Research, Development and Commercialisation
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OCTOBER 2012

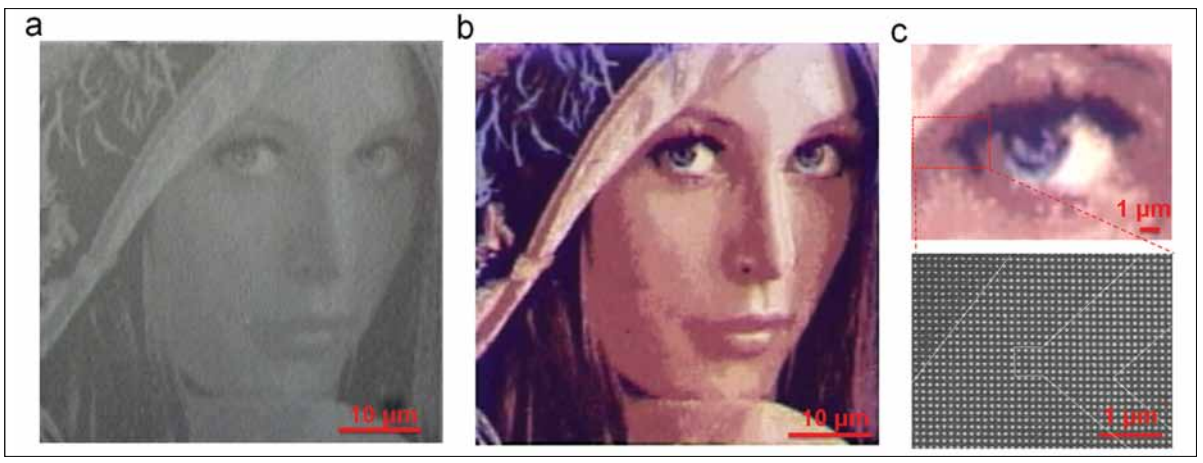
PERSPECTIVES

Institute of Materials Research and Engineering
A*STAR
www.imre.a-star.edu.sg

CORPORATE NEWS

The highest possible resolution images in full colour

Inkless, full colour images that are printed at the equivalent of 100,000 dots per inch (dpi). That is what IMRE scientists have developed using an innovative method that 'prints' images with metal-laced nanometer-sized structures. The novel breakthrough has the potential to revolutionise the way images are printed and can be developed for use in high-resolution reflective colour displays as well as high density optical data storage.



An image printed at 100,000 dpi using the new method developed at IMRE.

"To emphasise the scale of the achievement, current industrial printers such as inkjet and laserjet printers can only achieve up to 10,000 dpi while research grade methods are able to dispense dyes for only single colour images," explained Dr Karthik Kumar, one of the key researchers responsible for the breakthrough.

The resolution of IMRE's printed colour images very much depends on the size and spacing between individual nanostructures, or 'nanodots' of colour. The closer the dots are together and because of their small size, the higher the resolution of the image. IMRE's new method was able to precisely position these extremely small nanostructures and help demonstrate the highest theoretical print colour resolution of 100,000 dpi.

The inspiration for the research came from stained glass, which is traditionally made by mixing tiny fragments of metal into the glass. The 'nanoparticles' from these metal fragments scattered light passing through the glass and gave stained glass its colour. Based on this and with the help of modern nanotechnology tools, the researchers patterned metal nanostructures and designed the surface to reflect the light to achieve the colour images.

"IMRE's novel breakthrough allows colouring to be treated not as an inking matter but as a lithographic matter," said Dr Joel Yang, the project leader of the research. "Instead of using different dyes for different colours, we encoded colour information into the size and position of tiny metal disks. These disks then interacted with light through the phenomenon of plasmon resonances."

IMRE worked with A*STAR's Institute of High Performance Computing (IHPC) to design the nanostructure patterns using computer simulation and modelling. Dr Ravi Hegde of IHPC said, "The computer simulations were vital in understanding how the structures gave rise to such rich colours. This knowledge is currently being used to predict the behaviour of more complicated nanostructure arrays."

The researchers are currently working with Exploit Technologies Pte Ltd (ETPL), A*STAR's technology transfer arm, to engage potential collaborators and to explore licensing the technology. The research was published online in August 2012 in *Nature Nanotechnology*.

For more details about the technology, please contact

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Dr Karthik Kumar
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For more information about the research publication please refer to K. Kumar, H. Duan, R. S. Hegde, S. C. W. Koh, J. N. Wei & J. K. W. Yang. "Printing Colour at the Optical Diffraction Limit"; Nature Nanotechnology, 7, 557-561, (2012); DOI: 10.1038/NNANO.2012.128.

How do you 'build' a 100,000 dpi image?

The A*STAR team that made the breakthrough *- (L-R) Dr Duan Huigao, Dr Ravi Hegde, Dr Karthik Kumar, and Dr Joel Yang.*

The team built a database of colour that corresponded to a specific nanostructure pattern, size and spacing. These nanostructures were then positioned accordingly. Similar to a child's 'colouring-by-numbers' image, the sizes and positions of these nanostructures defined the 'numbers'. But instead of sequentially colouring each area with a different ink, an ultrathin and uniform metal film was deposited across the entire image causing the 'encoded' colours to appear all at once, almost like magic.

The research was featured on the cover of **Nature Nanotechnology, September 2012, Vol. 7, No. 9.**

Encouraging cross-disciplinary work - IMRE Scientific Research Forum 2012

The annual forum brings IMRE's various research groups together for cross-disciplinary sharing as well as getting researchers out of their R&D comfort zones.

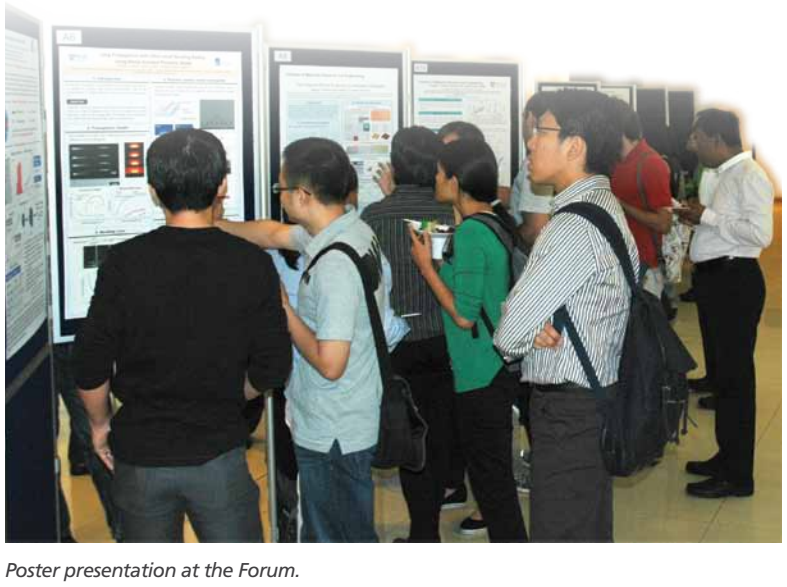
Learning from one another *- Participants at IMRE's Scientific Research Forum 2012.*

Held from 23 to 24 August 2012, the forum consisted of oral and poster presentations as well as a Postgraduate Student Poster Competition. More than that, the annual event was an opportunity for researchers working on different projects to share their achievements and challenges with one another.

"In this information age, shared knowledge is sometimes a crucial factor that takes a research or a technology to the next level. You may have all the information at your disposal in any given area but there is nothing like getting a different perspective from a colleague to inject fresh, new ideas into what one is doing," said Dr Karthik Kumar who was on the organising committee for this year's Forum.

Some of the topics covered included research on plasmonics at sub10-nm scale, superlenses, enhanced chemical processes, nanolithography, the latest developments in characterisation, and polymer anti-fouling surfaces, among many others.

This year's event also saw early career researchers at the forefront of the planning and implementation of the Forum's scientific programme. The aim of this was to prepare the young researchers for eventual leadership roles in future conferences, both in and outside IMRE.

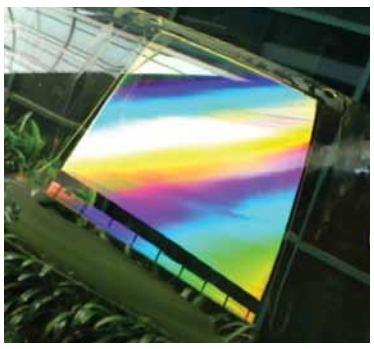


Poster presentation at the Forum.

CORPORATE NEWS

Nanoimprinting manufacturing goes into high gear

Fast, high-volume production of plastics with specially engineered surfaces will soon be available using a cheaper and simpler method. IMRE and its Industrial Consortium On Nanoimprint (ICON) partner companies have started pilot roll-to-roll nanoimprint technology to mass produce two types of patterned nanoimprinted plastic films – low-reflectivity and self-cleaning films.



Prototype of nanoimprinted film produced using roll-to-roll manufacturing.

Films with low reflectivity and better viewing angles, as well as durable, scratch-resistant films with 'self-cleaning' surfaces will soon be made using nanoimprint technology. This technology can be more cost effective than conventional batch production of such films as it employs roll-to-roll processing, which enables the continuous, high throughput production of materials on a large scale. The mass-produced anti-reflective films can potentially be used on mobile devices and tablets while the self-cleaning plastics can be applied to walls and windows.

Innox Higa Singapore Pte Ltd, Micro Resist Technology GmbH, NTT Advanced Technology, SABIC Innovative Plastics, Solves Innovative Technology and Evonik (SEA) Pte Ltd will work together with IMRE as part of ICON to develop the materials and scale up production of the films. The partners are developing tougher resins for the nanostructures that are then patterned onto the plastics via IMRE's unique nanopatterning processes. The process is then scaled up using ultraviolet roll-to-roll nanoimprinters so that the films can be used in eventual prototyping on surfaces and devices.

For more information about nanoimprinting and ICON, please visit www.imre.a-star.edu.sg/ICON.

IMRE and NJC to work on nurturing young scientists

A Memorandum of Understanding (MoU) between IMRE and National Junior College (NJC) will promote scientific research in Singapore by creating awareness among students in the areas of materials science.

Nurturing future scientists together *- Representatives from A*STAR and NJC at the event included (third from left) Prof Lye Kin Mun, Deputy Executive Director, A*STAR Science and Engineering Council (SERC), (fourth from left) Prof Andy Hor, IMRE's Executive Director and (fourth from right) Mrs Virginia Cheng, Principal of NJC.*

The MoU will see budding student-scientists gain first-hand research experience while being mentored by seasoned researchers in materials R&D. The students will be involved in materials-related projects such as forensic investigation of materials, new chemical and catalytic processes for use in energy harvesting, and the development of new materials for sustainable energy R&D like organic solar cells. The students can also use the projects to participate in science fairs and have the opportunity to publish their work in international journals.

Some 19 research projects have already been lined up this year for the NJC students. The annual student attachments are expected to last from six months to a year each. After undergoing the requisite safety training, the students will be immersed in an actual research environment and work closely with their IMRE research supervisors.

Long-standing partnership

IMRE has been a partner with NJC in outreach since 2004. As a testament to the close ties that the organisations share, IMRE was recognised as one of the Community Partners that contributed to National Junior College's second consecutive PARTNERS (Outstanding) Award. The award was given by the Ministry of Education on 12 Sep 2012 at its annual Work Plan Seminar.

PEOPLE

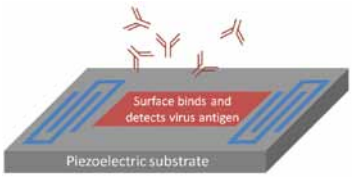
Dr Jiang Ying

Having the right chemistry for research: Profile – Dr Jiang Ying

She is an A*STAR National Science Scholarship award recipient. With a PhD in Chemical Engineering from Stanford University, Jiang Ying is one of the many early career researchers who have joined IMRE in the past year. Her passions run from solar cells to virus detection based on fundamental knowledge of molecular interactions.

What is your area of expertise?

I have experience in conjugated polymer design and synthesis, and the application of these materials in electric devices such as thin-film transistors and solar cells. At IMRE, I started with inorganic sol gel chemistry for fabricating ceramic films but I've transited to studying the interaction between surface functional groups for the detection of an influenza virus antigen. I hope to gain better intuition for various material systems through this research. Going forward, I hope to design projects that continue to develop and expand my interest in supramolecular chemistry, and the interaction between molecules, light and mechanical energy.



A surface acoustic wave sensor with a surface functionalised to specifically detect influenza virus is the type of work Dr Jiang is working on.

What sort of impact do you think this research has?

Most consumer products today contain aspects of material science and engineering. For example, the design of a device that detects flu viruses quickly and easily would have significant impact in helping us combat disease and enhance healthcare.

What do you see as the greatest challenge for you as an early career researcher?

I usually take time to recognise and develop my interests. However, being in a competitive research environment has also trained me to quicken my pace with respect to recognising opportunities, crystalising ideas and sharpening my "entrepreneurial spirit". Competition brings vibrancy and multiplicity, which are always good things to have.

What do you think are the most important qualities a scientist must have?

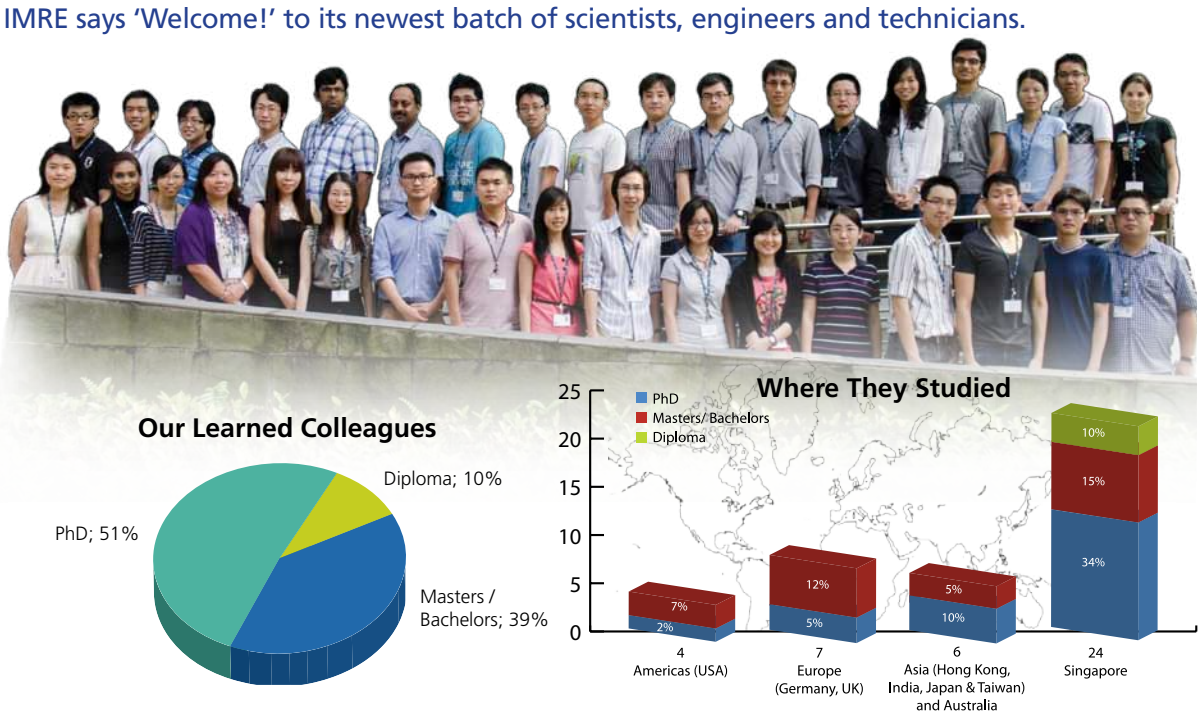
Not one unique set of qualities could fit a person wanting to be a scientist as there are many different fields. Generally, curiosity and open-mindedness come first to my mind. A passion for asking "what if" and "dare-to-do" mentality are good to have if you want to discover new connections between ideas, enhance creativity and explain unexpected observations. For applied scientists - a goal-oriented mindset and an entrepreneurial outlook would be important. Finally, of equal importance with creativity and productivity is objectivity or the need to remain fair-minded and be aware of the fine line between rigorous science and wishful thinking.

Do you have any words of advice for aspiring scientists?

Just as with any career, depending on which stage one is at, there are different things to focus on. But generally, reading widely and setting goals (realistic goals, both short and long term) are good things to keep in mind. Also learn to fail - that's the best way to learn!

New Staff at IMRE

IMRE says 'Welcome!' to its newest batch of scientists, engineers and technicians.



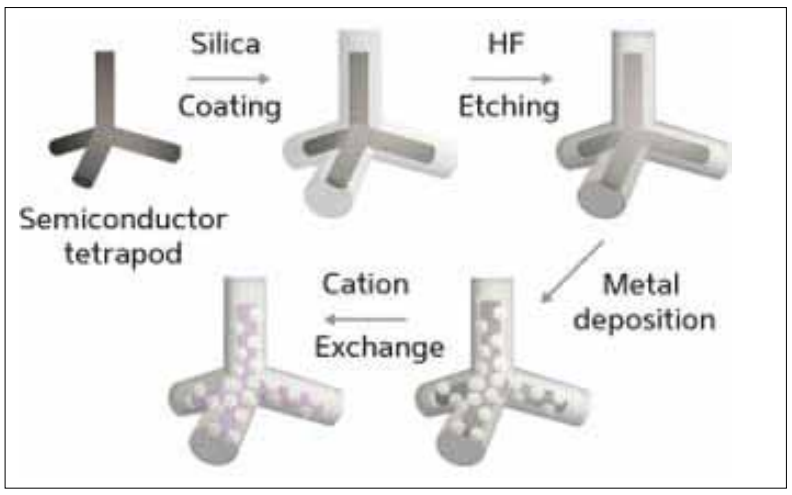
(Top row, left to right) Zhang Xing; Lum Yanwei; Jonathan Low; Ren Yi; Sreenivasa Reddy Puniredd; Sahoo Nanda Gopal; Ady Suwardi; Aaron Thong Zhenghui; Shen Zhiyuan; Zhou Hui; Wang Guan; Li Bing; Tao Junguang; Leong Wei Lin; Sourabh Banerjee; Liu Hui; Lee Weng Yew; Mitali Kakran.

(Bottom row, left to right) Weichao Zhai; Gopalakrishnan Theebarina; Koh Xue Qi; Jassamyn Soh; Sharon Ting; Wu Mengfei; Zhang Shuangyuan; Pan Yongzheng; Connie Liu; Thammanoon Sreethawong; Chong Yuen Tung, Christy; Lee Jing Jun Coryl; Li Jing; Ong Wen Jie; Steven Lukman; Lim Yuan Chong Jason; Michael Leong.

Absent: Hong Shuzhen; Meysam Sharifzadeh Mirshekarloo; Poon Suk Yean Polly; Tan Chor Seng; Wang Mian.

New coated nanoparticle for more efficient hydrogen generation

Lian, J., Xu, Y., Lin, M. & Chan; Y. Aqueous-phase reactions on hollow silica-encapsulated semiconductor nanoheterostructures; Journal of the American Chemical Society 134, 8754–8757 (2012); dx.doi.org/10.1021/ja301805u.



Schematic to show the creation of the platinum-decorated semiconductor tetrapod with a hollow silica shell.

What: An IMRE team has created a new type of platinum-decorated semiconductor nanoparticle photocatalysts that do not agglomerate to allow more efficient water-splitting for production of hydrogen.

How: Conventional platinum-decorated semiconductor nanoparticles tend to clump together in water. The IMRE team solved the agglomeration issue by coating the nanoparticles with a thin hydrophilic silica shell. The encapsulation allows the nanoparticles to be easily dispersed in water. The team produced the metal–semiconductor nanostructures using ultra-small, cadmium-containing, semiconducting tetrapods and coated it in silica. The team then created a hollow shell around each tetrapod via etching. Platinum was then deposited on the tetrapod arms. The team also discovered that the encapsulation enabled unprecedented cation exchange reactions which swapped cadmium ions for silver or palladium ions and yielded new platinum-semiconductor tetrapods.

Why: Platinum-decorated nanoparticle systems are one of the most promising photocatalysts being developed in the race to produce an efficient water to hydrogen conversion reaction which is powered by sunlight. IMRE's development of the new coated nanoparticles could pave the way for the commercial development of such cheap and simple conversion reactions.

For more information about the publication, please contact

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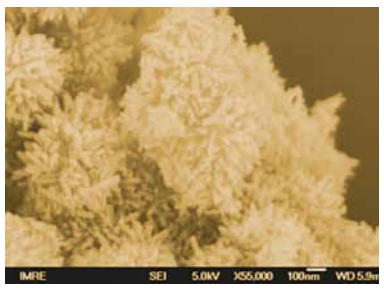
Developing high energy and power density storage technology

IMRE was selected as the lead institution in a grant by A*STAR to champion research in this area together with its National University of Singapore (NUS) partner.



A representative SEM image of IMRE's mesoporous metal oxides. These sea urchin like submicron secondary particles possess high specific surface area and pore size of a few nanometers, promising good potential in energy storage applications.

Scientists from IMRE and NUS will spearhead four projects that are designed to build up capability in advanced high-density energy storage devices that could have potential application in areas such as electric vehicles and smart grid energy storage solutions.

The strategy for the team is to look into developing strong metal-air and supercap scientific and engineering know-how, mastering battery and supercap materials research and engineering capabilities, developing a strong intellectual property portfolio in advanced energy storage systems, and train manpower to meet Singapore's future demand in the energy industry sector.

"We hope to be able to establish ourselves in this area so that we can actively engage industries along the entire energy storage supply and value chain," said Dr Zong Yun, who is one of the principal IMRE scientists involved in energy storage R&D. "Eventually we want to bring the technology to a scale where we can offer customised energy storage solutions to applications in areas like renewable energy storage, high power consumption portable electronic devices, electric vehicles and smart grids."

For more information about this work, please contact

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Giving local enterprises that competitive R&D edge

Whether it is a personalised one-to-one or the larger one-to-many consortia-type collaboration, IMRE works with many local small and medium enterprises (SMEs) to enhance their R&D capability and give them the opportunity to compete on a global scale.

"R&D may be seen as unaffordable for most SMEs but in order to stay ahead of others, innovation and R&D are key. ICON is an excellent platform for SMEs to tap on the available resources in A*STAR and jumpstart R&D at a nominal cost."

- Mr Koh Teng Hwee, Managing Director of Solves Innovative Technology

IMRE helps local SMEs enhance their technological capabilities.

The quote by Mr Koh at the launch of A*STAR's first nanotechnology consortium, the IMRE-led Industrial Consortium On Nanoimprint (ICON), sums up the rationale behind IMRE's drive towards engaging and enabling local companies like Solves Innovative Technology. Solves worked with IMRE to build the first made-in-Singapore tool for advanced manufacturing of nano-sized structures. The production-grade tool is faster and more accurate with a reduced processing time for precision nanometer-sized patterning.

"Our charter is to translate good material science into technologies and know-how that propels the capabilities of our industries to higher levels," said Dr Mark Lim, IMRE's Director (Industry & Enterprise). "We do this via innovative collaboration models leveraging on transferring, licensing and commercialising our R&D as well as seconding our scientists to local companies."

Recent collaboration examples include research projects with The Banshing Group, Cima NanoTech, Hoestar PD Technology Pte Ltd, TechnoDigm Innovation Pte Ltd and LinkStar Microtronics Pte Ltd. Banshing is growing as a high value equipment maker and contract manufacturer in moulding through their partnership with IMRE in materials research. IMRE and Cima NanoTech are developing transparent conductive materials, components, and applications leveraging SANTE(™) technology, Cima NanoTech's ultra conductive, high transparency, and flexible transparent conductive nano particle network. Hoestar is tapping on IMRE's piezoelectric technology to realise a new 'health' monitoring system for machinery. TechnoDigm is using IMRE's unique material-critical transducer technology to realise a novel fluid dispersal system that could be applied to high performance fluid dispensers which are widely used in biomedical to electronics manufacturing. IMRE is working with LinkStar Microtronics to transform their laser diode products for potential application in the areas of optical networking, optical characterisation, optical monitoring and gas sensing.

IMRE also actively supports local companies by seconding research staff to SMEs through A*STAR's Technology for Enterprise Capability Upgrading (T-UP) initiative. The scheme enables local enterprises to access the pool of R&D talent at A*STAR's research institutes like IMRE and with partial funding provided.

For more information on how IMRE can help your company, please contact

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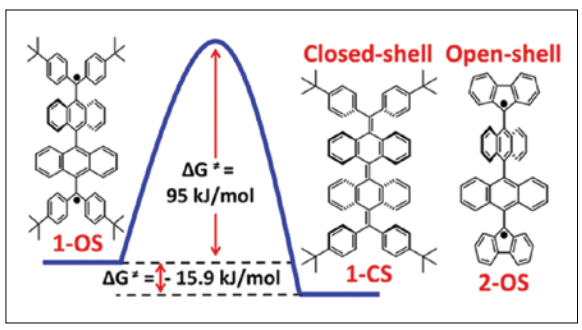
More stable open-shell hydrocarbon

Zebing Zeng, Young Mo Sung, Nina Bao, Davin Tan, Richmond Lee, José L. Zafra, Byung Sun Lee, Masatoshi Ishida, Jun Ding, Juan T. López Navarrete, Yuan Li, Wangdong Zeng, Dongho Kim, Kuo-Wei Huang, Richard D. Webster, Juan Casado, and Jishan Wu; Stable Tetrabenzo-Chichibabin's Hydrocarbons: Tunable Ground State and Unusual Transition between Their Closed-Shell and Open-Shell Resonance Forms; Journal of the American Chemical Society 134, 14513-14525 (2012).



Stable Chichibabin's hydrocarbons with tunable ground state and unusual conversion between their closed-shell and open-shell resonance forms.

What: Chichibabin's hydrocarbon as a classical open-shell polycyclic aromatic hydrocarbons (PAHs) has been long studied. However, research into these compounds are complicated by their inherent high reactivity. A multinational research team has developed two new stable benzannulated Chichibabin's hydrocarbons 1-CS and 2-OS.

How: The ground state electronic structure and geometry of the hydrocarbons were studied using a variety of methods such as steady-state and transient absorption spectra, NMR, electron spin resonance (ESR), superconducting quantum interference device (SQUID), etc. 1-CS and 2-OS exhibited tunable ground states, with a closed-shell quinoidal structure for 1-CS and an open-shell biradical form for 2-OS. Their corresponding excited-state forms 1-OS and 2-CS showed different decay processes. The biradical 1-OS displayed an unusually slow decay to the ground state (1-CS) while a quick transition from the quinoidal 2-CS (excited state) to the orthogonal biradicaloid 2-OS (ground state) was observed during the attempted synthesis of 2-CS.

Why: Because of their unique electronic, optical, and magnetic properties, stable open-shell PAHs have significant potential applications in materials sciences such as for ambipolar charge transport, spintronics, Li ion batteries, non-linear optics, photovoltaics, and magnetic resonance imaging.

For more information about the publication, please contact

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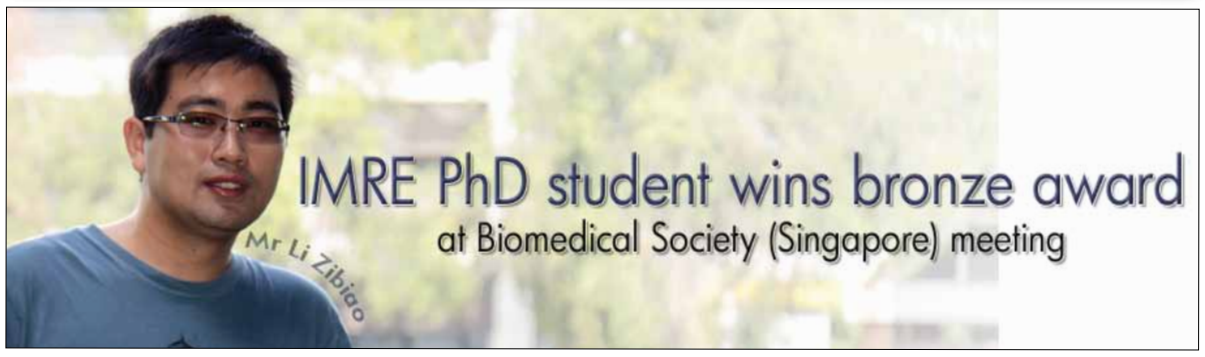
AWARDS



Award for IMRE attachment student

Mr Li Zibiao, supervised by IMRE's Dr Li Jun, won the Bronze Award in the Technical Presentation, Graduate Category at the Biomedical Engineering Society's (Singapore) 6th Scientific Meeting for his work on "Engineered Biodegradable Hyperbranched Hydrogel with Mechano-responsive Property for Easy Cell Recovery Application."

Best Poster Award at international conference

Dr Neucheva Olga Alexandrovna's poster entitled "Switching of a Single Molecule: Pentacene on Si(100)" won the Best Poster Award in Molecular and Nano-electronics at the International Conference on Nanoscience + Technology, Paris, France on 27 Jul 12. The award was presented by the European Physical Society.

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UPCOMING EVENTS

Diary of upcoming events @ IMRE

02 November 12
Lab-on-a-chip Workshop: Novel 3D Microfluidics, Bioassays, and Signal Enhancement

05 November 12
4th Dalton Transactions International Symposium

09-11 January 13
3rd M3 @ Singapore

19-23 August 13
15th Asian Chemical Congress

20 August 13
1st Asian Chemistry Research Fair
In conjunction with 15th Asian Chemical Congress

To find out more about IMRE's seminars and events, please visit www.imre.a-star.edu.sg/eventsall.php

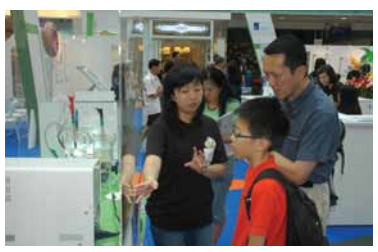
OUTREACH

Visits and Events

X-periment 2012

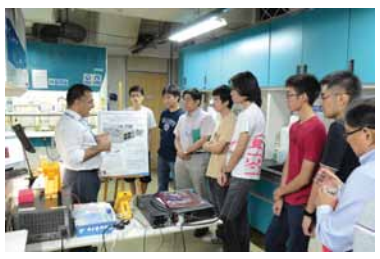
27-29 Jul 12

In our continuing effort to introduce materials research to the public and make science interesting to the layperson, IMRE scientists showcased work on water splitting. The research is related to developing technology to efficiently generate hydrogen as a clean source of fuel. X-periment was the annual Singapore Science Centre and A*STAR-organised Science Festival event and was held at the Marina Square Atrium.



Visitors to the IMRE booth at X-periment exhibition.

Introducing materials science to Singapore Polytechnic visitors



Introducing materials science to the visitors from Singapore Polytechnic.

04 Sep 12

26 students and lecturers from Singapore Polytechnic visited IMRE to understand more about what goes on in materials research. Dr Karthik Kumar gave a presentation on *"The many colors of gold and silver"* before the students were given a laboratory tour.

Promoting science as a career

06 Sep 12

Some 40 students visited various laboratories in IMRE such as those working on printed electronics, artificial cell membranes and carbon reinforced materials as part of the A*STAR Research Exposure Programme. The aim of the visit was to introduce secondary school students to science and IMRE and promote research as a viable career choice.

Students being briefed on research at IMRE.

Anglican High School students at SkyMRE

07 Sep 12

IMRE researcher Mr Ong Wen Jie, who is also an Anglican High alumnus, shared his research experiences and his reasons for pursuing a career in science during the visit. Apart from visiting the research laboratories, Dr Zhang Lei also introduced piezoelectric materials to the students and demonstrated the R&D using a working battery-less remote controller prototype.

The battery-less remote controller being demonstrated to the Anglican High students.

National Junior College (NJC) Engineering Day 2012

22 Sep 12

Organised annually by NJC to interest students in a career in science and engineering, the theme for 2012 was "2025" to envision what engineering might be like in the future. IMRE researchers conducted a simple experiment on polarising lenses as well as talked to students on potential scholarship opportunities in A*STAR.

An insight into DuPont's R&D strategies

25 Sep 12

A*STAR scientists were fortunate to learn about some of DuPont's strategies for enabling technologies and how these could be used to solve global issues from Dr Thomas Connelly, Executive Vice-President (EVP) and Chief Innovation Officer (CIO). Dr Connelly was hosted at IMRE for a DuPont Executive Dialogue where he outlined the processes and inner workings that went into the global MNC's R&D mindset, which was geared towards using science to solve some of the major challenges that a world population faces today such as food, energy and protecting the environment. Dr Connelly also spoke at length about integrated science and how some of these multi-disciplinary research initiatives had contributed to DuPont's many innovations. The talk was attended by A*STAR scientists from the physical and biomedical sciences research institutes.

Dr Thomas Connelly, EVP and CIO of DuPont, outlining some of the world's major challenges and how science can help provide viable solutions.