Research, Development and Commercialisation
MICA (P) 050/03/2010 • ISSN 0219-1830

JULY 2010

PERSPECTIVES

Institute of Materials Research and Engineering
A*STAR
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CORPORATE NEWS

New Executive Director for IMRE – Creating the Right Chemistry for Materials R&D

Prof Andy Hor – renowned educator and mentor from the National University of Singapore, recognised scientist in the field of organometallic materials and catalysis, and now Executive Director of A*STAR's Institute of Materials Research and Engineering (IMRE). We find out about his vision for IMRE.

"When a challenge arises, take it head on!" said Prof Andy Hor, IMRE's new Executive Director during his maiden speech to staff just after taking over the reins of Singapore's materials research institute from his predecessor Dr Lim Khiang Wee, who is now full-time at A*STAR's Graduate Academy. His comments were in reference to the resourceful, can-do spirit of the people of Hong Kong and how he is bringing that culture to Singapore and to IMRE. But he was not speaking as a native of Hong Kong but as a naturalised Singaporean who has spent 25 years doing research and teaching future generations here.

"Learning not to depend too much on others to provide for everything helps develop a competitive, vibrant and creative environment – traits that lead to innovation in research and technology", added Prof Hor an experienced researcher and educator who had headed NUS' Department of Chemistry and was Vice-Dean for the Faculty of Science.

Prof Hor also drove home the message that materials research is essential to Singapore's future, explaining that virtually every key industry thrives on new materials development. "One of the reasons why I took up this challenge to head IMRE was the unique opportunity to make a difference in Singapore's push towards an advanced knowledge-based economy!" said an excited Prof Hor elaborating on his involvement at a time when Singapore is gearing up to drive research investment to 3.5% of its GDP from the current 2.9%. This is a significant milestone that puts Singapore within distance of other first world R&D nations like Norway and Israel. The best way to achieve this is to help local industry grow through the viable materials-enabling technologies that IMRE creates.

For this, he has mapped out a few key areas to focus on. IMRE must be recognised as a place where world-class research is done. "When people think about materials research they should automatically think about IMRE, not only locally but abroad", explained Prof Hor as he elaborated on the need for excellent research quality and to be able to instantly associate that quality


Prof Andy Hor with his wife (Beng Hwee) on a hiking trip in Hong Kong in 2009

with the work done in IMRE.

"The innovations that we create must have visible impact for the man on the street", outlined Prof Hor on the importance of having tangible, real-world, applicable outcomes from the research done to show the continuing and ubiquitous role that materials science plays in everyday life. Today, anything from transistors, the building blocks of electronics, to new generation flexible solar cells, are just some examples of materials R&D. Some of IMRE's focus will be channelled towards solving current social challenges such as energy, the environment and sustainability. This focus was reinforced by his recent visit to the World Expo in Shanghai where sustainability was a core recurring theme.

Finally, but certainly not least, research talent will be the crucial element in creating the right chemistry for IMRE's success. "The talents – those doing research now and the future materials scientists - will be the ones to propel IMRE to the next level", said Prof Hor as he works to make IMRE a magnet for research talent by raising the expertise of existing staff and also preparing a solid pipeline of materials researchers through increased engagement with students and scholars. From his years in Imperial College, Oxford, Yale and finally NUS he recounted that the most valuable lesson learnt was that while he took great pride in his own research, he had even greater pride in the people that he had worked with and helped develop.

"Our research breakthroughs, commercialised technologies and the current core of talents – IMRE's achievements these past 10 years speaks for itself", said Prof Hor as he acknowledged his predecessors for the solid foundation they had laid for IMRE. "They have made a great place for us, and one that would always have room for the best people".

An Educator and a Chemist

Prof Andy Hor has many titles to his name but the ones that he is particular proud of are those of an educator and chemist:

- GIST-SNIC Award in Chemistry Education (2010);
- Outstanding Scientist Award, Faculty of Science NUS (2007);
- Outstanding Educator Award, NUS (2002);
- Japan Chamber of Commerce & Industry (JCCI) Award (Education) (1996);
- Finalist, The Outstanding Young Persons (TOYP) of Singapore Awards (1996 & 1994);
- ASEAN Achievement Award (Science) (1994);
- National Young Scientist and Engineer Award, National Science & Technology Board (Singapore) (1991);
- Fellow (Humboldt, Commonwealth, ASAIHL, Jackson Memorial, Anthony Mason, etc);
- Numerous Teaching Excellence Awards.

Singapore research is vibrant says Nobel Laureate

Prof Robert Huber is surprised by the speed at which research has grown in Singapore.

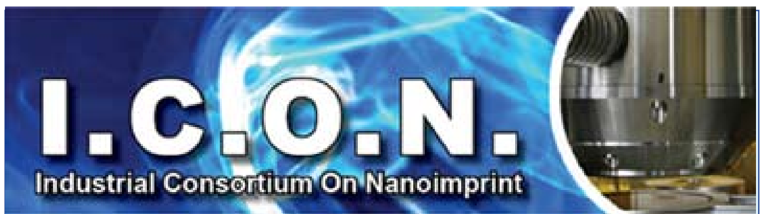
Every time that Prof Robert Huber, winner of the 1988 Nobel Prize in Chemistry, comes to Singapore he sees something new in its research scene, be it focus on a new area of research or a new research institute. "The Singapore research scene is very vibrant with new changes every time I visit, which is a trait that is unique to this country" said Prof Huber who visits Singapore regularly. "The speed at which developments in the research arena takes place is tremendous!"

He gave the example of materials science as one of the areas that had evolved significantly in Singapore. "One of the leading fields in science today is nanotechnology and our obsession with making everything smaller. Here, new materials and new ways of making the materials, leveraging on multiple disciplines – chemistry, physics, engineering – will be important to Singapore's future, especially in areas like water and energy sustainability", added Prof Huber. "IMRE will be able to contribute greatly to this cause".

Asked if he had advice for scientists aiming for a Nobel Prize and the secret to his own Nobel success, he mentioned, "Hard work and luck! Lucky to be working in a promising new field and having the right teachers and collaborators. But most of all, work hard and never give up especially on the things and beliefs you are convinced of!"


Prof Robert Huber, winner of the Nobel Prize in Chemistry 1988

Prof Robert Huber was in Singapore as one of the plenary speakers at the Inaugural Conference on Molecular & Functional Catalysis (ICMFC-1) held in July 2010, but took time out to give a seminar at IMRE on *"Proteins and their Structures, Basic Science and Application"*.



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)
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Publication Highlights

Listed below are some highlighted IMRE research publications.

"Click" chemistry with nanoparticle nano-building blocks

Dominik Janczewski, Nikodem Tomczak, Shuhua Liu, Ming-Yong Han and G. Julius Vancso, "Covalent Assembly of Functional Inorganic Nanoparticles by "Click" Chemistry in Water"; Chem. Commun., 2010, 46, 3253 - 3255, DOI: 10.1039/b921848c

Abstract: Huisgen 1,3-dipolar cycloaddition click reaction with functional quantum dots and magnetic nanoparticles in water is presented. The introduction of click enabling groups on the surface of the nanoparticles is combined into one step with a transfer into water process. Reaction between acetylene and azide groups is used for the fabrication of covalent spherical assemblies in solution.

The paper was featured on the front cover of the Chemical Communications journal, Volume 46, No. 19, 21 May 2010 issue, and was one of the Top Ten most downloaded articles from Chemical Communications for the whole month of May 2010.

For more information about the publication, please contact

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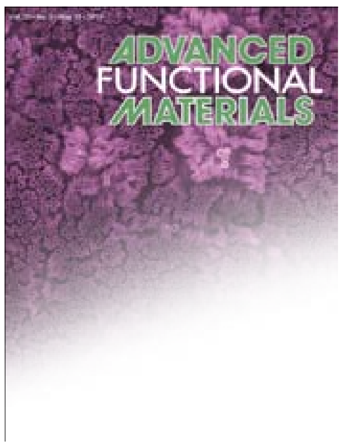
New method for preparing TiO_2 nanotubes on a variety of substrates opens up opportunities for optoelectronic applications such as organic solar cells

Thelese R. B. Foong, Yaodong Shen, Xiao Hu, Alan Sellinger, "Nanotube Arrays: Template-Directed Liquid ALD Growth of TiO_2 Nanotube Array - Properties and Potential in Photovoltaic Devices"; Adv. Funct. Mater. 9/2010



Abstract: Dense and well-aligned arrays of TiO_2 nanotubes extending from various substrates are successfully fabricated via a new liquid-phase atomic layer deposition (LALD) in nanoporous anodic alumina (AAO) templates followed by alumina dissolution. The facile and versatile process circumvents the need for vacuum conditions critical in traditional gas-phase ALD and yet confers ALD-like deposition rates of 1.6-2.2 Å cycle-1, rendering smooth conformal nanotube walls that surpass those achievable by sol-gel and Ti-anodising techniques. The nanotube dimensions can be tuned, with most robust structures being 150-400 nm tall, 60-70 nm in diameter with 5-20 nm thick walls. The viability of TiO_2 nanotube arrays deposited on indium tin oxide (ITO)-glass electrodes for application in model hybrid poly (3-hexylthiophene) (P3HT):TiO_2 solar cells was studied. The results achieved provide platforms and research directions for further advancements.

The paper was featured in the Advanced Functional Materials journal, Volume 20, No. 9, 10 May 2010 issue.

For more information about the publication, please contact

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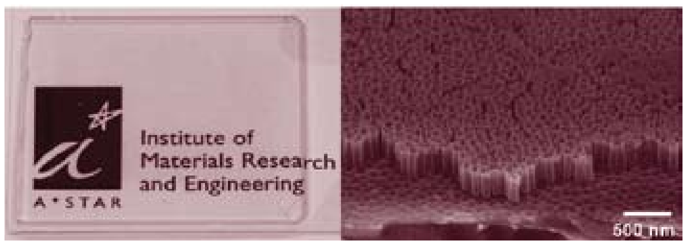
Transparent, well-aligned TiO_2 nanotube arrays (NTAs) have potential applications in self-cleaning coating, transparent electronics, and solar cells

Lee Kheng Tan, Manippady K. Kumar, Wen Wen An, and Han Gao, "Transparent, Well-Aligned TiO_2 Nanotube Arrays with Controllable Dimensions on Glass Substrates for Photocatalytic Applications"; ACS Applied Materials & Interfaces, Vol.2, No.2; 498–503, 2010

Abstract: Transparent, well-aligned TiO_2 nanotube arrays (NTAs) with controllable dimensions are grown on glass substrates via atomic layer deposition (ALD) of TiO_2 onto free-standing porous anodic alumina (PAA) templates. Photodegradation of aqueous methylene blue (MB) solution and solid stearic acid (SA) film using TiO_2 NTAs of various wall thicknesses are investigated. The Pd functionalised TiO_2 NTAs, with a wall thickness of 15 nm and height of 200 nm, has the highest photodegradation efficiency at 76% after 4 hours of UV irradiation. These functionalised NTAs are able to photodegrade MB molecules completely as no obvious demethylated by-products are observed during the process. It also demonstrates excellent photocatalytic activity for solid contaminants such as SA film. By using the ALD technique, the nanotube wall thickness can be precisely controlled so that it is sufficiently thin to be transparent while sufficiently thick for excellent photocatalytic performances. The transparent TiO_2 NTAs on glass substrates with excellent photocatalytic properties might have potential applications in self-cleaning coating, transparent electronics, and solar cells.



The sample glass substrate (left), covered with Pd-functionalised TiO_2 nanotube arrays, is uniform and optically transparent, and gives a clear view of the IMRE logo beneath. The TiO_2 nanotube arrays are well-aligned, highly ordered, and firmly attached onto the glass substrate as can be seen from the scanning electron microscope image (right) with a scale bar of 500 nm. The nanotube wall thickness can be precisely controlled using ALD and made to be sufficiently thin so that it is transparent but thick enough to have excellent photocatalytic properties

The paper was one of the top 10 most-accessed articles published in ACS Applied Materials & Interfaces during the first three months of 2010.

For more information about the publication, please contact

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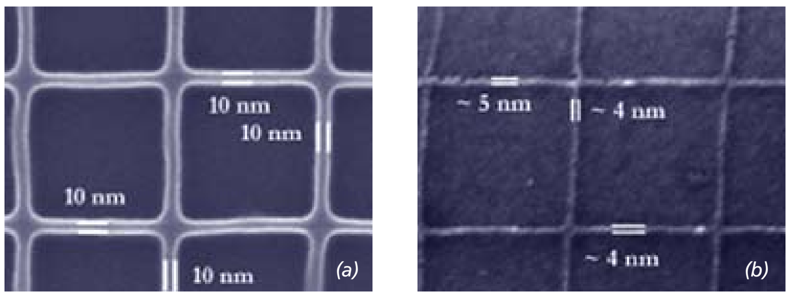
The thinnest, smoothest metal lines in the world to date

New method improves nanoscale line width roughness as well as shrinking the line below sub-10 nm line widths. The super-thin, high integrity metal lines created surpass today's semiconductor industry requirements.

Scientists from IMRE, University of Cambridge (UK) and Sungkyunkwan University (South Korea) have created 7 nm line width metallic lines with line width roughness, of only 2.9 nm, a value which is well beyond the 2010 target of 3.2 nm set in the *International Technology Roadmap for Semiconductors*. 2011's target line width roughness is 2.8 nm.



Nanoscale lines of (a) copper naphthenate and (b) copper after hydrogen reduction

The ability to create such distinct lines and patterns on a sub-10 nm scale level is essential in the further miniaturisation of electronic components. Rough, undefined patterns and lines results in poorly made, energy-inefficient devices.

"Our thin, unbroken and smooth lines are important in ensuring the efficiency of ever shrinking electronic devices and may lead to more powerful processors. Furthermore, our work shows that continuous metallic lines as small as 4 nm are possible to make", says Dr MSM Saifullah, a Research Scientist with IMRE. The method could be potentially used to make interconnects, the 'highways' that carry electrical pulses and data in extremely small integrated circuits (ICs). The smoother and uninterrupted 'highways' lead to faster data transfer rates and less energy wasted, in the form of heat.

The novelty of the method is in the material and the technique that is used. The current "lift-off" approach for making metal lines at this scale requires more steps, uses more materials and results in rough, and quite often broken lines on a sub-10 nm scale. Using an organometallic material, and a combination of electron beam lithography and gas treatment, the researchers were able to easily chip away the organic portions in a uniform manner, leaving the desired metallic patterns.

The research was published in *Advanced Functional Materials*, a leading full-paper materials science journal.

For more information about the technology, please contact

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M. Nedelcu, M. S. M. Saifullah, D. G. Hasko, A. Jang, D. Anderson, W. T. S. Huck, G. A. C. Jones, M. E. Welland, D. J. Kang and U. Steiner , "Fabrication of sub-10 nm Metallic Lines of Low Line width Roughness by Hydrogen Reduction of Patterned Metal-organic Materials", *Adv. Func. Mater.* **2010**, 20, 2317-2323.

Glossary – Of Lines Widths and Roadmaps

- Line width roughness (LWR) - The measure of how the line width changes along the line. This is typically measured as a standard deviation and expressed as 3 times standard deviation under ITRS. The more the line width changes, the rougher the line is.
- *International Technology Roadmap for Semiconductors* (ITRS) - The ITRS is the fifteen-year assessment of the semiconductor industry's future technology requirements. The ITRS is sponsored by the five leading chip manufacturing regions in the world: Europe, Japan, Korea, Taiwan, and the United States.

AWARDS

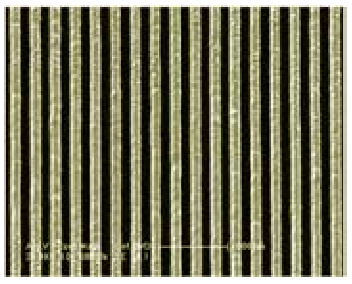
Postgraduate student attached to IMRE wins IEEE Best Student Paper Award

Mr Zhang Liang bags the Gold Award at IEEE Photonics Singapore's Best Student Paper Award Competition held earlier this year.

Mr Zhang Liang

Out of a nationwide field of local PhD students from the universities and A*STAR research institutes, Mr Zhang Liang, a PhD student attached to IMRE won the IEEE Best Student Paper Award 2010 in a competition oganised by the IEEE Photonics Society (Singapore), NTU, NUS, and sponsored by Agilent Technologies and Rohde & Schwarz.

After being shortlisted with 25 other students for the final round of the competition, Zhang Liang presented his work on "Linearly polarised light emission from InGaN LED with sub-wavelength metallic nanograting", which was done in IMRE. The judging panel comprising professors and research scientists from NUS, NTU and A*STAR conferred the Gold Award on his work which involves using metal nanowire gratings based on plasmonic effect to obtain polarised light directly from InGaN light emitting diodes (LEDs). This is very useful in LED applications for displays and backlighting.



SEM image of aluminium grating with line width of 70nm used to generate polarised emissions from InGaN LED

"I am thankful for Dr Teng Jinghua's mentorship, which was certainly a factor in guiding my research in IMRE and ultimately contributing to this award", said Zhang Liang about Dr Teng Jinghua, a Senior Sceintist and his supervisor here at IMRE.

IMRE alumnus wins UK Prize for entrepreneurship

Dr Adrian Burden, former IMRE researcher who developed and subsequently spun off anti-counterfeiting technology here, is awarded UK entrepreneurship prize.

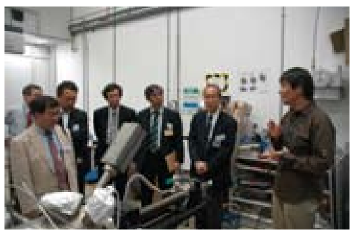
Dr Adrian Burden (right) receiving the JEMI prize from JEMI UK Ltd's Chairman, Mr Ian Tonge (left)

Dr Adrian Burden, President (Europe) of Bilcare Technologies, received the UK Joint Equipment and Materials Initiative (JEMI) Prize during the S2K 2010 European Semiconductor Conference. The award is in recognition of an individual's entrepreneurial spirit and for creating commercial success from a technology derived from the semiconductor, nanotechnology, or MEMs technology devices industry.

Adrian and Dr Peter Moran were senior IMRE researchers who developed and commercialised an anti-counterfeiting technology made from tiny, micro and nanometer-sized structures, which provide unique materials-based signatures. These "materials fingerprints" have been incorporated into tags and labels that are used to authenticate genuine products and credentials in real-time using a reader, mobile phone and a central, secure database. This led to IMRE's first spin-off company Singular ID Pte Ltd, with Adrian and Peter as CEO and CTO, respectively. The company was subsequently acquired by leading pharmaceutical packaging and healthcare company, Bilcare Ltd.

VISIT & EVENTS

1st Singapore-Japan "Workshop on Advances in Nanomaterials: Applications in Electronics, Energy and Health"



Speakers from the workshop visiting IMRE's atom technology lab

19 Apr 10

The workshop was the first jointly organised event by IMRE, NUS and National Institute of Materials (NIMS), Japan with the aim of exploring joint research and exchange programmes with NIMS. The workshop was attended by over 130 participants from Japan and Singapore. From the workshop, IMRE and NIMS had fruitful discussions on possible areas of collaboration including materials characterisation, nanoimprint technology, materials interface research and even biomaterials research.

Visitors from University of Twente, The Netherlands

04 May 10

IMRE hosted 20 students and professors from the University of Twente, The Netherlands who were on a tour to different countries to find out more about research worldwide. The students were briefed on research in IMRE and visited the Characterisation and Micro-Raman laboratories.

Students from the University of Twente visiting IMRE

National Science Challenge (NSC) 2010

Participants from the National Science Challenge being briefed before conducting the experiment

05 May 10

Three teams taking part in the nationally televised science competition programme were at IMRE for the filming of one of the NSC's Outdoor Challenge segment. The theme set by IMRE researchers for the challenge revolved around "Analytical Testing and Microfluidics", where teams were judged on their teamwork, sample preparation and accuracy in determining the amount of Vitamin C in a sample that was provided.

Meet-The-Scientist session - "Fascinating Science Magic"

19 May 10

Dr Loh Xian Jun and Mr Tan Mein Jin from IMRE conducted the session at the Science Centre, Singapore that was attended by 100 teachers and students. The researchers used scientific experiments that created spectacular effects to promote the 'magic of science', for example using a solution of methylene blue and glucose that alternates between two colours just by shaking or letting it rest.

Visiting delegates from the CIPM-CCL Working Group

19 May 10

22 members of the CIPM-CCL, or International Committee for Weights and Measures-Consultative Committee for Length Working Group visited IMRE to learn more about the characterisation capabilities here. The CIPM is tasked with promoting worldwide uniformity in units of measurement.

Delegates from the CIPM-CCL Working Group being briefed on some of IMRE's characterisation facilities

IMRE Workshop on "Atom Technology and Its Applications"

10 Jun 10

Atom Technology has immense potential in new engineering applications for the improvement of human technology and lifestyle.

Prof Andy Hor, new Executive Director of IMRE, welcoming participants to the Atom Technology workshop

The workshop brought together leading companies working in Atom Technology, and its closely related areas, to discuss future applications in electronics and mechanics. With a host of international academic and industry speakers, the idea of the workshop was to seed atom-scale technologies that would eventually lead to industrial applications. The topics covered included an overview of Atom Technology (CEMES/CNRS, France), Atomic Precise Manufacturing (Zyvex Labs, USA), advancements in Scanning Tunnelling Microscopes (Unisoku, Japan and Omicron, Germany), Atomic Switches (National Institute for Materials Science, Japan), Computational Modelling of Molecular Manufacturing (Syracuse University, USA), and Multiprobe STM for Future Atom Technology (IMRE). Partly sponsored by Fujitsu Asia Pte Ltd, the event was attended

(continue to page 4)

Institute of Materials Research and Engineering
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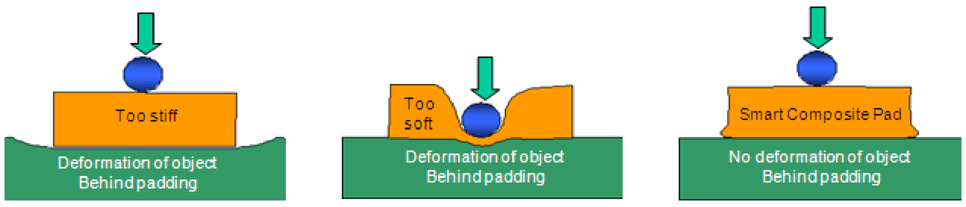
PATENTS FILED & GRANTED

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.

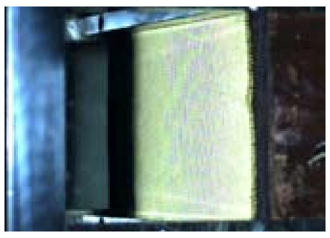
Highlights of IMRE patents filed from Feb '10 – May '10

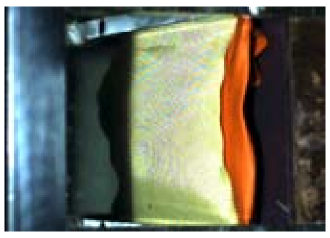
Spreading the Load

Researchers have invented a new flexible, lightweight material that dissipates high impact energy effectively, while offering mobility and comfort to its wearer.



Deformation of a smart composite pad under impact compared to other foam materials





A projectile punches into the clay witness behind a piece of ballistic fabric (far left) but fails to penetrate another sample that has the ballistic fabric backed by IMRE's smart polymer pad (left)

Based on the same principles of how a cornstarch solution hardens on impact, or the shear thickening fluid phenomenon, IMRE and NUS researchers have invented a new made-in-Singapore flexible, lightweight, and impact-resistant composite material.

The 'smart' material is soft and can conform to the shape of irregular surfaces. It offers a high degree of comfort and mobility to wearers but instantly stiffens upon impact to protect the wearer from knocks and falls, shrapnel from explosives, or injuries from weapons such as clubs. The material can withstand high-impact loads and will not crack under repeated loading.

Tests have shown that the new composite material is more effective than commercially available protective foams (used in sports) of greater thickness in dissipating impact energy. A 2cm thick version of the new material is comparable in performance to hard ceramic or steel plates when worn as a protective pad behind ballistic vests to reduce blunt trauma injuries. This could be used to replace the thick, heavy steel plates that are worn beneath Kevlar armour, thus improving mobility and comfort for the wearer.

The material is a composite which consists of a polymer and a combination of other materials engineered using a patented method developed in Singapore. It works based on the concept of shear thickening, meaning the material is soft and fluid at rest but becomes rigid upon impact.

The technology has huge potential in the sports industry where blunt force trauma accounts for a significant portion of sports-related injuries. Its advantage over existing materials is the softer, more flexible padding that absorbs greater impact but does not hinder movement, which ultimately improves an athlete's performance.

The technology can be applied to a number of areas, including body armour, sports protective equipment, surgical garments, and even aerospace energy absorbent materials. IMRE is now looking for industry partners to help evaluate and scale-up the technology.

For more information about this patent, please email

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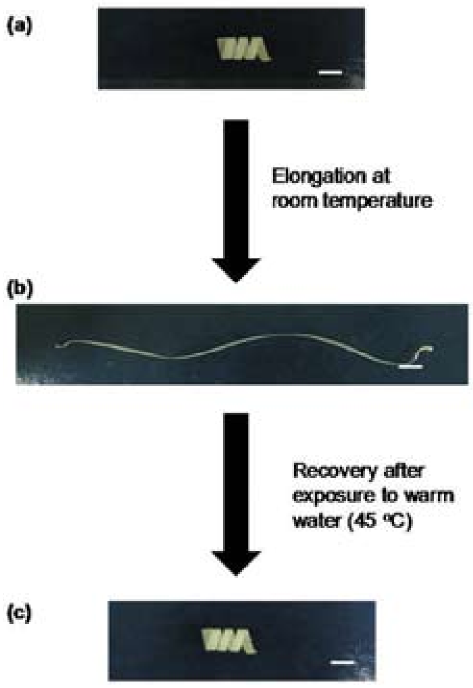
In the blink of an eye - Fastest response shape memory polymer

IMRE scientists have developed shape memory polymers that are biodegradable and biocompatible but most importantly, have the fastest recovery response times.



Springing into action - IMRE's shape memory polymer

Shape memory polymers (SMPs) belong to a group of polymers which show dual shape properties, where they can be moulded into a different shape but reverts back to the original shape under certain conditions, such as a change in temperature.

Such materials have been explored for use as remote assembly equipment, 'smart' biomaterials, heart stents and fabric fibres. However, current shape change polymers are not biodegradable and have limited shape memory deformation, where the transformation is sometimes not complete. A major problem is also the length of time it takes for the transformation, or for the 'recovery' of the polymer, to occur. Current recorded times range from 10 seconds to hours. Even at 10 seconds, the time scale is too long for applications in biomedicine, and body implants. For example, in order to seal a leaking blood vessel in the body, an immediate response is needed instead of a delayed 'recovery' of the polymer.

Researchers in IMRE have developed a new biodegradable and biocompatible shape memory polymer that can recover its shape in less than 5 seconds. The polymer, made up of an organic component and an inorganic component, typically takes between 0.7 to 3 seconds to recover, providing an almost instantaneous shape recovery process. The use of the inorganic component allows the material to recover faster, in the same manner a rubber band snaps back after being pulled.

The new material could be used both in niche areas of biomaterials such as biodegradable heart stents, wound patches, remote activated nanocarriers as well as in mass market consumer products such as hair care products, 'smart' clothes, and even advertisement displays.

For more information about this patent, please email

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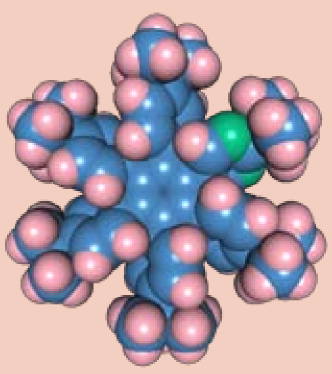
VISIT & EVENTS

(continued from page 3)

by some 80 scientists, engineers and business development managers. As a result of the workshop, IMRE is now speaking with research organisations and industry to explore the possibilities of collaborative research projects and partnerships aimed at potential technological and commercialisation outcomes.

Atom Technology has immense potential in new engineering applications for the improvement of human technology and lifestyle in areas like personal computers, communication devices, healthcare, energy as well as water production and conservation. For example, imagine being able to fit a billion transistors into the space that one transistor currently occupies, and the scale of computing that is possible with atom technology becomes evident.

IMRE's work on Atom Technology



The atomic-scale research conducted in IMRE includes work on atomic and molecular devices as well as an industry collaboration on atomically precise manufacturing with Zyvex Labs, USA. Zyvex Labs is hosted in IMRE under a "Lab-in-a-Research-Institute" scheme, where their local laboratory, equipment and office are based in IMRE. Some of IMRE's successes in atom technology include the development of the world's first controllable molecular-sized gear.

UPCOMING EVENTS

Diary of upcoming events @ IMRE

30 July – 01 August 2010
X-Periment 2010 Exhibition @ Marina Square Mall

03 August 2010
Launch of Industrial Consortium On Nanoimprint (ICON) in conjunction with the 4th Industrial Symposium on Nanoimprint Lithography

11 August 2010
MRS-S Conference on "Advances in Nanomaterials: Energy, Water & Healthcare" @ IMRE

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

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