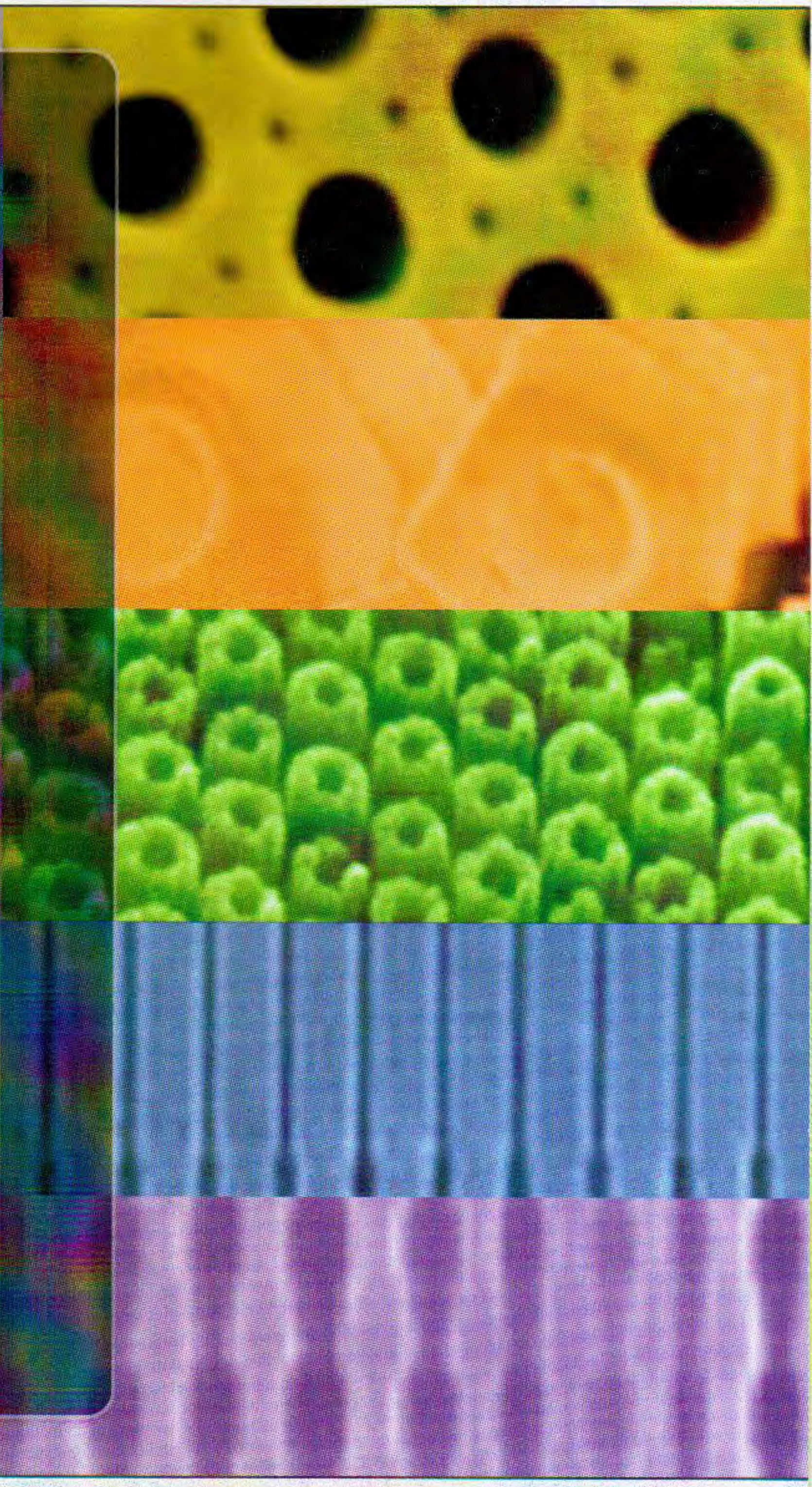
UCSD Jacobs | School of Engineering

FALL 2011

MATERIALS NEWS

UC SAN DIEGO **DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING** NEWSLETTER

IN THIS ISSUE



ABOUT THE COVER IMAGES: SEM pictures of various aluminum oxide nanotemplate configurations by modified anodization techniques (courtesy of former Materials Science graduate student Kevin Noh)

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Letter from the Director

This is the seventh newsletter describing the UC San Diego's Materials Science & Engineering (MSE) Program, and I hope you enjoy reading about education and research activities in our program.

Our MSE Program at UC San Diego is a university-wide, highly interdisciplinary program with more than 80 participating faculty members. The professors and students in our program come from various divisions of UCSD, including the Jacobs School of Engineering (departments of electrical engineering, mechanical engineering, structural engineering, bioengineering, nanoengineering), Division of Physical Sciences (department of physics, department of chemistry & bio chemistry), Division of Biological Sciences, the School of Medicine, and the School of Pharmacy.

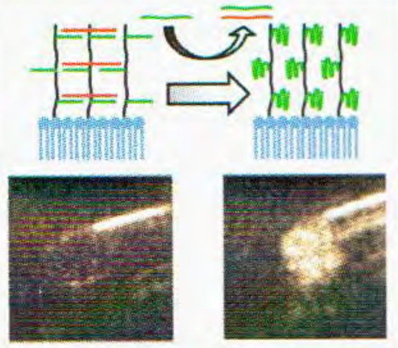
MSE faculty members are mostly outstanding in their research and education career, with the faculty now including 7 National Academy of Engineering, 5 National Academy of Sciences, 3 Institute of Medicine members, and the recent National Medal of Science Award this year to Prof. Shu Chien who is also our MSE member. Having such an excellent quality of faculty, combined with one of the highest per-faculty research grants in the nation, provides a stimulating environment for our graduate students working toward their Ph.D. degrees. The total number of our graduate students in Materials Science and Engineering is now over ~115. UCSD's MSE Program was ranked 14th last year among all Materials Science doctoral programs in the United States by the prestigious National Research Council (NRC) data-based assessment.

I am always proud of faculty and graduate students in our MSE program and their accomplishments. With future newsletters, we will continue to share the latest information on academic, research, and career progress of our faculty, students, postdocs, and alumni from our MSE Program.

Sungho Jin
Director, UCSD Materials Science & Engineering Program
Distinguished Professor of Materials Science

DNA Coated Microbubbles with Tunable Ultrasound Contrast Activity

Matthew Nakatsuka, a graduate student in the Materials Science & Engineering (MSE) program at UCSD, through collaborative research between the Electrical and Computer Engineering and Nanoengineering departments, recently demonstrated the design and synthesis of tunable microbubble ultrasound contrast agents that respond specifically to biochemical triggers in vitro. Ultrasound is a painless, economical, and ubiquitous imaging modality commonly used for disease diagnosis. However, limitations in sensitivity have complicated its use for early disease detection. Contrast agents can improve signal-to-noise ratios, but these contrast agents are delivered throughout the entire body, making it difficult to determine whether a small "dark" spot is a precancerous lesion or an imaging artifact. Recently, to overcome these challenges, Matt Nakatsuka and his mentors Dr. Andrew Goodwin, Prof. Sadik Esener, and Prof. Jennifer Cha published a paper in Advanced Materials on the design and fabrication of "smart" microbubbles that only emit a positive signal when triggered by a biochemical cue, such as a DNA strand or a protein.



Addition of DNA to smart microbubbles activates their ultrasound contrast

The authors are currently tailoring this biochemically-responsive ultrasound contrast agent to detect malignant blood clots in vivo. This work was funded in part by NIH grants R21-EB012758 and K99-CA153935.

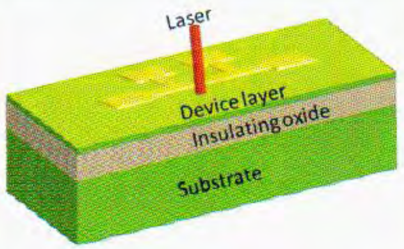
Using Nanoporous Materials for Energy Capture

Advanced blast and impact mitigation materials have been actively researched for many decades, to develop lightweight and small-sized protective and damping systems, such as advanced combat helmets (ACH), vehicle armors, etc. Recently, Prof. Yu Qiao's team including Materials Science & Engineering graduate students (Taewan Kim and Weiyi Lu) developed novel nanoporous-materials-functionalized (NMF) liquids that can not only dissipate, but also "capture" the mechanical energy carried by stress waves. The energy capture capacity can be related to the small ligament length and the large impedance mismatch of the nanoporous materials, so that the wave energy is "isolated" in the confined liquid phase and does not transmit through the solid phase The NMF liquids can exist in either liquid form, "dry water" form, or gel form. A NMF liquid consists of nanoporous particles mixed with a liquid/gel. The inner surfaces of nanopores must be non-wettable to the liquid phase. As the liquid is forced into nanopores by a sufficient high external pressure, a tremendous amount of energy is captured. Their energy absorption efficiency can be higher than that of conventional energy absorption materials by orders of magnitude (~ 102 J/g). The response rate can be on the scale of 107 Hz.

Various NMF Liquids

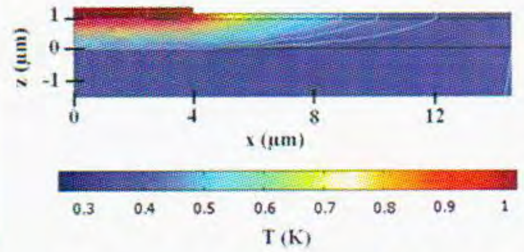
Monitoring Heat Propagation in Nanostructures through Optical Reflectance

The harness of wasteful heat and its efficient dissipation has assumed much importance recently, in view of the need for energy conservation and enhanced integrated device density. Such considerations provide motivation for monitoring heat/thermal wave propagation in materials. However, a major issue in understanding heat transport of lower dimensional structures, such as thin films or nanowires, is the prevalent use of physical contacts, which serve for heat transfer from a heat source into the material that needs to be characterized. The thermal boundary resistance, due to contact-material mismatch, yields an apparent value of the thermal conductance which varies from device to device, as interface conditions are mostly unpredictable.



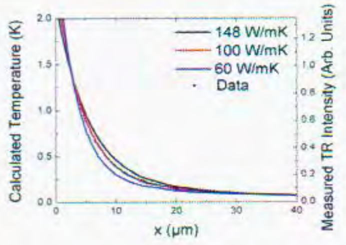
A diagram of the experimental principles involved in the measurement of the temperature profile of a heated silicon-on-insulator (SOI) device structure sample by rastering a laser beam (e.g., He-Ne laser), as a function of distance from the heater, and monitoring the resultant reflectance.

In recent papers published in *Applied Physics Letters*, *Journal of Applied Physics*, and the *Engineering Measurements Encyclopedia* (John Wiley, Inc.) Max Aubain and Professor Bandaru have proposed that the variation of optical reflectance from the surface in response to a change in temperature, *i.e.*, the thermoreflectance, can be used to monitor heat conduction processes within the films. The underlying rationale is that the temperature modulates the refractive index, which in turn influences the reflectance. The methodology involves shining light (*e.g.*, from a He-Ne laser) onto a material and monitoring the reflectance (both the magnitude and the phase), correlated to a tempera-ture profile. Finite element modeling (FEM) of the experimental profiles can then yield the thermal conductivity of the structures. Using such methods, *e.g.*, a reduction of thermal conductivity in silicon-on-insulator (SOI) based structures was observed, with implications in understanding the heat dissipation characteristics of micro/opto-electronic devices.



Finite Element Modeling (FEM) of the temperature along the sample cross-section, indicated at the peak of a given heating cycle.

The advantage of the use of such optical methods is the possible elimination of electrical resistance based sensing/thermometry. Concomitantly, the proposed technique provides a quick, non-contact based optical metrology with high temperature resolution (~ 0.01 Kelvin) to determine the temperature profiles and thermal energy distributions in materials. In addition to exploring the practical utility of the method for industrial applications, the research team aims to measure the anisotropy of the thermal conductivity tensor, which could then yield insight into the relevance of the isotropy assumption, prevalent in the literature.

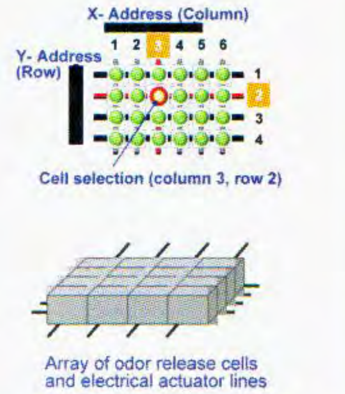


A typical thermoreflectance scan across the surface of the device layer indicating the experimental data superposed on modeled temperature profiles with varying thermal conductivity. The error bars are too small to be visible. (from M. S. Aubain and P. R. Bandaru, "Determination of diminished thermal conductivity in silicon thin films using scanning thermoreflectance thermometry," Applied Physics Letters, vol. 97, p. 253102, 2010)

X-Y Matrix Addressable Odor-Release System Developed for Smell-o-Vision

Odor-generating device being tested in the lab for Smell-O-Vision (above), and CNBC TV news coverage (below).

Much research has been dedicated to the development of virtual reality for entertainment and engineering. Although the devices for the added sensual experience for virtual reality have been developed in recent years, only few odor generating devices with practical and useful control have been developed for the sense of smell.



Schematics of the on-off switchable X-Y matrix odor generating system.

Previous technologies for the controlled release of scents were not simple enough and were much too coarse and crude in nature, and it is hard to apply them to delicate home electronics or personal devices owing to their bulkiness, their lack of reproducible release over multiple cycles, their slow response times to stimuli, as well as their inability to dynamically adjust the amount/intensity of odor according to the recipient's needs.

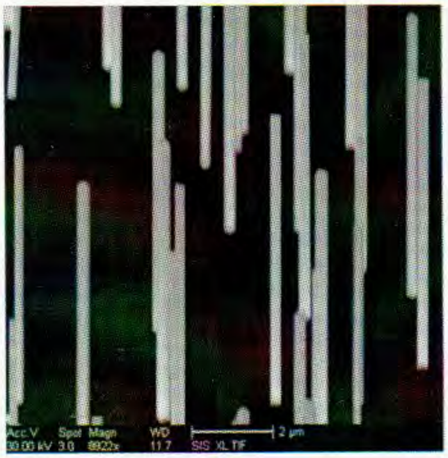
Materials Science graduate student Stanley Hyunsu Kim, Mechanical and Aerospace Engineering student Calvin Gardener, and colleagues in Prof. Sungho Jin's lab have discovered the technology that would make a practical odor generating system possible. In a paper published in the journal Angewandte Chemie, they have demonstrated that it was possible to generate odor, at will, in a compact device small enough to fit on the back of a TV with potentially thousands of odors. Their method is based on an array of PDMS elastomer-based cells that are filled with scent-containing solutions. Only the cells at the X-Y matrix crosspoint receives sufficient thermal actuation to release the odor; thus many odors in the matrix array can be processed in a convenient manner. They tested their device with two commercially available perfumes, "Live by Jennifer Lopez," and "Passion by Elizabeth Taylor." In both cases, a human tester was able to smell and distinguish the scents within 30 centimeters of the test chamber. The scent would ultimately be programmed and synchronized with what is shown on TV, and a viewer would be able to smell coffee or pizza or perfume as it is displayed on the screen.

For more information, please see the published article by Hyunsu Kim, Jongjin Park, Kunbae Noh, Calvin J. Gardner, Seong Deok Kong, Jongmin Kim, and Sungho Jin in **Angewandte Chemie International Edition**, 50, 6771 (2011).

CVD Growth of Single-Crystal Ni Nanowires

Chemical-vapor-deposition (CVD) techniques represent a promising approach for the synthesis of a broad range of nanostructured materials, with a recent emphasis on nanowires (NWs). The realization of many NW applications requires efficient and economical NW synthesis techniques that preferably avoid the need for templates or costly single-crystal substrates, and also affords process adaptability. Towards this end Materials Science & Engineering pro fessor and his graduate students (Keith T. Chan, Jimmy J. Kan, Christopher Doran, Sohini Manna, and Eric E. Fullerton) developed a single-step route for the reduction-type synthesis of nanostructured Ni materials using a thermal CVD method. By tuning the CVD growth parameters they can synthesize various Ni products including vertically-oriented Ni NW arrays which form atop untreated amorphous SiO_2||Si substrates. Figure 1 shows an SEM image of an example NW array. Each NW is (001)-oriented and can range in diameter from 100 – 300 nm and up to 5 mm in length [1].

In sharp contrast to the majority of NW materials, these Ni NWs are grown in the absence of any foreign catalyst or template and form consistently over large areas.



Vertically aligned single-crystal Ni(001) nanowire arrays grown by thermal CVD onto an amorphous SiOx substrate.

The most common and well-studied CVD methods for NW synthesis have focused on the elemental and compound semiconductors as well as functional materials such as C nanotubes. The synthesis of these high-aspect-ratio and highly oriented terials typically relies on the vapor-liquid-solid mechanism using foreign catalyst seeding and lattice-matched single-crystal substrates. Most transition-metal NWs are synthesized via guided electrodeposition techniques where the the polycrystalline metal NWs are formed within pores of membranes. The new CVD approach for the synthesis of single-crystal transition-metal NWs (*e.g.* Ni, Co, Fe) would enable their use in wide-ranging applications involving magnetic and catalytic functions. The synthesis approach is based on a thermal CVD process which was extensively used in the 1950's and 60's for the growth of single-crystal whiskers and films of Fe, Co, Ni and their alloys and oxides using both hydrated and anhydrous metal-halide precursors such as $FeCl_2$, $FeBr_2$, $CoCl_2$, $CoBr_2$, $NiCl_2$, and $NiBr_2$. Here, this early work was extended to achieve a significantly increased degree of morphological control with a focus on $NiCl_2$*$6H_2O$ precursors for the growth of Ni nanostructures. An understanding of the new properties that emerge in these NW materials and their relationship to function should lead to a broad range of applications based on high-surface-area transition-metal nanostructures such as catalysis, fuel cells, sensors, batteries, and magnetic devices. For instance such Ni and Ni-based materials are vital components in such processes as the steam reformation of CH_4 in synthesis gas production, tar reduction in lignocellulosic biomass conversion, aqueous phase reform of sugars and sugar alcohols, and electrochemical reduction of CO_2 to syn thesis gas.

For more information, see the published article, "**Oriented growth of single-crystal Ni nanowires onto amorphous SiO_2**," by K. T. Chan, J. J. Kan, C. Doran, L. Ouyang, D. J. Smith, and E. E. Fullerton, Nano Lett. 10, 5070 (2010).

Student Awards & Honors

Tobin Kaufman-Osborn - MSE student Tobin Kaufman-Osborn (in Prof. Andrew Kummel's group) won a prize on SRC Techcon for his work on passivation/functionalization of Ge for gate oxides. His group also received a new grant on the topic as custom SRC funding from Applied Materials.

James Hamlin and Diego Zocco - MSE students in Prof. M. Brian Maple's group in the Physics Department, James Hamlin and Diego Zocco, were named Winners of the National Nuclear Security Administration, US DOE's "Stewardship Science Academic Alliances 2011 SSAA Annual Publication Contest". The citation reads "In recognition of the outstanding article "Novel d- and f-electron Materials Under Extreme Conditions of Pressure, Temperature and Magnetic Field," published in the 2011 Stewardship Science Academic Alliances Annual.

Brian Maple, D. A. Zocco, J. J. Hamlin, and R. E. Baumbach - Brian Maple and group members D. A. Zocco, J. J. Hamlin, R. E. Baumbach and collaborators at Oak Ridge National Lab, Lawrence Livermore National Lab, and University of Alabama, received a Top Cited Article 2005 – 2010 Award from the journal "Physics" for their article, "Effect of pressure on the supercon ducting critical temperature of $La[O_{0.89}F_{0.11}]FeAs$ and $Ce[O_{0.88}F_{0.12}]FeAs$", Physica C: Superconductivity and its Applications, Volume 468(21), Page 2229, 2008.

MSE Faculty Award

Prof. Shu Chien Receives National Medal of Science Award

President Obama named seven eminent researchers as recipients of the National Medal of Science last month. One of the award recipients is Prof. Shu Chien at UCSD for his pioneering work in cardiovascular physiology and bioengineering. He is a professor in Bioengineering, and is also a participating professor in UCSD's Materials Science & Engineering Program.

The National Medal of Science was created in 1959 and is administered by the White House by the National Science Foundation. Awarded annually, the Medal recognizes individuals who have made outstanding contributions to science and engineering.

Ekaterina Evdokimenko - Third year MSE graduate student Ekaterina Evdokimenko, who is working with Prof. Joanna McKittrick, received NSF award to participate in the NSF-sponsored student poster symposium at the ASME-IMECE 2011 in Denver in November 11-17, 2011.

David Nelles – David Nelles, an MSE student of Prof. Gene Yeo, School of Medicine, received an NSF graduate fellowship in April 2011.

About The Editor

Diana Villwock is a second-year graduate student in the department of Material Science & Engineering at UCSD. Born in Giessen, Germany, she moved to San Diego at the age of eight with her family, where she lived until 2003 when she attended UCLA for her undergraduate studies. In 2007, she earned a Bachelor's of Science in Biochemistry, and then continued to earn her Master's Degree in Biomedicine at the Johannes Gutenberg University in Mainz, Germany. She is currently performing research in Prof. Sungho Jin's group, where she is examining the behavior of osteoblast cells when cultured on different surfaces including nanostructured titanium. In particular, she is analyzing the effects of super-hydrophobic surface coatings on the adhesion and growth of osteoblast cells. Outside of research, she enjoys playing the piano, singing, and outdoor activities.

About the MSE Department Graduate Coordinator

Charlotte Lauve was born in Germany and raised in Texas and California. She grew up in San Diego, and has done extensive traveling, camping, fishing, surfing and horse back riding. She has a son and daughter, as well as a son in law who is a Marine and two step sons all over the age of 21. Charlotte has worked at UCSD for almost 23 years as the Graduate Coordi nator for the MSE Graduate Program. Outside her work at UCSD, she enjoys spending time with her husband, two cats, and yellow lab, Kona. During desert season, she enjoys taking Kona and her children out to the desert where they ride on her 250 quad. During the summer, she particularly enjoys going camping and boating at Lake Mojava.

New Graduate Students 2011

Welcome to 29 New Graduate Students who joined our Materials Science & Engineering Program this academic year!

Anna Alexander
Georgia Tech

Jihye Baek
Soongsil Univ Seoul

Michael Brasino
U of Washington

Tze-Han Chen
Tsing Hua Univ

Roger Yu-Jiu Chiu
Linkoping Univ

Mary Edmonds
Arizona St Univ

Lorenzo Ferrari
Univ of Milan, Italy

Michael Franks
Tsukuba Univ, Japan

Yoonho Heo
KAIST, Korea

Joshua Hoemke
Univ Michigan

Michael Hwang
Seoul Nat Univ

Gary Johnston
UC San Diego

Sungwoon Kim
Korea Univ

Justin TaeKyoung Kim
Yonsei Univ

Joon Lee
Yonsei Univ

Isaac Chin Hung Liu
Tsing Hua Univ

Justin Liu
Northwestern Univ

Douglas Long
UC Santa Cruz

Natalie Mendez
UC San Diego

Scott Olson
Lehigh Univ

Matthew Ondeck
Carnegie Mellon Univ

Michael Porter
Univ Hawaii

Matthew Rozin
Univ Mass-Amherst

Casey Sanchez
CSU Fullerton

Camille Sybert
Cal Poly

Yeh Tsai
National Tw Univ

Jing Xu
Univ Sci Tech China

Chun-Hao Yang
Cheng Kung Univ

Hyojung Yoon
Inha Univ

Taylor Yuen
UC San Diego

We would love to hear the achievements and milestones from the UC San Diego Materials family that comprises students, alumni, faculty, visiting scientists, and staff for inclusion in our net newsletter!

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