Research, Development and Commercialisation
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# PERSPECTIVES

Institute of Materials Research and Engineering
A*STAR
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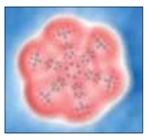
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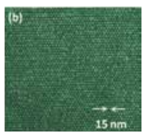
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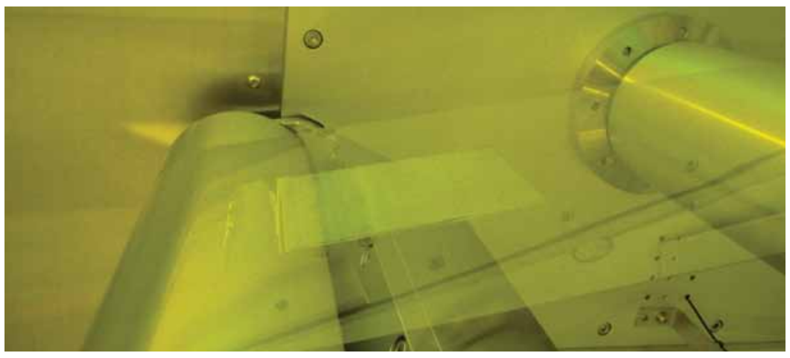
## Roll-to-roll nanomanufacturing launched in IMRE

IMRE's Industrial Consortium On Nanoimprint (ICON) puts roll-to-roll nanoimprint manufacturing to the test with industry partners.



*One of the square plastic films bearing nanometer-sized patterns being rolled out of the prototype roll-to-roll UV nanoimprinter - Roll-to-roll processing will allow such unique plastics to be manufactured on a large scale.*

Roll-to-roll nanoimprinting can easily and quickly mass produce films and surfaces with nanometer-scale textures for a host of new applications in biomedical devices, optical films, plastic electronics and flexible solar cells. IMRE and its partners in ICON are planning to manufacture such structures using this new process. The fast, mass production method can create large area nanostructured components, opening the way for new consumer applications not previously conceptualised or economically feasible.

The collaboration is the third industry-themed project by ICON that involves local and international partners such as Solves Innovative Technology Pte Ltd (Singapore), Advanced Technologies and Regenerative Medicine, LLC (ATRM) (USA), Young Chang Chemical Co. Ltd (South Korea), EV Group (Austria), Micro Resist Technology GmbH (Germany) and NTT Advanced Technology Corporation (Japan). Some of the applications that the consortium hopes to harness with roll-to-roll nanoimprint include anti-fouling surfaces, anti-reflection films to enhance the efficiency of solar cells, wire-grid polarisers, and optical films for flat panel displays.

ICON will be introducing two types of roll-to-roll techniques - a thermal and a UV-based version. The thermal method makes patterns on the substrate directly, can accommodate a variety of plastics for different applications, and is ideally suited for the fabrication of micro- and nano-fluidic devices, biochemical assays as well as other biomedical applications. The UV technique allows quicker processing because it is a room temperature process, and offers the advantage of fabricating the nanostructures on cross-linkable resins, thus imparting higher thermal and mechanical stability to the imprinted products.

"The roll-to-roll nanoimprinting technique is a crucial centerpiece iin ICON's plan to complete the value chain for harnessing the true potential of our bio-mimetic multifunctional nanoimprint technology surfaces", said Dr Low Hong Yee, an IMRE senior scientist who heads the team developing the roll-to-roll nanoimprint technology. "With this method we can merge nanoimprint technologies into real-world applications and on an industrial scale", explained Dr Low.

For more information on ICON, please visit IMRE's website or contact

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## Home of the world's smallest working gear!

Researchers set a Guinness World Record with a 1.2nm controllable, molecule-sized gear, which is officially the world's smallest. The gear is 100,000 times smaller than the width of a single strand of hair.

IMRE scientists and their collaborators from the French Centre National de la Recherche Scientifique (CNRS) have officially demonstrated the world's smallest, fully controlled rotation of a molecule-sized gear. The achievement which was published in a 2009 Nature Materials paper was recognised in the most recent issue of the Guinness Book of World Records as the world's smallest.

The research opens the way for the future development of molecule-sized machines that may lead to innovations like pocket-sized supercomputers, miniature energy harvesting devices and data computing on atomic scale electronic circuits.

Before the team's success, attempts to rotate single molecules resulted in their random and uncontrolled rotation. IMRE's scientists were able to solve the matter by manipulating a pinion-like molecule, which was custom synthesized by CNRS collaborators, mounting it to an atom sized adsorbate and controllably rotating it clock and anti-clockwise with the tip of a Scanning Tunnelling Microscope, which is a powerful microscopy tool capable of imaging materials down to their atoms but which can also be used to manipulate a single molecule or one atom at a time on conductive surfaces.

For more information about the research, please contact

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Dr Carlos Manzano
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Reference for the research paper:
***Step-by-step rotation of a molecule-gear mounted on an atomic-scale axis***
Manzano, C., Soe, W.-H., Wong, H.S., Ample, F., Gourdon, A., Chandrasekhar, N. & Joachim, C. Nature Mater. 8, 567 (2009); Doi:10.1038/nmat2467

## Recognition for IMRE's women researchers

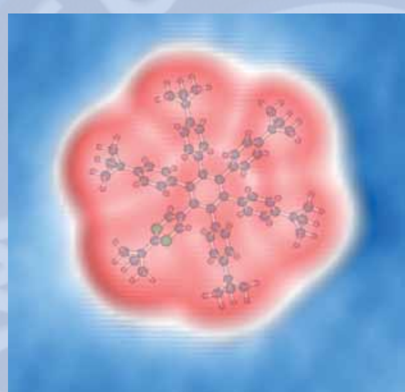

IMRE's Dr Liu Bin and Dr Teo Ee Jin were recognised for their research work in the L'Oreal Singapore For Women in Science National Fellowships 2011. Dr Liu was one of two recipients of the prestigious L'Oreal award while Dr Teo was chosen as one of the award finalists.

For two years running, female IMRE scientists have clinched the prestigious L'Oreal For Women In Science Award that recognises the achievements of women in contributing to the Singapore science scene.

Dr Liu Bin won the prestigious L'Oreal Singapore For Women in Science National Fellowships 2011 for her efforts to make solar energy accessible to the masses. Dr Liu Bin's research focused on creating low cost, high efficiency solar cells by using new materials, and optimising device design and architecture.

Dr Teo Ee Jin was selected as a finalists of the same award for her research on using plasmonics to merge the electronics and photonics at the nanoscale level for a faster and more compact microprocessor. The aim of this project is to explore the use of gallium nitride light emitting diodes (LEDs) as a new platform for providing electrical excitation of surface plasmon polaritons, leading to a significant increase in spontaneous emission rates for super-bright, ultrafast LED devices.

## Geared up for a World Record



Looking like a wheel, the gear is made out of a hexa-t-butyl-pyrimidopentaphenyl benzene ($C_{64}N_2H_6$; HB-NBP) molecule, which consists of a central core composed of one pyrimidine and five phenyl rings all connected to a central planar phenyl. This is connected to the 'spokes' of the wheel which are made up of six t-butyl outer groups that lift the central molecule core from the substrate surface. The molecule was mounted on an atom-sized impurity that acted as a pinning axle and manipulated using the microscope's tip, which turned this molecule-gear step-by-step.

Institute of Materials Research and Engineering
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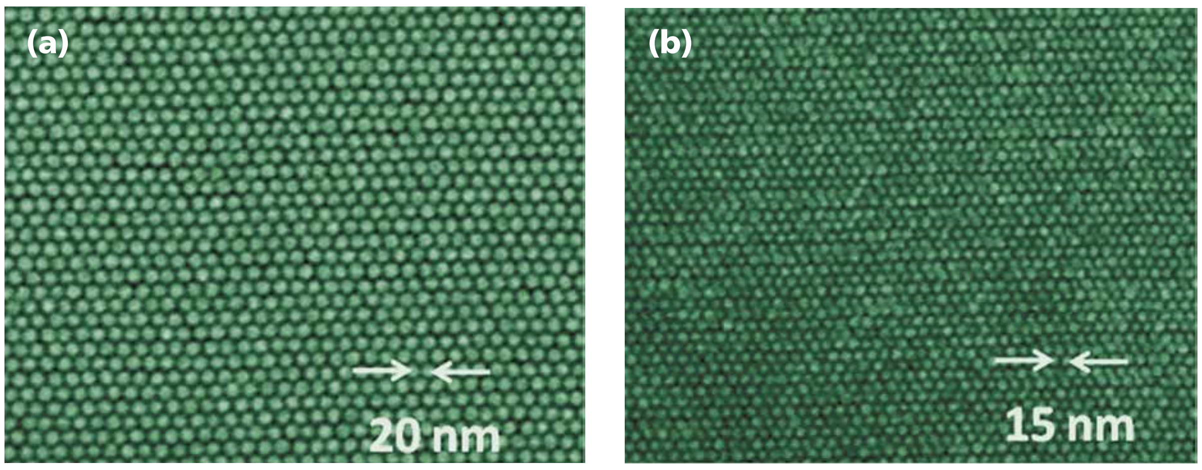
CORPORATE NEWS

# Packing in more bits for a bigger byte

IMRE scientists, working with peers from A*STAR's Data Storage Institute and National University of Singapore, have used nanopatterning to create uniform arrays of magnetic bits that can potentially store up to 3.3 Tbit/in$^2$ of information, six times the recording density than in current hard disks.




*Scanning electron microscopy images of magnetic bits at densities of (a) 1.9 Tbit/in$^2$ and (b) 3.3 Tbit/in$^2$ formed after depositing Co/Pd multilayers onto resist structures.*

It's like packing your clothes neatly in your suitcase when you travel. The neater you pack them the more you can carry. In the same way, the team of scientists has used nanopatterning to closely pack in more of the miniature structures that hold information in the form of bits, per unit area. In contrast to the disk platters in current hard disks, on which nanoscopic magnetic grains are randomly distributed, the team used a method based

**"The method can potentially pack in six times more bits and information into a single inch…"**

on the concept of bit-patterned media, where magnetic islands are patterned in a regular fashion, with each island storing one bit of information. The method can potentially pack in six times more bits and information into a single inch, which tremendously increases the storage density of devices like hard disk drives. IMRE has already created bits that have densities up to 3.3 Tbit/in$^2$.

"What we have shown is that bits can be patterned more densely together by reducing the number of processing steps", said Dr Joel Yang, the IMRE scientist who is leading the project. The key to the research was the use of a high-resolution e-beam lithography process which was developed by Dr Yang during his time at the Massachusetts Institute of Technology.

Current technology uses very tiny 'grains' of about 7-8 nm in size deposited on the surface of storage media. However, information or a single bit, is stored in a cluster of these 'grains' and not in any single 'grain'. IMRE's bits are about 10nm in size but store information in a single structure.

"In addition to making the bits, we demonstrated that they can be used to store data. The only problem is that we are now making bits that are too dense to be tested with existing hard-disk tester techniques!" explained Dr Yang. "Instead, we used magnetic-force microscopy to characterise and show that the bits can be switched independently of their neighbours."

The researchers are now looking at increasing the storage density further.

"Even our current methods have their resolution limits", added Dr Yang. "We are looking at alternative nanopatterning methods using self-assembly of nanoparticles for instance, to help us go beyond these limits".

For more information about this research, please contact

Dr Joel Yang
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Reference:
***Fabrication and characterization of bit-patterned media beyond 1.5 Tbit/in$^2$***
Joel K WYang, Yunjie Chen, Tianli Huang, Huigao Duan, Naganivetha Thiyagarajah, Hui Kim Hui, Siang HueiLeong and Vivian Ng
Nanotechnology 22 (2011) 385301;Doi:10.1088/0957-4484/22/38/385301

PEOPLE

# Profile - Prof Tamio Hayashi

Prof Tamio Hayashi heads the Hayashi Group at the Department of Chemistry, Graduate School of Science, Kyoto University, Japan and is a Visiting Scientist at IMRE.

Prof Hayashi is one of the most highly cited chemists in the world. He has published some 370 papers and with total citations of around 24,400 (H-index 85) for his well-known work on asymmetric catalysis. Here, chiral catalysts are used to speed up the production of enantiomer compounds, which are used heavily in pharmaceutical manufacturing and a range of other applications. Chiral molecules are not superimposable on their mirror images and are often called enantiomers. Though they are composed of the same number of atoms, each of the mirror-image enantiomers has different chemical reactions due to the optical nature of the mirror-image molecules. Studies on asymmetric catalysis can help improve the efficacy of current medicines significantly.

**What is the scientific achievement that you take pride in most?**
I developed conceptually new chiral catalysts and new catalytic asymmetric reactions, which have often been used by researchers around the world and has been cited more than 20,000 times.

**What is your key research field?**
My interests lie in the development of new selective organic transformations catalysed by transition metal complexes, especially catalytic asymmetric reactions.

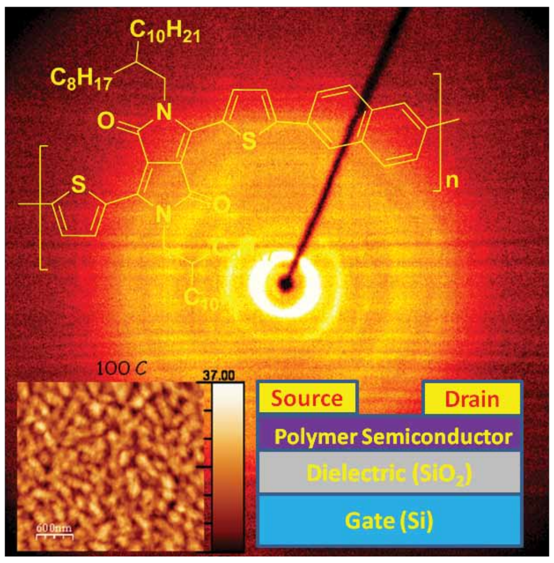
**What is your inspiration for taking up a career in science?**
Science offered an avenue to do something new and creative.

**Do you have any advice for aspiring young researchers on how to achieve a fruitful research career?**
Aim to be at the top of your field in a niche research area. Once this has been achieved aim then to make that area significant, beneficial and widely recognised as important. For this you need persistence. One's native ability as a researcher is not invariable but is improved by persistent efforts!

RESEARCH

# New material can be used in both organic thin film transistors (OTFTs) and solar cells

***High mobility organic thin film transistor and efficient photovoltaic devices using versatile donor–acceptor polymer semiconductor by molecular design; Energy Environ. Sci., 2011, 4, 2288; Prashant Sonar, Samarendra P. Singh, Yuning Li, Zi-En Ooi, Tae-jun Ha, Ivy Wong, Mui Siang Soh and Ananth Dodabalapur; DOI: 10.1039/c1ee01213d***




*Schematic of an OTFT device geometry with two-dimensional X-Ray diffraction and thin film morphology of PDPP-TNT.*

***Abstract:*** IMRE scientists have developed one of the few high performance materials currently in existence which can be used in both OTFTs and organic solar cells or photovoltaics (OPVs). The same material is able to provide close to 1 cm$^2$V$^{-1}$s$^{-1}$ hole mobility for OTFTs and 4.7 % power conversion efficiency for OPVs. The material is a new donor–acceptor based, solution-processable, low band gap polymer semiconductor called PDPP–TNT. It was synthesised via Suzuki coupling using condensed diketopyrrolopyrrole (DPP) as an acceptor moiety with a fused naphthalene donor building block in the polymer backbone. The polymer exhibits p-channel charge transport characteristics when used as the active semiconductor in organic thin-film transistor (OTFT) devices. Due to its appropriate HOMO (5.29 eV) energy level and optimum optical band gap (1.50 eV), PDPP–TNT is also a promising candidate for OPV applications.

**"The same material is able to provide close to 1 cm$^2$V$^{-1}$s$^{-1}$ hole mobility for OTFTs and 4.7 % power conversion efficiency for OPVs."**

OTFTs are basically switches and are important components for making low cost active matrix displays. Additionally they can be used for making logic circuitry and memory arrays for low cost electronic products such as smart cards and inventory tags. Using organic semiconductor compound like PDPP-TNT to produce OPVs, which are used to harness solar energy, helps reduce costs as the polymer is easy to process and can be made into large area devices. The researchers are also looking to use the new polymer in other applications such as inverters, chemical sensors, photodetectors and memory devices.

For more information about the publication, please contact

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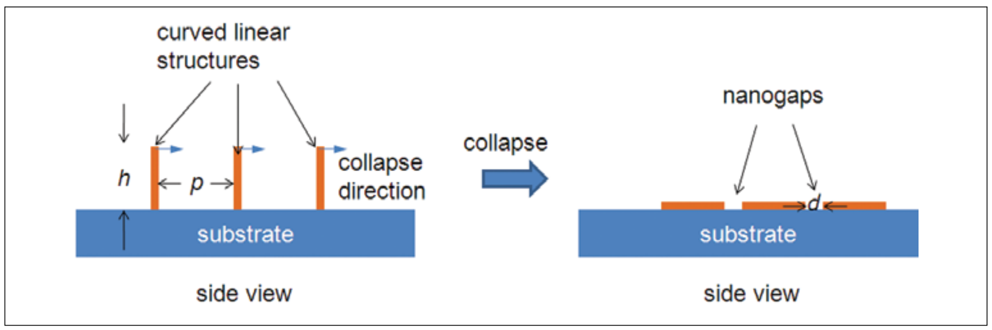
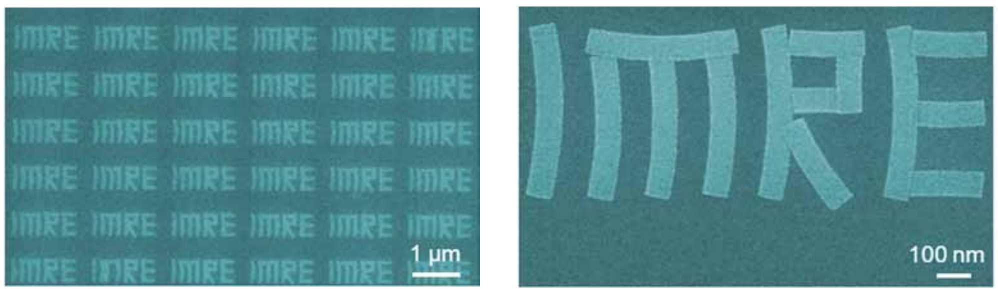
RESEARCH

## Unique patterning technique - Controlling how nanostructures fall

***Controlled Collapse of High-Aspect-Ratio Nanostructures; Small 2011, 7, 2661-2668; Huigao Duan, Joel K. W. Yang, and Karl K. Berggren; DOI: 10.1002/smll.201100892***




*Schematic showing how the collapse of the nanostructures is done.*




*To demonstrate the capability and precision of the new technique the researchers were able to controllably pattern structures that spelled out the word 'IMRE' (left) with each letter being about 500nm in length (right).*

**"…the collapse can be done with such precision that intricate patterned surfaces can be created"**

***Abstract:*** When nanopatterning on substrates, the collapse of high-aspect-ratio micro- and nanostructures is a common problem that occurs due to capillary forces during the sample-drying process. In addition, the undesirable collapse of these structures is also random. IMRE's researchers Huigao Duan and Joel Yang, in collaboration with Karl Berggren at MIT have successfully turned this problem into a useful fabrication tool by controlling the collapse of 10-nm-scale structures in the shape of nanostructures. In a recent paper published in the journal of *Small*, the authors demonstrate that the collapse can be done with such precision that intricate patterned surfaces can be created. This novel patterning method is done by engineering either an asymmetric cross section, curvature or tilt in the nanostructures prior to collapse. The researchers have shown that such deliberate collapsing can be used to create linear structures from collapsed pillars and planar rectangular structures from collapsed fence-like linear structures. The method can also be used to create small gaps by controlling the collapse of adjacent structures. This new technique can be used to improve the performance of beam-based lithography methods for certain types of patterns by increasing throughput and resolution, reducing the proximity effect, and reducing irradiation damage, which is common in conventional methods such as in ion-beam lithography. In addition, this controlled-collapse concept provides a possible platform with which to study the mechanical behaviour of structures at the 10-nm scale. One of the possible uses for the controlled collapse technique is to fabricate complex 3D patterns that could be metalised and used as plasmonic devices.

This achievement came from an ongoing research to develop new techniques for making sub-10-nm gaps in metal nanostructures for plasmonic applications. Upon excitation of plasmon resonances, electromagnetic fields crowd and intensify in these gaps, rendering these useful in efficiently coupling light in and out of nanoscopic materials such as quantum dots, fluorescent molecules and magnetic materials.

For more information about the publication, please contact

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AWARDS


## Recognised for his work on 'green' materials

IMRE scientist, Dr Liu Hongjun, was one of the awardees of the 2011 World Future Foundation (WFF) PhD Prize in Environmental and Sustainability Research.

Dr Liu Hongjun was recognised for his studies which involved a new resource-friendly synthesis method for preparing enantio-pure chiral compounds. The compounds are important in the pharmaceutical industry and as an organic dye for a possible 'greener' catalyst in harvesting solar energy compared to current metallic catalysts.

The WFF prize recognises excellence in environmental and sustainability research done during PhD studies at the National University of Singapore and Nanyang Technological University.

Online Survey

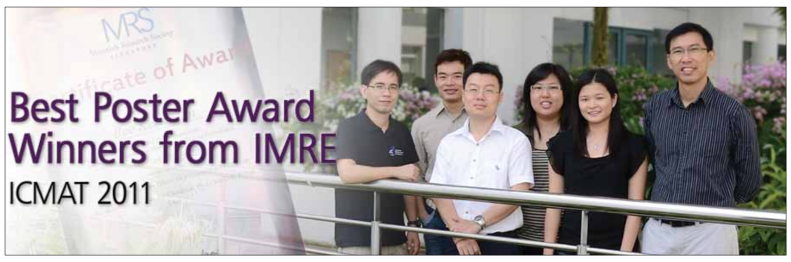
## Tell us what you think of PERSPECTIVES!


Dear Readers,

Since its first issue in April 1998, IMRE's PERSPECTIVES newsletter has been reaching out to you, our readers, collaborators and stakeholders, both in academia and industry. The newsletter has grown and matured through the years. As we seek to continually improve on the newsletter and its content, we would like to hear from you, our current readers as well as potential subscribers, about what you think of the newsletter and what else you would like to see in it.

**Please do help us to make the PERSPECTIVES better by answering 10 simple questions online at IMRE's website at**

**http://www.imre.a-star.edu.sg/newsletter.**

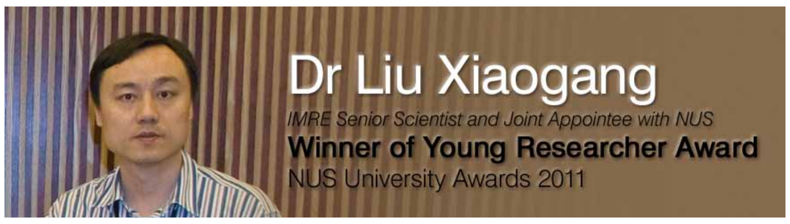



## IMRE researchers come out tops

IMRE research teams garner best poster awards at the recent International Conference on Materials for Advanced Technologies (ICMAT), which was held from 26 June – 1 July.

IMRE's research on "Enhancing the photovoltaic output of a ferroelectric UV sensor" by Yao Kui, Gan Bee Keen, Lai Szu Cheng, Goh Phoi Chin, Chen Yi Fan and "Micro-pyramidal III-Nitride MQWs Array with ZnO nanopillar reflectors" by Soh Chew Beng, Jayce Cheng Jian Wei, Tay Chuan Beng, Rayson Tan Jen Ngee, Liu Wei, Chua Soo Jin won *Best Poster Award* in the Symposium A (Nanostructured Oxides, Interfaces, Heterostructures and Devices) category.

In Symposium JJ (Solution Processing Technology for Inorganic Films, Nanostructures and Functional Materials), Laura-Lynn Liew, Hong Quang Le, Gregory K.L. Goh won the *Best Poster Award* with their research on "Microwave Assisted Hydrothermal Growth of Epitaxial ZnO Films".



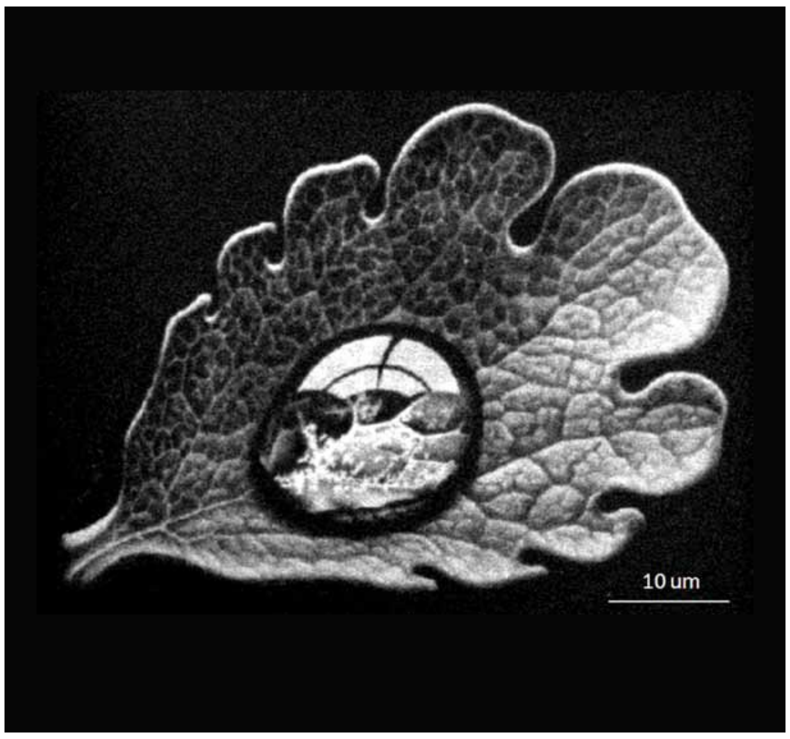

## Young Researcher Award

Dr Liu Xiaogang, a senior scientist with IMRE who holds a joint appointment with the Department of Chemistry, NUS, was awarded the Young Researcher Award at the NUS University Awards 2011. The award recognises researchers below 40 years of age for their achievements and promise in research.

AWARDS

## A picture paints a thousand nanostructures

IMRE researcher wins Grand Prize in the prestigious micrograph contest at the 55th International Conference on Electron, Ion and Photon Beam Technology and Nanofabrication (EIPBN) held in Las Vegas, USA in June 2011.




*The winning entry - A scanning-electron micrograph image of M.C. Escher's 1948 Dewdrop, miniaturised to 4,000 times its original size using IMRE's patented nanophotography technique.*

Dr Joel Yang's scanning electron microscopy (SEM) image of M.C. Escher's 1948 Dewdrop was created using IMRE's patented method of nanophotography, as demonstrated using high-resolution electron-beam lithography. His Grand Prize micrograph was selected from a field of 86 other competing micrographs. The patterned structure is 4,000 times smaller than the original but still preserves both the fine detail and grayscale information of the original mezzotint. EIPBN is one of the world's leading symposiums on lithography and nanofabrication.

For more information about nanophotography, please contact

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UPCOMING EVENTS

## Diary of upcoming events @ IMRE

**09 – 11 Jan 12**
**Molecular Materials Meeting (M3) @ Singapore**
***Biopolis, Singapore***

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

Past issues of our newsletters are available on our website at

**www.imre.a-star.edu.sg**

For general enquiries please write in to
**enquiry@imre.a-star.edu.sg**

OUTREACH

# Science outreach

IMRE's outreach activities are designed to reach out to show the relevance of material science and technology in our everyday life.

*Inspiring young minds at X-periment.*

In its ongoing outreach efforts, IMRE took part in the X-periment 2011, the kick-off event for the A*STAR and Science Center Singapore-organised Singapore Science Festival. X-periment 2011 was held at the Suntec City Convention Centre from 22 to 24 July. IMRE showcased R&D on hydrophobic and hydrophilic nanoimprinted surfaces as well as functional coloured silk cocoons. Researchers also conducted science demonstrations such as the polymer cross-linking behaviour by using common glue and a detergent solution to create a bouncy ball.

Drs Karen Chong, Chua Yang Choo and Davy Cheong also presented a science show entitled "*Chemistry here, there and everywhere*" on 27 July. The presentation combined chemical demonstrations, slide shows and videos to emphasise the importance of chemistry in daily life.

In another activity, IMRE hosted the nationally televised National Science Challenge on 28 July. The competition pitted secondary three students in various science-themed quizzes and challenges. The participants were in IMRE to compete in a segment on organic photovoltaics or solar cells.

IMRE researchers also took part in the Engineering Day on 31 August organised by National Junior College, which is the South Zone Centre of Excellence (Science and Technology). At the exhibition, IMRE showcased the flexible armour technology made from composite materials capable of dissipating high impact energy and explored the physics of looking at things in polarised light.

*IMRE's Dr Davy Cheong (left) demonstrating his flexible, high impact-resistant material to students at NJC's Engineering Day.*

## Visit by NUS Engineering students

**12 September 11**

Engineering students visited IMRE to find out more about the SERC Nanofabrication, Processing and Characterisation (SnFPC) laboratory. The students were shown the various key materials research tools.

## A*STAR Metamaterials Workshop

*Participants at the Metamaterials Workshop.*

**01 July 11**

The workshop held in Biopolis was organised by A*STAR's Metamaterials Programme which is led by IMRE's Dr Teng Jinghua. The workshop was a chance for the local research community to learn about the latest metamaterials developments locally and globally from renowned speakers and scientists who work in the field of metamaterials.

## Visit by undergraduates from University of Twente

*Undergraduates from Twente being introduced to IMRE's research.*

**19 September 11**

Some 30 student and educators from the University of Twente, The Netherlands were briefed on IMRE's research capabilities, particularly in biomaterials and healthcare-related R&D such as biosensors and research on artificial cell membranes.

## Visit by Temasek Junior College (TJC) students

*An IMRE researcher demonstrating the battery-less remote control technology to students.*

**01 September 11**

TJC students and teachers with a keen interest in science were taken on a tour of IMRE's facilities and briefed on some of our research work. The R&D introduced included the characterisation laboratory, research on organic solar cells, LEDs and microfluidics as well as a demonstration of the IMRE battery-less remote control prototype.