Research, Development and Commercialisation
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April 2010

PERSPECTIVES

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

CORPORATE NEWS

Metamaterials – Making the impossible, possible

A research programme aims to create new materials by engineering and altering the structures of such materials to open up a whole new world of materials properties not seen before in nature.

Metamaterials are artificially created structures with feature sizes much smaller than the wavelength of light and possess extraordinary electromagnetic properties not readily observed in natural constituent materials such as negative refractive index. This allows metamaterials to endow properties like super-resolution imaging, confine light in the nano-scale, tune optical response, enhance light absorption, and create planar high-gain antennas.

"Metamaterials are allowing researchers to explore unique properties never before seen in nature!" said Dr Teng Jinghua, a Research Scientist with IMRE. Research groups in the US and Europe have reportedly made metamaterials that are engineered to bend visible light around the object that it coats, thus in theory, making it invisible.

"But metamaterials are more than just about becoming the invisible man", adds Dr Teng who is currently driving an A*STAR-led multi-party research programme to look into metamaterials, involving researchers from A*STAR and the local universities. The aim of the programme is to seed and develop capabilities and ultimately, applied metamaterial technologies. The programme will bring together A*STAR Science and Engineering Research Council's and the local universities' resources in nanofabrication, optics, photonics, and microwave research.

Scanning electron microscope (SEM) image of a 'U'-shaped metal/dielectric multi-stack metamaterials structure – In theory, this 'U'-shaped metamaterial should be able to tune the refractive index in the visible light wavelength, for example, to a refractive index of 1, which is the refractive index of air.

Apart from applications in defense (cloaking technologies), metamaterials have the potential to impact work in nanoelectronics, sensing, data storage, green energy, high-speed communications, microwave and millimeter wave technology, optics and photonics, and in aerospace technology. For example, metamaterials can enhance the sensitivity in bio-sensors by using resonant structures or plasmonic nano-structures to dramatically increase the local optical field intensity, increase storage capacity with super focusing and super-resolution imaging, and make zero reflection surfaces to enhance light collection and light-material interaction for use in green energy materials like solar cells.

For more information about the Metamaterials Programme, please contact

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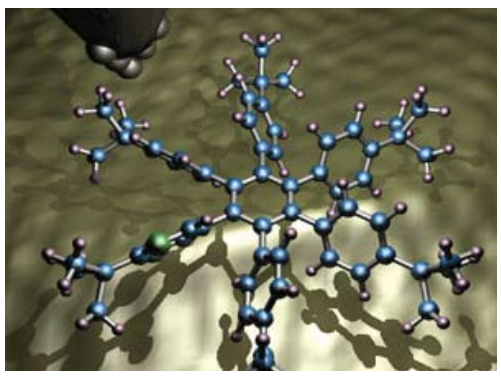
Now you see it, now you don't!

For metamaterials, the theory of invisibility or cloaking works by creating materials that help to 'bend' light as opposed to reflecting light, as is common with most objects. Light is reflected off objects into the human eye so that objects become visible. But if the light is not reflected back into the human eye, as is the case with invisible light 'bending' metamaterials, the object that is coated with the metamaterials can effectively disappear from view!

Banking big on building small

With an eye towards making atomic scale interconnections - the fundamental links that transmit electrical signals and pulses in computer chips - and packaging technology so tiny that a billion of them can fit on one of today's interconnects, its little wonder that Prof Christian Joachim is so excited.



Representation of molecular gear pinned to gold surface with an STM tip close to one of the gears teeth.

*Image courtesy of Dr We-Hyo Soe, A*STAR IMRE*

"Imagine a billion nerve cells taking the place of each one of the nerve cells currently in your brain and you will be able to imagine the scale of computing power and the impact that may be achieved with this research", explained Prof Christian Joachim, Director of Research, and Head of the Molecular Nanoscience and Picotechnology Group, at France's elite Centre National de la Recherché Scientifique (CNRS).

Since 2005, Christian has been a Visiting Investigator at IMRE under a unique A*STAR programme that brings in top calibre, established researchers from across the globe to help seed research and technology that has economic viability to Singapore. Christian and his team work on the fabrication and characterisation of nanostructures composed of atom wires connecting a single molecule logic gate.

In 15 to 20 years, microelectronics will reach its technology limits because there will not be enough atoms in a transistor-like structure on a semiconductor surface for it to work like a transistor. IMRE's work explores new ways of constructing a computing unit at the atomic scale, its atomic scale interconnection technology and its adapted packaging technology. Compared to conventional approaches to interconnects of a single molecule, the programme is developing new technologies to interconnect a single molecule logic gate or atomic scale circuit at atomic scale precision. The programme is creating a completely new field of research by constructing the first full multi-electrode interconnection machine at the atomic scale.

As part of his studies into building structures at the nanometer (one billionth of a meter) scale, the phenomenon of single molecule mechanics is also being studied. Here, Christian and his team had scored a major breakthrough in nanotechnology by becoming the first in the world to invent a 1.2nm molecular gear whose rotation could be deliberately controlled.

"Making a gear the size of a few atoms is one thing, but being able to deliberately control its motions and actions is something else altogether. What we've done at IMRE is to create a truly complete working gear that will be the fundamental piece in creating more complex molecular machines that are no bigger than a grain of sand!" The research was published in the June 2009 issue of the scientific journal, *Nature Materials*, one of the most prestigious journals in materials science.

Workshop on "Atom Technology and its Applications" – 10 June 2010

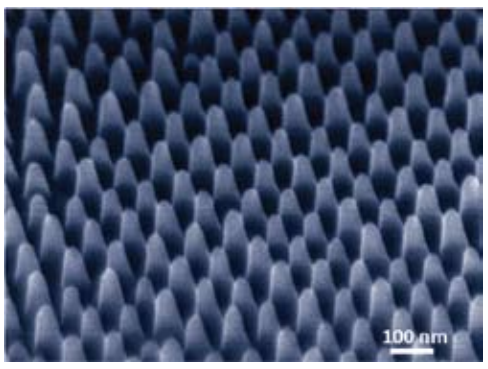
Watch out for the coming Atom Technology Workshop on 10 June 2010. For more details, please check in on the IMRE Events page regularly at the IMRE website at www.imre.a-star.edu.sg

CORPORATE NEWS

Making its mark using nano-sized features

The Industrial Consortium On Nanoimprint (ICON) is a new industry consortium that seeks to foster the sharing and transfer of nanoimprint technology with industries to encourage the adoption of this powerful technology on a wider scale.

Nanoimprint technology (NIT) has evolved from a semiconductor industry-limited lithography process into a platform technology that can be used for a wide range of products. For many applications, nanoimprinting is used as a direct patterning technique where permanent and functional nanostructures are formed. Today, NIT is no longer exclusive to the semiconductor and data storage industries and is quickly gaining interest from other sectors such as the optical components and biomedical industries.



Nanoscale Si pillar arrays of high density and uniformity currently achievable over full-wafer level

"Unlike most other nanopatterning technologies, NIT is highly versatile in terms of the types of materials that can be used, which opens up a wide spectrum of application potentials. More importantly, NIT is a readily scalable technique suitable for adoption by industry", said Dr Low Hong Yee, Head of IMRE's Patterning and Fabrication Capability Group.

Unlike the well-defined specifications for semiconductor devices and data storage media, there is little data on the design rules for many of NIT's emerging applications. The new consortium hopes to tackle this head-on and encourage the mass adoption of nanoimprint technology in the manufacturing of products and services sooner.

"The timing is right", added Dr Low who leads a group of experienced nanoimprint technologists whose achievements include new nanoimprint techniques for complex, 3D nanostructures and efficient wafer scale-size mass production of nanopatterns. "Our interactions with companies in the last two years have revealed an increasing number of diverse industries showing interest in NIT. While these interests come from diverse sectors of the economy, we realise that there are certain convergent themes that can be established for multi-party collaborative pre-competitive research and development with industry partners, which bodes well for the launch of the consortium".

The consortium is currently being formed and is slated for launch in August 2010.

For more information about ICON, please contact

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Visit our website at http://www.imre.a-star.edu.sg/nil/ for more information on ICON.

You are invited to the

Launch of Industrial Consortium On Nanoimprint (ICON)

in conjunction with the

4th Industrial Symposium on Nanoimprint Lithography

3 August 2010 (Tuesday)

Institute of Materials Research and Engineering (IMRE)
3, Research Link, Singapore117602

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Finding solutions to a pesky problem – Biofouling prevention

HVS Engineering Pte Ltd and IMRE are working on building a new eco-friendly system that uses seawater to cool commercial heat exchangers – minus the pesky creatures that come with marine water.

The humble barnacle in itself may seem harmless but multiply the organism by a million and you have a problem - termed as 'biofouling' - that is costing billions of dollars worth of maintenance to the shipping industry and industries that use piped seawater.

HVS' anti-macrofouling mitigation system during pilot trials at the Singapore Refining Company

"Our technology uses a continuous mechanical cleaning movement to disrupt the developmental cycle of biofouling organisms and 'knocks off' the organisms in their early larvae stage before they can settle", said Mr Alex Chow, founder of HVS Engineering which has to date been very successful in tackling micro-organism biofouling in treated water for industrial heat exchangers in a number of Singapore landmarks including Biopolis and Suntec City. Their mechanical cleaning method is effective and eco-friendly compared to the conventional micro- and macro-fouling control techniques that use costly and toxic chemical and oxidising compounds. However, their experience with marine macro-organism biofouling was limited, leading to the collaboration with IMRE, which had started research on marine biofouling prevention in 2007.

Heat exchangers transfer heat from one medium to another efficiently and are used quite widely in refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, and petroleum refineries. Though most use treated water in their systems, the use of cheap and readily available seawater will be a boon for industries located along the coast, for example, the oil refining companies like Singapore Refining Company, Shell and Exxon Mobil on Jurong Island.

"To tackle the problem of marine biofouling, we started by looking at the settling larvae stage of the biofoulers and how they interact with different surfaces", explained Dr Ryan Chaw, an IMRE Research Engineer involved in the project through a unique A*STAR scheme called Technology for Enterprise Capability Upgrading (T-Up), where researchers are seconded to industry to provide invaluable scientific and research expertise.

"Finding out when the biofoulers like barnacles begin attaching to surfaces is easy enough but how they attach to materials, their adhesion strength and the best way to prevent the adhesion is the real challenge that we tackle!"

IMRE's role in the project is to provide technical information and the research strategy in marine biofouling prevention to complement HVS' existing anti-fouling system so that it can operate with seawater instead of treated water. The success of the research may see the results being applied to the shipping industries, power plants, desalination plants, and oil & gas industries.

Biofouling – A lot of extra baggage

Barnacles, calcified tubeworms, clams and other marine macro-organisms are part of a worldwide problem termed as "biofouling". This is where small marine crustaceans and shellfish stick onto the outer surfaces of ships or inner tubes of piping carrying seawater, which disrupts the flow of water, forcing ships to use up more fuel and choking water pipes. Biofouling on ships can cause as much as a 25% increase in fuel consumption. The bio-superglue that the organisms use to attach to surfaces is so strong that some have been known to stick fast to commercial Teflon!

For more information about marine biofouling prevention, please contact

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For T-Up enquiries, please contact

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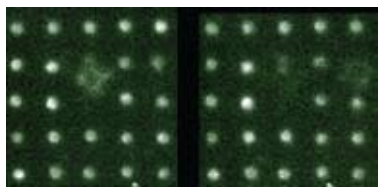
RESEARCH

Micro depots - Unique biomolecular storage and delivery systems

Nanopatterning is being used to create arrays of precise biomolecular micro-storage and delivery capsules that protect and dispense their cargo at controlled intervals and at targeted sites in the body.

IMRE has developed the technology to pattern arrays of "micro depots" for controlled loading, storage and release of the biomacromolecules. The permeability of the capsules, triggered by pH, allows the flow of relatively large objects like biomacromolecules into and out of the capsule. The micro depot system can be used in a number of applications such as precise and efficient drug delivery systems for the pharmaceutical sector. It can also be applied in lab-on-a-chip (LOC) devices, which are used in chemical and biological detection, analysis and reaction as well as in medical drug formulations.



Microdepot system - Site-specific release of the TRITC-labeled dextran by focused laser beam

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RESEARCH

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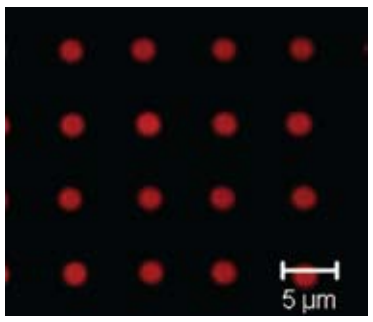
IMRE is the first to demonstrate the new micropatterned capsules that can do 'loading' and time- and site-specific 'unloading' with micrometer precision. The system can be used to load capsules with proteins that perform cascading enzymatic reactions inside patterned capsules to form patterned microreactors. The time- and site-specific release of the capsule's cargo can be triggered by focused laser beams such as NIR lasers that can penetrate the human skin to a certain depth or even by using focused ultrasound waves. The system could also provide the basic platform for advanced LOC devices where host molecule(s) can be immobilised onto a substrate in a pre-determined pattern. These patterned and functionalised colloidal particles greatly enhance the detection efficiency and sensitivity of LOC devices.



Microdepot system — CLSM imaging in situ of resorufin formation

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AWARDS

Congratulations!

IMRE clinches the *Patent Power* Award and *Scientist-Entrepreneur* Award at the A*STAR Awards 2010 ceremony.

*(LEFT PHOTO) Dr Lim Khiang Wee (right), Executive Director of IMRE and Prof Jackie Ying (left), Executive Director of IBN jointly receiving the A*STAR Patent Power Award trophy from A*STAR Chairman, Mr Lim Chuan Poh (centre).*

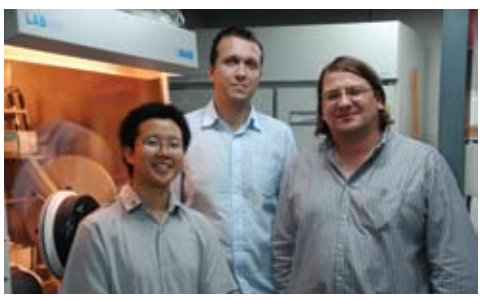
*(RIGHT PHOTO) Mr Senthil Ramadas (left) and Dr Mark Auch (right) receiving the Scientist-Entrepreneur Award from A*STAR Chairman.*

The A*STAR Awards were introduced in 2007 to recognise outstanding staff and institutes for their contributions to A*STAR. At this year's A*STAR Awards, held during the annual A*STAR Workplan Seminar on 14 April 2010, IMRE was jointly awarded the *Patent Power* Award with the Institute of Bioenigneering & Nanotechnology (IBN). The award recognises the A*STAR institute with the most primary patents produced per budget dollar in a particular year. Mr Senthil Ramadas and Dr Mark Auch of IMRE's spin-off company, Tera-Barrier Films Pte Ltd, were also honoured with the *Scientist-Entrepreneur* Award, which is given out to staff or former staff who have successfully commercialised or spun off their research to industry.

IMRE attachment student strikes gold!

National Junior College (NJC) student attached to do research in IMRE wins gold at the annual Singapore Science and Engineering Fair (SSEF) national competition, organised by the Singapore Science Centre and A*STAR.

While classmates her age may be spending their time on extra-curricular activities and travelling in their free time, Long Hao was busy looking at minute structures, thousands of times smaller than the diameter of a human hair.


Long Hao (left) with her IMRE supervisors Dominik (centre) and Nikodem (right)

"I'm so fortunate to have had this invaluable opportunity to be mentored by Dr Dominik and Dr Nikodem in IMRE. It's certainly a once-in-a-lifetime experience to be able to explore at the frontiers of knowledge at such young age", said Long Hao, a first year student from NJC who was attached to IMRE for three months, doing research on *Quantum Dots-loaded Smart Polymeric Patterns*.

Under the supervision of IMRE researchers, Dr Dominik Janczewski and Dr Nikodem Tomczak, Long Hao worked on optimising the patterning technique to find the optimal condition for the cross-polymerisation and investigated the responsive behaviour of the patterns in cross-polymerised CdSe/ZnS QDs. Applications for these include fluorescently tagged microfluidic valves, or active sensing element in chemo- and biosensing microdevices.

Medals Galore!

IMRE's attachment students came away with a total medal haul of 10 awards from SSEF, including 2 Golds, 2 Silvers, 3 Bronze and 3 Merit awards.

Enhancing an imaging technique into a powerful research tool

IMRE's Atomic Force Microscopy (AFM) is more than just a tool to image molecules and wet samples at nanometer resolutions. Our highly adaptable AFM research uncovers events that happen at the liquid-solid interface and directly affect liquid flow.


Customised atomic force microscope for high-resolution imaging in liquid media

The use of AFM in a liquid environment is often confined to being a microscopy technique, with sub-micrometer resolution, for samples that have to be kept wet, such as biological specimens (e.g. cells). However, liquids interact with the solid substrates they are covering at the molecular scale, giving rise to unexpected and markedly different behaviour from bulk liquid. To observe and address these phenomena requires resolution on the order of a nanometer and less, about 100 to 1000 times smaller than in typical liquid imaging applications.

By enhancing the sensitivity beyond that of commercially available equipment, IMRE is part of a small number of institutions capable of obtaining molecularly and atomically resolved AFM images in liquid. IMRE also customises AFM probes in-house to tailor to specific research needs, for example in combined AFM / electrical characterisation, or to eliminate artefacts common in conventional AFM instruments. Using this capability, IMRE has recently demonstrated that liquid molecules may crystallise next to a solid interface. The crystalline region can extend for several nanometers – very significant by molecular standards – into the bulk region, at temperatures well above the melting point of the bulk liquid.

For more information about this research, please email

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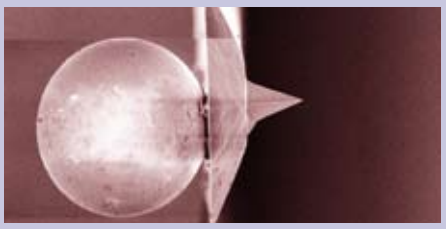
'Seeing' atoms using a super-sharp needle


Tailoring to specific research needs - Scanning electron microscope (SEM) image of a micromechanical AFM probe fitted with a rare earth magnetic particle for magnetostatic actuation in liquid

In Atomic Force Microscopy (AFM), the microscopic structure of a sample is sensed by measuring the forces acting on a sharp tip brought near to the sample surface. By repeating this process in many different locations on the sample, an image can be constructed. The sharpness of the probe allows an atomic force microscope to "see" much smaller structures than, for example, a conventional optical microscope – sometimes down to individual atoms.

VISIT & EVENTS

NTU MSE-IMRE Materials Science Challenge and Eduweek

23 - 25 Feb 10

NTU's Materials Science and Engineering (MSE) Club and IMRE jointly organised NTU's MSE EduWeek and Materials Science Challenge which was held from 23 – 25 Feb 10 and on 24 Feb 10, respectively. Dr Soh Chew Beng from IMRE gave a presentation about careers in research to a group of 40 NTU students during the Eduweek, which was complemented by an IMRE recruitment drive after the talk. An industrial visit to IMRE was also arranged for NTU students who were keen to learn more about the research environment. This year's MSE-IMRE Materials Science Challenge, a national level competition based on materials science topics, saw a total of nine junior colleges and two polytechnics taking part.


Participants at the MSE-IMRE Materials Challenge

A*STAR Workshop on Printable Electronics Research

*Prof Charles Zukoski, A*STAR SERC Chairman, opening the Printable Electronics Workshop*

08 Jan 10

The workshop brought together overseas and local experts and scientists to discuss the research and accomplishments in printable and molecular electronics, ranging from materials design and process studies to device physics and technology integration. Among the topics discussed were strategies for fabrication of RFID circuits and TFT-based backplane integrated devices, printable materials design for TFTs, and low bandgap polymers for organic photovoltaic devices.

(continue to page 4)

Listed below are highlights of some recently filed IMRE patents. To find out more about our patents, please write in to enquiry@imre.a-star.edu.sg.

Highlights of IMRE patents filed from Oct '09 – Jan '10

Modified for more efficient hydrogen generation in eco-friendly fuel cells

A new patented technique solves the problem of hydrogen generation capacity for the borohydride system in eco-friendly fuel cells.

Hydrogen generator module

This invention relates to a hydrogen generation system that includes a screw reactor and uses a liquid catalyst, which helps to improve the hydrogen generation capacity for borohydride-type fuel cell systems.

Sodium borohydride ($NaBH_4$) is an inorganic compound that offers an inexpensive source of hydrogen for use in fuel cell systems, and produces by-products such as sodium metaborate. Fairly stable, the compound could potentially be used in conventional hydrogen fuel cell systems for storing hydrogen. However, current fuel cell systems are unable to use high concentrations of sodium borohydride as the compound clogs up fuel cell reactors. The limited durability of current heterogeneous catalysts also leads to the higher cost of hydrogen generators.

IMRE's two-pronged solution is the introduction of a screw pump in the reactor and a liquid catalyst. Both liquid catalyst and concentrated sodium borohydride are pumped into the inlet of the reactor with the screw, where the screw helps force the waste out to the separator container. Sodium metaborate is formed from the reaction and is distributed in the solution promptly and thoroughly to make the hydrolysis reaction fast and deep.

The modifications help create a hydrogen generator that generates high purity hydrogen gas from the aqueous solution of sodium borohydride. IMRE's technology ensures that the reactors are not clogged up and that the hydrogen generation rate is stable and easy to adjust. The modified system also has a shorter startup time (~10 s) for the reactor to reach its normal steady-state rate of hydrogen generation.

The modifications will enhance fuel cells which are suited for portable power systems with applications of between 1 to 1000W. It is a safe and convenient hydrogen storage and production system with a high hydrogen-storage density compared to other hydrogen generation systems currently available.

For more information about this patent, please email

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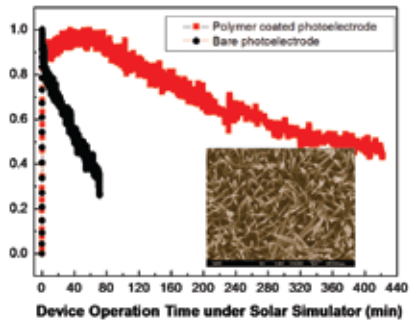
New photoelectrodes for water electrolysis

Polymer coating makes photoelectrodes more cost-effective and durable for water electrolysis.

IMRE has invented an efficient and durable photo-electrode for water electrolysis by making use of polymer to provide a protective coating for the outermost layer of the photoelectrode.



Graph showing lifetime improvement by the modified photoelectrode under solar light. (Inset) Scanning electron microscope (SEM) picture of the ZnO nanostructure of the photoelectrode

Photoelectrodes are electrodes capable of turning the light into electrochemical power. They are essential elements in a number of devices such as dye-sensitised solar cells, photoelectrochemical cells, and other electrolytic systems. As some of the photoelectrodes in these devices are immersed in an ionic electrolyte medium, they are subjected to chemical corrosion from the electrolyte. In the case of dye-sensitised photoelectrode, the problem is aggravated by the fact that the organic dye is extremely susceptible to corrosion and dissolution in the aqueous electrolytic medium. Conventional technologies using thick metal-oxide or conductive polymers (Polypyrrol) as a protective film reduces the electron transfer efficiency between the electrode and electrolyte. The ideal is to have a protective coating which is extremely thin and conformal to the mesoscopic profile so that the surface area for optical absorption and the contact area with the electrolyte can be maximised.

IMRE makes use of chemical-resistant, non-porous, water-impermeable, surface conformal and optically transparent polymer ultra-thin films to provide a protective coating with low charge-carrier barrier for the outermost layer of the photoelectrode. An ultra-thin polymer interlayer in between the back anode electrode (e.g FTO/ITO) and photoactive layer is also incorporated, which effectively increases the durability of the photoactive layer against electrolyte corrosion.

The interlayer also serves to smooth the interface between the back anode electrode and photoactive layer, which eliminates any sharp protrusion of ITO and photoactive layer across the interface. Studies had suggested that these sharp protrusions cause current stresses that may degrade the material and lifetime of the electrode.

The new photoelectrode can be applied to all kinds of photoelectrochemical cells and dye-sensitised solar cells. Companies with established research in hydrogen production for power sources will also benefit from this technology.

For more information about this patent, please email

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VISIT & EVENTS

(continued from page 3)

Singapore Airshow 2010

*The A*STAR booth at the Singapore Airshow 2010*

02 - 07 Feb 10

The Singapore Airshow was held at the Changi Exhibition Centre. IMRE highlighted its Carbon Fibre-Reinforced Nanocomposites which has the potential for being used to build lighter but stronger aircraft components. To learn more about IMRE's nanocomposites research, please visit http://www.imre.a-star.edu.sg/rnd/imre_Factsheets.asp.

IMRE Scientific Advisory Board (SAB) Meeting

4-6 Mar 10

IMRE's SAB met to discuss research initiatives and strategies with key researches from IMRE. Among the members who attended the meeting were Prof Dame Julia Higgins, Prof Andrew B. Holmes, Prof Harold G. Craighead, Mr David Duncan, Prof Michael Aziz, Prof Anthony Ryan and Dr Yoshiharu Doi.

The IMRE SAB meeting in session

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

4th MRS-S Conference on Advanced Materials

17-19 Mar 10

IMRE and the Materials Research Society-Singapore (MRS-S) co-organised the conference that brought together Singapore-based materials researchers and organisations. Attended by 160 participants, the conference covered topics such as nanomaterials, biomaterials, functional materials, optoelectronics and photonics, polymers, microelectronics and advanced characterisation techniques. Dr Lim Khiang Wee, Executive Director of IMRE welcomed the delegates with a brief on IMRE's capabilities and some of its recent achievements in the field of materials science. A total of 131 posters and 26 invited presentations were presented.

The poster session at the 4th MRS-S Conference on Advanced Materials

UPCOMING EVENTS

Diary of upcoming events @ IMRE

10 June 2010
Workshop on "Atom Technology and its Applications"

03 August 2010
Launch of Industrial Consortium on Nanoimprint (ICON)

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