Research, Development and Commercialisation
MICA (P) 119/03/2009 • ISSN 0219-1830

OCTOBER 2009

PERSPECTIVES

Institute of Materials Research and Engineering
A*STAR

www.imre.a-star.edu.sg

'Growing' materials innovation

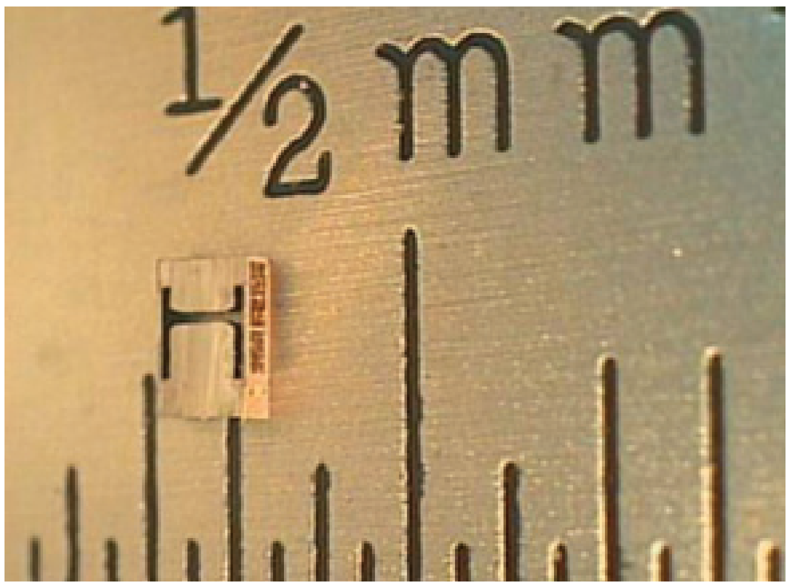
The ability to "grow" materials efficiently and accurately as each new layer of atoms is added is essential in ensuring that the produced material performs flawlessly. Materials growth can also help customise materials with certain desired properties.

The Materials Growth group in IMRE aims to understand, improve and develop new methods of materials growth to produce top-notch, advanced and innovative materials that can be used in a number of applications.

Dr Chi Dongzhi is Head for the Materials Growth capability group

Ferroic materials

Ferroic materials research involves solid state synthesis and thin film preparation of piezoelectric and ferroelectric materials for sensors, actuators and energy transducers, including lead-free ceramic compositions, ferroelectric polymers and multiferroics. Some of the R&D in this area includes lead-free piezoelectric films, pioneering work on large photo-voltage research, improving the efficiency in ferroelectric thin films, and wafer-based micro-fabrication methods for batch production of ferroelectric as well as piezoelectric thin film micro sensors and actuators. Applying the research, the team has demonstrated a number of proto-types including ferro-electric thin film UV sensors and dosimeters as well as a piezoelectric battery-less remote controller. The researchers have also built-in miniaturised piezoelectric accelerometers and integrated piezoelectric sensors onto manufacturing tools to create a real-time machine condition monitoring system.



A miniaturised piezoelectric actuator sample developed from the three-dimensional batch microfabrication process

Electronic materials

Electronic materials research looks at the growth and impurity/Schottky barrier height engineering of silicides and germanides. High-k oxides and group III:As/P for CMOS structures research is also being explored.

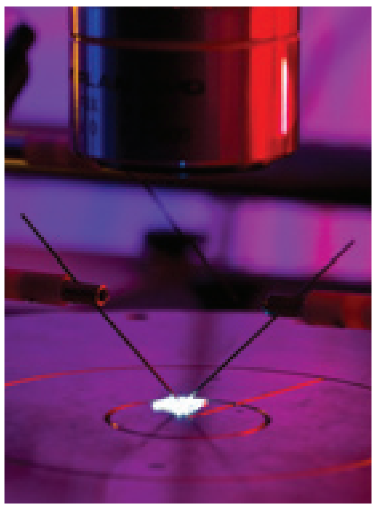
The team had pioneered work on impurity engineered Ni-alloy silicides that enhance the performance of Integrated Circuits and developed a class of impurity-engineered NiSi materials. The new silicide materials were then successfully integrated into nanometer size (down to 25nm) FinFETs, which is a significant reduction of transistor sizes compared to current commercial transistors (45-65nm).

"Reducing the transistor size results in two advantages - more can be packed into a smaller area and the smaller transistors translate to faster computing power," says Dr Chi Dongzhi who heads the Materials Growth capability group and drives the research into new silicide materials and processes.

Other achievements in this area include being the first to develop a conventional top gate structure high performance NiGe and PtGe Schottky source/drain Ge p-FETs, the frontrunner for future 16-nm technology node p-type transistors.

This demonstrates that a simple and lower thermal budget germanidation process, rather than complex dopant implantation and high temperature activation processes could build reliable and low resistivity source/drain in Ge p-FETs. The team conducts additional R&D on integration of high mobility GaAs on Ge and work on atomic and electronic structures of high-k oxide/semiconductor interfaces.

(continue to page 2)



True white LEDs have the potential to revolutionise consumer lighting

Right on Target - Pinpoint precision microactuators

The IMRE team invented a unique 3D microactuator for nanopositioning of read/write heads for hard disk drives (HDDs). The microactuator can be used to achieve high speed, precise nano-positioning. This means that the microactuator can be positioned very quickly with extremely high accuracy, which is within nanometers of the intended point, to read data. IMRE's actuators have an extremely high resolution of well below 1 nm and a high resonance frequency of 48.8 kHz. This is crucial as higher density storage HDDs will have data tracks very much closer together, making it hard for conventional read heads to read or write the data correctly. The technology is patented under the Patent Cooperation Treaty (PCT).

IMRE's microactuators will be a boon to the next generation of high-density HDDs

Big boost for research into sustainable materials

IMRE projects among 28 awarded with $27.5 million in A*STAR funding to conduct green research.

Sample of a high-strength and lightweight clay/epoxy carbon fibre reinforced polymer made in IMRE

As part of a concerted effort to look at new ways to manage environmental deterioration, stresses on natural resources and climate change, A*STAR has given $27.5 million in funding to local research institutes and universities to accelerate research into resource sustainability. Among the areas covered by the 28 projects are research on how to trap and use carbon dioxide, harness energy from biological matter such as algae, and develop environmentally friendly materials for the construction, aerospace and automotive industries. Development of one of the four main thrusts - *Sustainable Materials: Composites and Lightweight* - is led by IMRE's Dr He Chaobin, a senior scientist and expert in R&D on polymers and composite materials.

Investigating and developing high performance polymer composites

IMRE's projects centre around:

- **High-strength, low-weight carbon fibre reinforced epoxy**
  The materials could be used to make lighter but tougher automobile body parts, aircraft fuselage and frames for the aerospace industry and even blades for wind-energy turbines.
- **Studying how to make nanocomposites better**
  Using advanced computer modelling and simulation, scientists will investigate the static and dynamic mechanical properties of polymer nanocomposites and look at how to enhance the performance of the materials.

CORPORATE NEWS

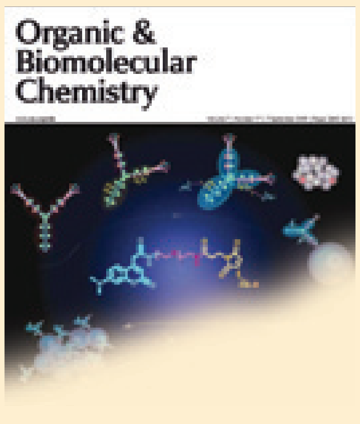
(continued from page 1)

Optoelectronic materials

Optoelectronic materials research focuses on vapour phase epitaxy of Group III:V compound semi conductors, and solution and vapour phase growth of zinc oxide (ZnO) films as well as nanostructures. IMRE has recognised expertise in III:As/P epitaxy and fabrication of lasers, detectors and switches and is part of national programmes on optical net-working and optical MEMs.

Successful R&D on patterned nanostructuring of materials surfaces has increased light extraction from light emitting diodes (LEDs).The researchers have also patented quantum dot-based white LED technology for solid state lighting that yields white LEDs with greater stability, higher efficiency, high colour quality and colour tunability compared to conventional phosphor-coated ones.

The outcome from some of the materials growth research such as hydrothermal ZnO, silicide materials, epitaxial GaN and III:As/P photonics is being used to further research into metamaterials, solar cells, solid state lighting and terahertz technology.

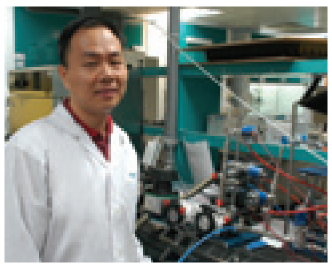


Inside Front Cover: Water-soluble biomolecular fluorescent tags

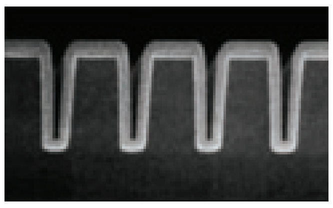
Org. Biomol. Chem., 2009, 7, 3400-3406

A paper by an IMRE researcher (Dr Song Hongyan et. al.) in collaboration with NUS researchers led by Asst Prof Martin J. Lear from the Department of Chemistry, was featured on the inside cover of Organic & Biomolecular Chemistry (volume 7, Number 17, 7 September 2009). Titled "Practical synthesis of maleimides and coumarin-linked probes for protein and antibody labelling via reduction of native disulfides", the work describes a proof-of-principle study of a new water-soluble coumarin probe with a maleimide thiol-reacting unit to fluorescently tag biomolecules.

Mutual benefit – Scientists to industry



Dr Gao Han



Cross-sectional SEM image for 300nm Al_2O_3 film deposited using ALD technology

Transfer of technology could not be any simpler than with the Technology for Enterprise Upgrading, or T-Up, programme that allows companies to leverage directly on the scientific expertise at A*STAR.

IMRE's Dr Gao Han is an expert in all things small. More precisely, his research work in the laboratory covers topics such as template-assisted growth of nanomaterials, unconventional methods for nanofabrication, particularly anodic aluminium oxide (AAO) and atomic layer deposition (ALD) in nanofabrication.

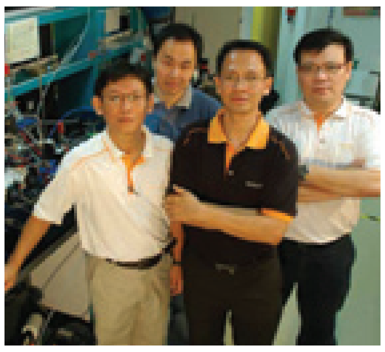
But for the past year, he has been applying his skills in an industry-type setting during his stint at Azimuth Technologies Pte Ltd (AZT). The secondment was made possible through the T-Up programme that grants industry direct access to A*STAR's vast pool of research talent. Senior scientists work in local companies to help identify critical technologies and build in-house R&D capabilities relevant to the company's operations.

"My job as a research scientist in Azimuth entailed developing ALD precursors for a number of metal oxides, some of which were tailored specifically to client requests", said Dr Gao Han who also continued advising on the development of the ALD machine design.

The partnership coupled basic research with the needs of the corporate world producing surprising results. For example, when developing a certain metal oxide, the coating lacked uniformity and repeatability at the wafer-scale size. After extensive trials, Dr Gao Han traced the cause to the extremely high viscosity of the precursors used, allowing AZT designers to use their expertise to modify the current chamber to generate a stable gas flow to deliver the viscous precursors, resolving the issue and leading to a new patentable design.

"The T-Up programme with IMRE has allowed us to reach new heights in manufacturing excellence for nanotechnology platforms and was, without question, a resounding win-win success for Azimuth and A*STAR", said Mr Wee Teck Wang, Managing Director for Azimuth Technologies.

"The experience had given us a better appreciation for more analytical approaches on process optimisation and characterisation, particularly in ALD, as well as increased our knowledge on established thin-film measurement methods such as QCM and ellipsometry. We are grateful to have gained these capabilities, which would not normally have been available to a typical resource-constrained SME like Azimuth."



The AZT-IMRE team - (L-R) Francis Tan (AZT), Gao Han (IMRE), TS Lai (AZT) and Wee Teck Wang (AZT)

How it all started - Super-precise coating technology

IMRE and AZT's collaboration began with the transfer of advanced technology know-how in atomic layer deposition (ALD) technology, a precise and advanced coating process that results in highly uniform thin films that conform to the shape and scale of an object. Compared with other technologies such as sputtering and evaporation techniques, ALD offers more precise atomic layer control of the coating thickness and the ability to create uniform coatings on intricate and complex 3D objects.

RESEARCH

Batteries not included!

Soon, we may never have to worry about replacing the batteries in the television or air-conditioner remote again with this battery-less remote control.

A team of researchers at IMRE have successfully used piezoelectric energy transducers to demonstrate a battery-less radio frequency (RF) remote control system powered solely by mechanical energy supplied by the user. All a person has to do is to push a button to supply the mechanical energy that will then be converted to electrical energy by the piezoelectric energy generator in the battery-less remote control. Information is then relayed to a receiving unit via an RF transmitting unit.

The team has developed the technical know-how for creating a prototype battery-less encoded digital signal controller that can operate over a distance of 30 m and control multiple receivers. The piezoelectric transducer can be customised for different energy requirements or applications.

For more information about this research, please contact

Dr Yao Kui
k-yao@imre.a-star.edu.sg

Piezoelectric materials - Turning mechanical energy into electricity

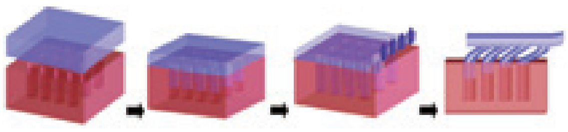
Piezoelectric materials, such as some ceramics and crystals, are able to generate an electric potential or voltage when a mechanical stress is applied upon them. The process is also reversible in that these piezoelectric materials will change shape when a voltage is applied to them. Some of the common examples of piezoelectric materials that are found in quartz watches (where the quartz crystal vibrates at a constant frequency), some microphones (where vibrations from sound are detected and converted into electrical signals), and ultrasound imaging systems in hospitals.

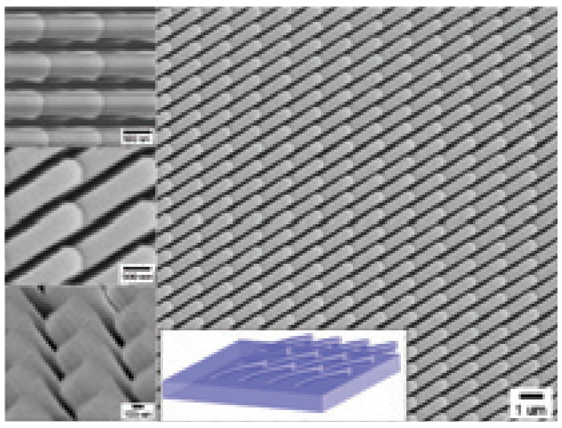
Piezoelectric R&D - Never having to bother about changing the batteries in a remote control anymore

RESEARCH

The power of nanoimprint technology

STRF website





IMRE's nanoimprint technology was featured in the Russian-language Science and Technology in Russian Federation (STRF) scientific resource website on 26 Aug 09. The article entitled "The Power of Nanoimprint Technology – Taking a Leaf from Nature", discussed IMRE's research on nanoimprint technology, from its 3D nanoimprint techniques to developments in mimicking natural surface structures.

An example of such research is the butterfly-mimetic photonic nanostructures (*image on the right, bottom*) which were fabricated by shearing large arrays of nanometer-scale structures, pre-patterned using nano-imprint lithography (*image on the right, top*). Mimicking natural surface structures endows materials with unique properties, in this case the iridescent colours similar to those found on a butterfly's wing.

AWARDS

Building talent for the future

Two researchers are in the pioneer IMRE batch to be given the opportunity to develop post-doctoral expertise under A*STAR's International Fellowship Award.

Dr Yu Haidong (left) and Dr Chung Hong Jing (right)

IMRE's Dr Yu Haidong and Dr Chung Hong Jing will be undergoing two years of post-doctoral training at top overseas laboratories under the A*STAR International Fellowship programme. Apart from enhancing their research experience and learning new skills that can be put to good use in their respective scientific careers, the researchers will get international exposure that will enable them to connect with the global research community and build international networks.

Dr Yu Haidong will be working at Harvard University, USA, in the area of biomimetics and bioapplications at Prof Joanna Aizenberg's laboratory. Prof Aizenberg is one of the pioneers of the rapidly developing field of biomimetic inorganic materials synthesis.

Dr Chung Hong Jing will be attached to Prof Seizo Morita's laboratory in Osaka University, Japan. Prof Morita's laboratory is one of the top research groups working on developing atom manipulating and identification techniques using advanced atomic force microscopy (AFM).

Awards for IMRE postgraduate student

IMRE postgraduate student, Mr Rinus Lee, bags two awards.

Rinus Lee

Mr Rinus Lee Tek Po, a National University of Singapore student currently pursuing his doctorate under the supervision of IMRE scientist, Dr Chi Dongzhi, has recently bagged two awards. He was awarded the Young Scientist Award at the European Materials Research Society (E-MRS) 2009 Spring Meeting in June 2009 for his winning paper titled "Sulfur Segregation at the Platinum Silicide/Silicon:Carbon Interface for Electron Barrier Height Reduction: An Approach to Enable Independent Control of Contact Resistances for N- and P-channel FinFETs with a Single Metal Silicide". Mr Lee was also one of four international candidates who were awarded prestigious one-year fellowships to the IEEE Electron Devices Society (EDS) Graduate Student Fellowship in August 2009. The award promotes, recognises, and supports doctoral degree research within EDS' field of interest, covering all aspects of engineering, physics, and other emerging materials.

VISIT & EVENTS

Visit by International Network of Young Scientist (INYS)

3 July 09

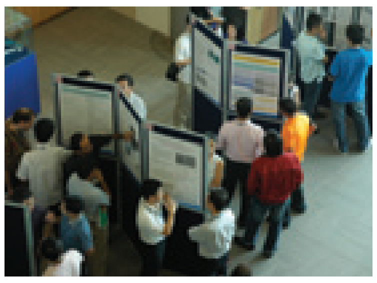
Twenty-six delegates from the INYS Initiative were briefed on IMRE's capabilities in characterisation, organic synthesis and biosensors. The delegates were in Singapore to attend the International Conference on Materials for Advanced Technologies (ICMAT) 2009.

University of Twente study tour

9 July 09

Fourteen undergraduates from the University of Twente, The Netherlands, visited IMRE's characterisation and cleanroom facilities as part of their annual study tour to find out more about research in Asia.

University of Twente study tour to IMRE



Fostering information sharing

IMRE Postgraduate Students (PG) poster competition

10 July 09

IMRE's annual competition had 66 posters by postgraduate students which highlighted some of the R&D projects that they were involved in.

Outreach to students

22 July 09

IMRE's Mr Goh Wei Peng and Mr Ho Jian Wei conducted a Meet-the-scientist seminar on "Harnessing Solar Energy: The Past, the Present and the Future" to some 140 secondary school students at the Science Centre Singapore.

Atom Technology seminar

11 August 09

The Atom Technology (Phase II) Open Seminar was organised to update the research community in Singapore about both international and local progress in atom technology.

X-periment exhibition at Marina Square

14-16 August 09

The IMRE Outreach Team took part in *X-periment 2009* at the launch of the A*STAR-Science Centre Singapore organised Science Month 2009 by show-casing the unique characteristics of everyday materials.

Reaching out to the public

Aerospace industry seminar

25 September 09

The "Advances on Technologies for the Aerospace Industry" seminar provided consortium members and invited guests of the A*STAR SERC's Aerospace Programme with valuable insights into technology advances in aerospace. The SERC Aerospace Programme brings the aerospace industry and the Singapore R&D community together to drive innovation in aerospace research.

Dr Lim Khiang Wee, Executive Director, IMRE opening the aerospace seminar (top) which included displays of IMRE's aerospace related technologies (below)

Institute of Materials Research and Engineering
A*STAR

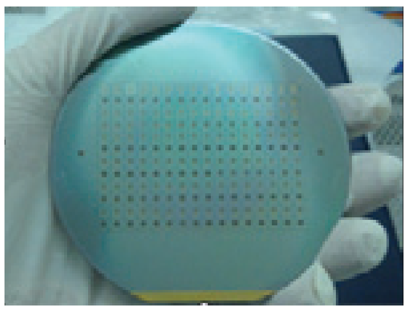
PATENTS FILED & GRANTED

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 Jul 09 - Sep 09

New built-in sensors help monitor health of materials

IMRE researchers have developed innovative sensors from piezoelectric thin films that can be embedded directly onto materials and components to help track the strains and vibrations that may affect performance.



Piezoelectric thin film micro sensors (top) batch produced on silicon wafer (above) for machine condition monitoring

The invention relates to piezoelectric sensors made of piezoelectric thin films that are directly coated onto the surface of an object for the purpose of strain and vibration condition monitoring. The sensors allow real-time *in-situ* self-monitoring and self-diagnosing of materials and components. This helps alleviate laborious manual checks and maintenance, reduces maintenance costs and warns of potential structural failures.

Conventional strain sensors detect strain based on resistance change, which uses an external power source and have slow response times. IMRE's unique piezoelectric thin layers are *in-situ* processed and deposited to obtain the sensors on the surface of the object to be monitored without any bonding agent layer. This produces piezoelectric strain sensors with much quicker responses, improved sensitivity, reliability, durability and effectiveness. IMRE's sensors work on low or even no external power source as electrical output is generated directly by the mechanical strain on the piezoelectric material. The fabrication methods also allow for mass production of large area piezoelectric thin films.

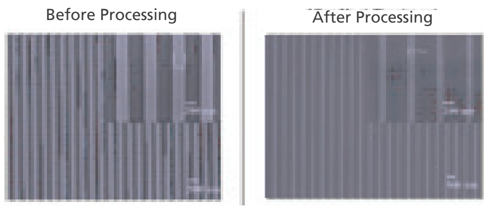
The proof-of-concept for these new sensors has been demonstrated by integrating them onto flexure disks on moving parts of industrial machines. Condition monitoring is vital in modern intelligent systems and can be used to monitor the health of materials and structures in different areas such as civil structures, vehicles, and machinery.

For more information about this technology, please email

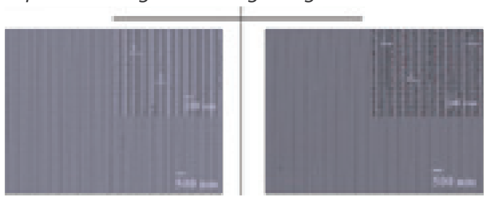
Dr Yao Kui
k-yao@imre.a-star.edu.sg

A simple method for making micro- and nano-sized patterns even smaller

A new and easy technique that relies on the deformation of material is set to shrink patterns sizes further while retaining pattern fidelity in nanoimprint moulds.



Imprinted using a 250 nm grating mould



Imprinted using a 100 nm grating mould

Nanoimprint lithography (NIL) is a low-cost, high-throughput and high-resolution patterning technique for organic materials that produces very tiny, uniform structures. The rapid development of this technique in the past decade has allowed the fabrication of features smaller than 100 nm. However, making moulds with features smaller than 100 nm is an expensive process, and even more so when large and dense areas of these features are required.

IMRE has developed pattern-able liquid phase organometallic resists to obtain sub-100 nm features after imprinting using moulds containing sub-micron-sized features. The researchers have developed a process that not only hardens the patterned material further but also reduces its feature size to almost a third of the original size. The new mould also retains nearly the same centre-to-centre spacing and keeps the original pattern fidelity. IMRE has successfully imprinted structures with a feature size of about 25 nm from a 100 nm grating mould using this process.

Imprinting using organometallics allow the direct imprinting of oxides and metals (as well as alloys), which is otherwise impossible for a standard silicon mould. Furthermore, the new process increases the hardness of the imprinted structure and reduces the feature size to sub-100 nm. These patterned structures can re-used as moulds themselves to imprint organic materials on a sub-100 nm scale.

For more information about this technology, please email

Dr M S M Saifullah
saifullahm@imre.a-star.edu.sg

Better blue light emitting materials

Monomer-enhanced blue light emitting materials have better efficiency and colour stability compared to conventional fluorene-based materials.

The deep blue OLED without encapsulation and driven at 6V was made using IMRE's new blue light emitting materials

The invention relates to the design of blue light emitting materials which are composed of monomers of different functionalities.

Blue light emitting materials are one of the key components in full colour display organic light emitting diodes (OLEDs) and can be used in solid state lighting. It also presents the most challenge because of their relatively low device efficiency and short lifetime, compared to green or red light emitting materials. The reasons for this are the poor charge injection and imbalanced charge transport in the active emissive layer between holes and electrons, as well as the poor colour stability attributed to fluorene-based blue light emitting polymers.

IMRE has designed new blue light emitting polymers that are composed of different monomers with different functionalities, which can balance hole and electron transportation in OLED devices thus improving device efficiency. It can also help to prevent intramolecular and intermolecular interaction between the hole transport and electron transport segments to enhance the electroluminescent spectrum, or colour stability for blue light emission.

The materials will be very useful as emissive layers for blue light emission in OLEDs for display or lighting applications.

For more information about this technology, please email

Dr Chen Zhikuan
zk-chen@imre.a-star.edu.sg

UPCOMING EVENTS

Diary of upcoming events @ IMRE

11 December 2009
IMRE Industry Day

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

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