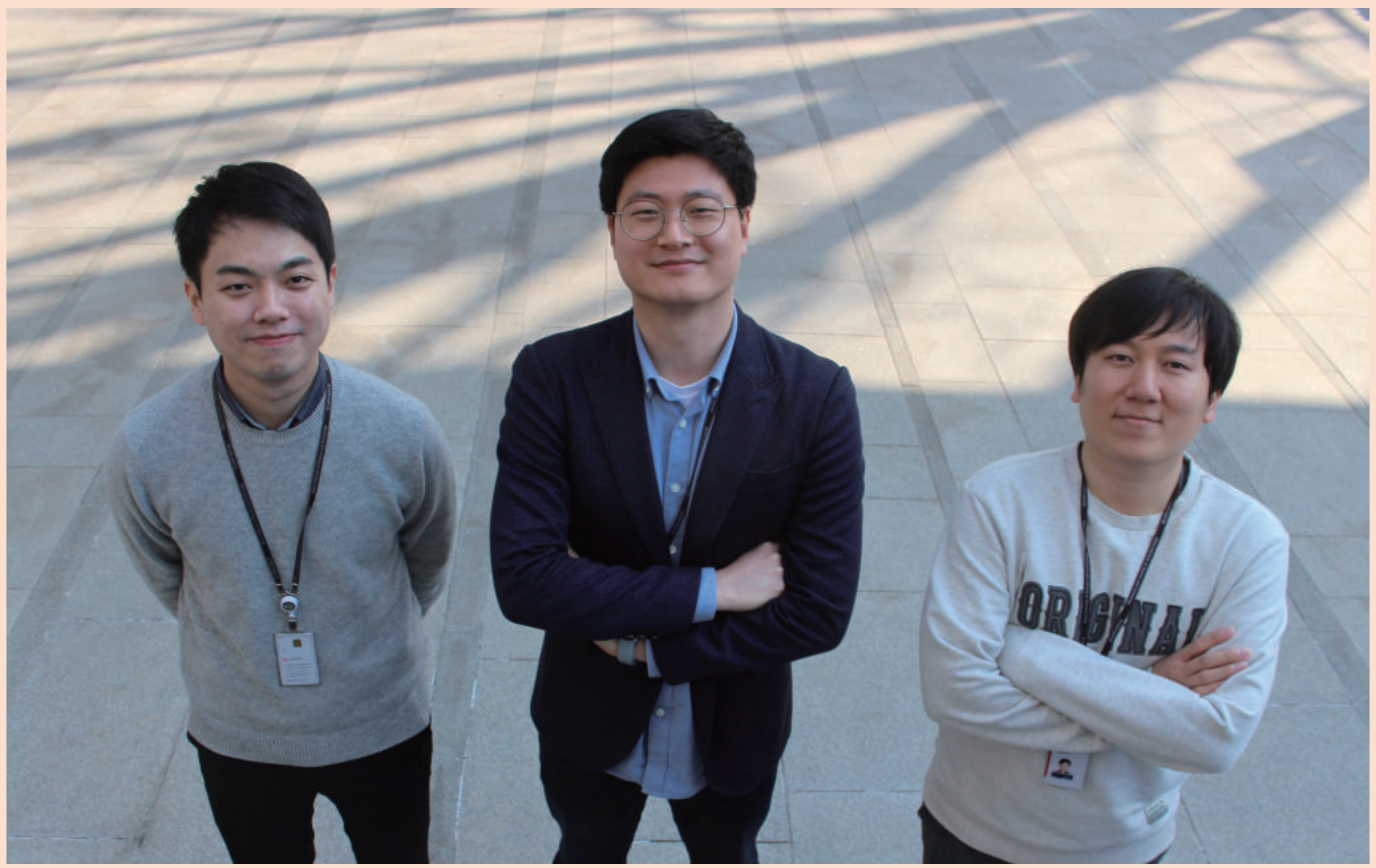
Dr. Ansoo Lee joined KIST in November last year. An organic chemistry major, Dr. Lee is working on research about identifying the causes of degenerative brain diseases and synthesizing candidates for diagnosis and treatment.

Dr. Lee dreamt about becoming a scientist with his identical twin brother. They went to the same school from elementary school to high school. Although they would at times compete with each other, they were good-willed rivals and complemented each other. Both are now living their dream in the field of science and technology – his brother at a company and Dr. Lee at KIST.

Dr. Lee hopes to dedicate himself to a wide range of different studies, utilizing the diverse nature of expertise at KIST. Dr. Lee says "I was always with people studying similar fields throughout my doctoral and post-doctoral course, but joining KIST has broadened my horizons because there are so many different people here," adding that "the advantages of a national research institute and working with different researchers will help expand my research."

Dr. Lee also says that "my research will focus on developing an effective treatment for dementia, Parkinson's disease, and other brain diseases," adding that "I hope to become an acclaimed researcher."

In closing, Dr. Lee gave advise to prospective researchers who want to join government-funded institutes. "Uncertainties about my future mounted as I finished my post-doctoral course. Unlike my expectations, my research wasn't producing results and it was hard because results are never guaranteed. But I thought to myself that 'persistence shall prevail'. Keep faith and confidence in yourself. Continue what you are doing and I'm sure there will be good results."



From corporate to public research institute, "developing semiconductors that can build an artificial nervous system is my dream"

"KIST is a place where your efforts pay off. My goal is to contribute to the field I love and to my country."

Dr Jungho Yoon joined KIST in the beginning of the year and is currently researching semiconductor devices and systems for "neuromorphic computing", which is widely considered to be the core of future artificial intelligence. Neuromorphic computing mirrors the human brain. The advantage of neuromorphic computing is that like the human brain, it doesn't require a lot of power, unlike computers that consume a lot of energy in order to process data between the CPU and memory.

The main reason Dr. Yoon joined KIST was because he wanted his research to contribute to the country. He says that "since corporate in-house research enhances market value or corporate profit, I wanted to come to KIST so that I could contribute to my country and increase the possibility of commercializing technologies."

According to Dr. Yoon, "neuromorphic computing requires research on semiconductors, materials, and raw materials, but studying the brain is just as important because it mimics the human brain. I look forward to joint research opportunities and working alongside colleagues, including researchers at the Brain Science Institute."

"KIST and other government-funded institutions are the best option for people who love research. I want to try new things like developing semiconductors that can be used to build artificial nervous systems in humanoid robots."

"A widely acclaimed expert of materials"

"KIST provides ample research opportunities. My dream is to become a world-renowned expert here at KIST."

Dr. Seon Joon Kim is part of an R&D project at KIST on developing multifunctional sensors and membranes using nanomaterials, especially using MXenes. Dr. Kim complete his post-doctoral degree at Drexel University, where MXenes were first discovered. MXene is a two-dimensional material with simple manufacturing processes and low cost production methods. Its excellent electrical conductivity and surface functionality makes a great option for secondary batteries, storage batteries, gas sensors, biosensors, etc.

Dr. Kim came across a job opening for a MXene specialist at KIST while completing his post-doctoral degree through a Korea-U.S. joint program. He says that "the abundant opportunities for working with experts in diverse fields is the biggest advantage of working at KIST," adding that "there is no lack of equipment and tools needed to develop new materials, and the advanced analysis center at KIST offers ample analysis tools for a wide range of research" Dr. Kim also added that KIST is a "place with research opportunities that are beneficial to society."

Material technology determines the performance of products and competitiveness of next-generation industries. This is why Dr. Kim wants to develop novel materials with completely new properties. "I want to create a new material that is versatile and can be used anywhere" says Dr. Kim, whose goal is to "become a world-renowned expert in this field."

Technologies leading us into the future

Research Organizations

Robotics & Media Institute

- Center for Imaging Media Research
- Center for Intelligent & Interactive Robotics
- Center for Medical Robotics

The Robotics and Media Institute (RMI) is the largest government-sponsored research institute in the areas of robotics and media in Korea. RMI has about 200 researchers working on various projects in advanced media interaction and robotic technologies, such as humanoids, field robots, social robots, soft robots, manipulators, sensors, actuators, AI, big data, IoT, VR/AR/MR, 3D display, facial recognition, and UI/UX, which are essential for the 4th industrial revolution.

RMI consists of 3 research centers (Center for Imaging Media Research, Center for Intelligent & Interactive Robotics, and Center for Medical Robotics) and 2 initiative programs (Lunar Exploration Program and Robot Research Platform Initiative).

KIST
Korea Institute of Science and Technology