## The Thirty-Fifth Annual Ross Tucker Award Recipients

*Peter Stone*
*University of California, Berkeley*
Thesis Advisor: Oscar Dubon

*Candace Chan*
*Stanford University*
Thesis Advisor: Yi Cui

## The Eleventh Annual EMS Undergraduate Award

*Sang-Tae Kim*
*University of California, Berkeley*

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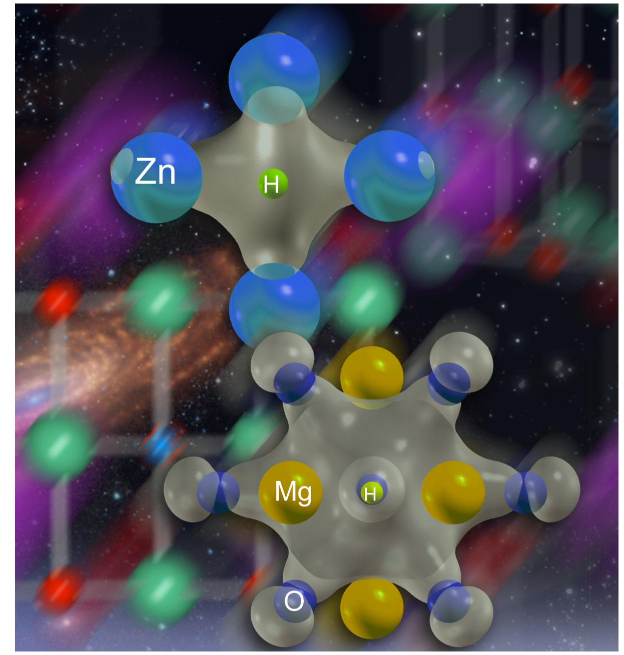


*The 37th Annual*

# ELECTRONIC MATERIALS SYMPOSIUM

A One-Day Symposium on Electronic Materials
Featuring Authorities Outstanding in their Fields

**Network Meeting Center at Techmart**
**5201 Great America Parkway**

**Santa Clara, California**
Friday, April 10, 2009

## PROGRAM

Friday, April 10, 2009
Network Meeting Center at Techmart, Santa Clara

8:00 Registration

**MORNING SESSION**
Session Chair: Prof. Yi Cui

8:30 **Welcome Remarks and Introduction**
Prof. Junqiao Wu, UC Berkeley

8:40 ***"Recent Advancements in Photovoltaics: Science, Technology and Policy"***
Dr. Charles Gay, Applied Materials, Inc.

9:25 *"Oxides as Semiconductors"*
Prof. Chris G. Van de Walle, University of California, Santa Barbara

10:10 **REFRESHMENTS** (Vendor Exhibit Area)

10:40 *"NanoMagnetic Biochips - A New Tool for Fighting Cancer and Rapid Triaging"*
Prof. Shan Wang, Stanford University

11:25 *"Finite Size Effects in Electrical Transport in Nanowires"*
Alec A. Talin, Sandia National Laboratories

12:10 **LUNCHEON**

1:10 **Luncheon presentation:** *"Condensed Matter Physics, and Comments on Einstein, Nanoscience, and Superconductivity"*
Prof. Marvin Cohen, University of California, Berkeley

**AFTERNOON SESSION**
Session Chair: Prof. Todd Weatherford

1:55 *"Phase Change Materials and their Application to Memory Technology"*
Dr. Simone Raoux (Presented by Dr. Geoffrey Burr), IBM

2:40 **35th Annual Ross Tucker Award**
**11th Annual EMS Undergraduate Scholarship**

3:00 **REFRESHMENTS** (Vendor Exhibit Area)

3:30 *"Thermally Enhanced Substrates Using Thin Film Diamond"*
Mr. Jerry Zimmer, $sp^3$ Diamond Technologies

4:15 *"Resolving Sub-nm Steps with a Low-voltage Miniature Scanning Electron Microscope"*
Dr. Lawrence Muray, Novelx Inc.

5:00 **Closing remarks**, Prof. Junqiao Wu

5:10 **HOSTED COCKTAIL PARTY**
**VENDOR'S SHOW**

**About the Cover:**

Hydrogen usually bonds to only a single atom, but in certain oxides hydrogen replaces oxygen and simultaneously bonds to as many as four other atoms (in ZnO) or six other atoms (in MgO). This highly unusual chemical bond also has important consequences for technology since it explains unintentional electron conductivity in oxides. The image shows a three-dimensional visualization of the multicenter bonds in ZnO and MgO. Isosurfaces of the electronic charge density distribution of the bonding states were obtained from state-of-the-art first-principles calculations. The MgO crystal structure is shown in the background.

* Image courtesy of Chris G. Van de Walle and A. Janotti from University of California, Santa Barbara

**General Information:** The registration covers admission to the symposium sessions, abstracts of the symposium presentations, luncheon, a vendor's exhibit, and a hosted cocktail hour following the symposium. The Electronic Materials Symposium Committee exists to promote the understanding of electronic materials within the industrial and academic communities of the San Francisco Bay area. This committee organizes the annual Electronic Materials Symposium, featuring presentations on advanced electronic, magnetic and optical materials processing, characterization and devices by outstanding speakers who have made significant contributions to their fields. Proceeds of the symposium are used to support electronic materials research and education in local universities.

# ELECTRONIC MATERIALS SYMPOSIUM

LIST OF VENDOR PARTICIPANTS

We would like to give special thanks to this year's vendors who provided the opportunity for many undergraduates to attend this conference through registration scholarships. Please take the time to stop by and visit the vendors' booths during the breaks and cocktail party.

## Agilent Inc.

Contact: Stuart Spencer
www.agilent.com

## Novelx Inc.

Contact: Jim Rynne
www.novelx.com

# Phase Change Materials and their Application to Memory Technology

*Dr. Simone Raoux*
*(Presented by Dr. Geoffrey Burr)*
*IBM*

Phase change materials can exist in two different phases – the amorphous and the crystalline phase – which exhibit distinctly different physical properties. It is possible to repeatedly switch the state of these materials, from the amorphous phase to the crystalline phase by heating the materials above its crystallization temperature, and from the crystalline to the amorphous phase by melt-quenching. Phase change materials have been utilized very successfully in all modern optical re-writable storage media such as CDs, DVDs, HD DVDs and Blu-ray disks. Recently, they have also been applied to solid-state random access memory (PCRAM) devices where their large difference in electrical resistivity is used to store information. This talk will review the unusual properties of phase change materials in particular as they are important for their application to PCRAM devices. The optical and electrical properties of phase change materials will be described. Novel deposition methods such as CVD and spin-on materials will be discussed. Experiments regarding the scaling properties of phase change materials performed on ultra-thin films, nanowires, nanoparticles and prototype devices demonstrate the very promising scaling behavior of this technology.

**Dr. Simone Raoux** is a Research Staff Member at the IBM Almaden Research Center. She received her MS degree in 1984 and Ph.D. degree in physics in 1988 both from Humboldt University, Berlin, Germany. From 1988 to 1991 she worked as a Staff Scientist at the Institute for Electron Physics in Berlin, Germany, doing research in the field of electrical breakdown. From 1992 to 2000, she was a Staff Scientist at Lawrence Berkeley National Laboratory and performed research in the fields of vacuum arc deposition, ion implantation, photoemission electron microscopy, X-ray magnetic circular dichroism, and near-edge X-ray absorption fine structure spectroscopy. Her current research interests include the physics and materials science of phase change materials. She is author or coauthor of more than 100 journal articles, holds 8 patents and recently edited a book entitled Phase Change Materials: Science and Applications (Springer 2008).



# NanoMagnetic Biochips - A New Tool for Fighting Cancer and Rapid Triaging

*Prof. Shan Wang*
*Stanford University*

Reproducible and multiplex protein assays are greatly desired by cancer biologists as well as clinical oncologists to rapidly follow numerous proteins in clinical samples. By simply applying patient serum or tissue samples to the magneto-nano sensor chip developed in our group, one can readily and quantitatively ascertain the presence or absence of a large number of tumor markers, such as those involved in HER-kinase axis pathway, in a multiplex format. This will allow physicians to determine the efficacy of relevant chemotherapy in real time. Combined with a different set of tumor markers, the new protein assays will also allow physicians to detect cancer early, e.g, stage 1 ovarian cancer, so that cancer survival rates can be improved greatly with early intervention. Combined with yet another set of protein markers such as CDKN1A and H2AX, this new tool will permit the rapid triaging of individuals with <1 Gy, 1-3.5 Gy, and >3.5 Gy exposure in mass radiation exposure scenarios. We have now successfully applied magneto-nano biochips based on giant magnetoresistance (GMR) spin valve sensor arrays and magnetic nanoparticle labels (nanotags) to the detection of biological events in the form of multiplex protein assays (4- to 64-plex) with great speed (30 min. – 2 hours), sensitivity (1 picogram/milliliter concentration levels), selectivity, and economy [1,2]. The technology is highly scalable to deep multiplex detection of biomarkers in a complex disease, and amenable to integration of microfluidics and CMOS electronics for portable applications. In particular, we have prototyped protein chips with an 8 x 8 array of 64 giant magnetoresistance (GMR) spin valve sensors. Each sensor is about 100 um by 100 um in area and covered with a unique protein feature, which can be spotted with a robotic inkjet or other types of pins. The total area of the chip is about 10 mm by 12 mm, while the active 8 x 8 sensor array occupies an area of only 3 mm x 3 mm. The fabricated chips are intrinsically multiplex by virtue of having 64 capture probe spots, enabling multiplex detection of up to 64 biomarkers in one test. Moreover, the sensors under an ultrathin passivation layer have proven to be chemically stable in aqueous solutions or serum samples. These chips are ideal for measuring multiple protein levels in a volume of only 10-50 uL of serum sample, from a human patient with minimal invasiveness in an emergency room or point of care.

[1] Wang SX, Li G (2008) Advances in GMR Biosensors with Magnetic Nanoparticle Tags: Review and Outlook (Invited Review for Advances in Magnetics), IEEE Trans. Magn. 44:1687-1702.
[2] Osterfeld SJ, Yu H, Gaster RS, Caramuta S, Xu L, Han SJ, Hall DA, Wilson RJ, Sun S, White RL, Davis RW, Pourmand N, Wang SX (2008), PNAS, 105, 20637-20640.

**Dr. Shan Wang** currently serves as the director ofthe Stanford Center for Magnetic Nanotechnology and is a full professor in the Department of Materials Science & Engineering and jointly in the Department of Electrical Engineering at Stanford University. He is a Co-Leader of the Stanford-led Center for Cancer Nanotechnology Excellence focused on Therapeutic Responses (CCNE-TR). His current research interests lie in magnetic nanotechnologies and information storage in general and include magnetic biochips, magnetic nanoparticles, nano-patterning, spin electronic materials and sensors, magnetic inductive heads, as well as magnetic integrated inductors and transformers. He has published over 155 papers, and holds 19 patents (issued and pending) on these subjects. Dr. Wang contributed one book and two book chapters on magnetic biochip, information storage, and embedded inductors, respectively, and gave more than 55 invited presentations in major scientific conferences and meetings. Dr. Wang was an inaugural Frederick Terman Faculty Fellow at Stanford University (94-97), an IEEE Magnetics Society Distinguished Lecturer (2001-2002), and was elected an IEEE Fellow (2009). He also received the Obducat Prize for 2007-8, a National Academies Keck Futures Initiative Award (2006), an IBM Partnership Award in 1999, and was selected to the CUSPEA program organized by Nobel Laureate T. D. Lee in 1986.

## Oxides as Semiconductors

*Prof. Chris G. Van de Walle*
*University of California, Santa Barbara*

Oxides have many applications, ranging from gas sensors to varistors. Transparent conducting oxides (TCOs) provide metallic conductivity while absorbing little or no visible light; they are essential for devices such as solar cells, light-emitting diodes, and flat-panel displays. Furthermore, controllable p-type doping will allow for optoelectronic de-vices such as light emitting diodes and detectors. Recent efforts to enhance the performance of oxide devices have highlighted the fact that the causes and mechanisms of conduction are still poorly understood. Oxygen vacancies are widely accepted as the source of n-type conductivity, but we have recently shown that this cannot be true in ZnO [1]. Based on first-principles calculations, we have suggested that hydrogen is a plausible cause of unintentional doping [2,3]. Surprisingly, substitutional hydrogen acts as a shallow donor. Hydrogen on an oxygen site bonds equally to the four surrounding Zn atoms, forming a multicenter bond [3]. Calculations for SnO2 show very similar behavior, indicating that substitutional hydrogen is a likely dopant in many other technologically relevant oxides.

References:
[1] A. Janotti and C. G. Van de Walle, Appl. Phys. Lett. 87, 122102 (2005).
[2] C. G. Van de Walle, Phys. Rev. Lett. 85, 1012 (2000).
[3] A. Janotti and C. G. Van de Walle, Nature Materials. 6, 44 (2007).

**Dr. Van de Walle** is a Professor in the Materials Department at the University of California, Santa Barbara. Prior to joining UCSB he was a Principal Scientist in the Electronic Materials Laboratory at the Xerox Palo Alto Research Center (PARC) (1991-2004). He received his Ph.D. in Electrical Engineering in 1986 from Stanford University, performed postdoctoral research at the IBM T. J. Watson Research Center in Yorktown Heights, New York (1986-1988), and joined Philips Laboratories in Briarcliff Manor, New York as a Senior Member of Research Staff (1988-1991). Prof. Van de Walle develops and employs first-principles techniques to model the structure and behavior of materials. He has performed extensive studies of semiconductor interfaces (including the development of a widely used model for band offsets) and of defects and impurities in semiconductors, with particular emphasis on doping problems and on the role of hydrogen. In recent years he has been focusing his attention on wide-band-gap semiconductors, oxides, and on the behavior of hydrogen in materials. He has published over 200 research papers, holds 19 patents, and has given over 100 invited talks at international conferences. Prof. Van de Walle is a Fellow of the American Physical Society (APS), a Senior Member of the IEEE, and the recipient of a Humboldt Award for Senior US Scientist and the David Adler Award from the APS. He has chaired a number of conferences, and was Program Chair for the 27th International Conference on the Physics of Semiconductors, Flagstaff, AZ, July 26-30, 2004.



## Recent Advancements in Photovoltaics: Science, Technology and Policy

*Dr. Charles Gay*
*Applied Materials, Inc.*

With increasing concerns related to climate change, and the world's need for renewable energy sources, industry has been expanding manufacturing technologies for producing clean energy equipment before non-renewable sources are exhausted. Solar energy, specifically photovoltaics (PV), is widely accepted as a viable source of alternative energy to replace traditional, non-renewable fuel sources. Over the last 10 years, advancements in PV technology have made solar a cost-effective solution. Advancements in crystalline silicon technology include SunPower's back contact cell which was successfully developed and commercialized over the past five years. In thin film technology, significant progress has been made in developing proprietary compositions of amorphous silicon/ microcrystalline technology for tandem junction solar applications. Dr. Charles Gay will discuss recent advancements in PV technology which have made solar a cost-effective alternative to non-renewable fuel sources. Additionally, he will discuss the level of involvement and commitment needed from academic, corporate and government agencies to ensure the long term sustainability and success of the solar PV industry.

**Dr. Charlie Gay** was named corporate vice president and general manager of the Solar Business Group at Applied Materials in 2006. An industry veteran with over 30 years of experience in the solar industry, Dr. Gay is responsible for establishing and building Applied Materials' solar business. Dr. Gay is also a cofounder of the Greenstar Foundation, an award winning organization that delivers solar power and internet access for health, education and microenterprise projects to small villages in the developing world. Prior to his leadership role at Applied Materials, Dr. Gay held executive level positions including president and COO of Siemens Solar Industries, Director for NREL, and president and CEO for ASE Americas Inc. He was also the chairman of the advisory board at SunPower Corporation. He holds numerous patents for solar cell and module construction and is the recipient of the Gold Medal for Achievement from the World Renewable Energy Congress.

# Finite Size Effects in Electrical Transport in Nanowires

*Dr. Alec. A. Talin*
*Sandia National Laboratory*

Nanowires continue to fascinate researchers, who are often motivated by the combination of high crystalline quality and nanoscale dimensions not easily accessible by 'top-down' lithographic means. The 'size-effect' frequently sited in nanowire literature is that of quantum confinement, i.e., where the density of states assumes a 1-dimensional character. These dimensions, typically <20 nm in diameter, are, in fact, seldom fabricated in practice. In my talk, I will discuss how finite dimensions, far from the quantum confinement limit, affect bulk and contact mediated transport in nanowires. Specifically, I will show that the onset of space charge limited conduction in nanowires occurs at a lower critical voltage, and has a different geometric scaling as compared to low aspect ratio specimens (i.e. thin films). I will also discuss recent measurement where we have probed the transport characteristics of the metal catalyst/ nanowire contact in the Au /Ge-nanowire system, demonstrating the presence of a Schottky barrier at the interface. Surprisingly, we find that the small bias conductance increases with decreasing diameter. Theoretical calculations suggest that this effect arises because electron-hole recombination in the depletion region is the dominant charge transport mechanism, with a diameter dependence of both the depletion width and the electron-hole recombination time.

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000*

References:

[1] F. Leonard and A. A. Talin, Size-dependent effects on electrical contacts to nanotubes and nanowires, Phys. Rev. Lett. 97, 026804 (2006).
[2] A. A. Talin, F Leonard, B. S. Swartzentruber , X.Wang, S. D. Hersee, Unusually strong space-charge-limited currents in thin wires, Phys. Rev. Lett., 101, 076802 (2008)

**Dr. Alec Talin** received his Ph.D. in Materials Science at UCLA under professor Stan Williams in 1995 working on ballistic electron transport at metal/semiconductor contacts. In 1996 he joined Motorola Corporate Labs in Phoenix, AZ, where he developed flat panel display technology, thin film growth, and managed the materials characterization laboratory. Since 2002 he has been a principal member of technical staff at Sandia/ Livermore and member of the Center for Integrated Nanotechnologies in Albuquerque/NM. Dr. Talin has co-authored over 70 refereed publications and has been awarded 21 US patents on subjects that include display technology, heteroepitaxy, nanoelectronics, and advanced lithography.



# Thermally Enhanced Substrates Using Thin Film Diamond

*Mr. Jerry. W. Zimmer*
*sp$^3$ Diamond Technologies*

As Moore's law pushes silicon scaling to its limits, silicon is beginning to confront several issues that require innovative materials solutions to increase transistor and interconnect speeds while dealing with the increasing thermal loads of advanced microprocessors. The unsurpassed thermal and mechanical properties of diamond can be used to solve some of the thermal issues and enhance the performance characteristics of silicon based circuits as well as the emerging market of GaN on silicon. This paper focuses on the integration of diamond with SOI technology for the manufacture of silicon on diamond (SOD) wafers which can be used either for silicon devices or as templates for GaN epi growth. The primary use for this technology is for thermal control but other niche markets may exist where the mechanical characteristics of diamond can also benefit MEMS devices made on SOI type substrates.

**Mr. Zimmer** is Chief Technical Officer and co-founder of sp$^3$. He currently directs all process, product and equipment development activities at sp$^3$ and was the primary architect of their hot filament diamond equipment and deposition technology. He has more than 20 years of semiconductor processing experience and 18 years of diamond deposition experience. He is the author or co-author of fifteen patents and has authored or co-authored more than a dozen papers on diamond technology, automation technology and semiconductor thin film deposition processes among other topics.

## Condensed Matter Physics, and Comments on Einstein, Nanoscience, and Superconductivity

*Prof. Marvin Cohen*
*University of California, Berkeley*

I'll discuss some of the history and conceptual underpinnings of condensed matter physics with emphasis on the last fifty years. During the World Year of Physics in 2005, I served as President of the American Physical Society, and we celebrated the centennial anniversary of Einstein's great accomplishments. I will describe a few of the activities in 2005 and how they were related to Einstein. Finally, I'll focus on some recent work in nanoscience and superconductivity that my colleagues and I have been doing.

**Dr. Cohen** is University Professor of Physics at the University of California at Berkeley and Senior Faculty Scientist at the Lawrence Berkeley National Laboratory. Cohen's current and past research covers a broad spectrum of subjects in theoretical condensed matter physics. He is a recipient of the National Medal of Science, the APS Oliver E. Buckley Prize for Solid State Physics, the APS Julius Edgar Lilienfeld Prize, the Foresight Institute Richard P. Feynman Prize in Nanotechnology, and the Technology Pioneer Award from the World Economic Forum along with other honors and a Doctorat Honoris Causa, University of Montreal. Cohen has contributed more than 730 technical publications. He is a Fellow of the American Physical Society, a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the American Philosophical Society, and a Fellow of the American Association for the Advancement of Science. In 2005, Cohen was President of the American Physical Society (APS), an organization representing more than 47,000 physicists in universities, industry and national laboratories.



## Resolving Sub-nm Steps with a Low-voltage Miniature Scanning Electron Microscope

*Dr. Lawrence Murray*
*Novelx Inc.*

Miniature scanning electron beam columns based on silicon microfabricated components and Schottky field-emission sources have been recently developed and deployed in commercial field emission scanning electron microscopes (FESEM). A second generation column, optimized for low-voltage imaging, was used to image defects in 6H-SiC using topographic mode. By comparing specific regions with AFM, steps of ~0.8nm could be identified. The images obtained with this technique are consistent with electron channeling contrast imaging (ECCI) but at significantly lower voltage, from 500eV to 1.2keV. The geometry of the detector, the collection angle, the beam convergence angle, and the source characteristics are consistent with optimum conditions for normal incidence ECCI.

**Dr. Muray** has an MS and Ph.D. from Cornell University in Applied Physics and BS from California Institute of Technology in Applied Physics. Dr. Muray has been working on advanced electron beam lithography and electron beam tools since the early '90s starting at IBM Research; first developing disruptive technology and later managing system integration and test groups. He has a strong background in design and simulation of miniature optical and electron optical MEMS devices, as well as reliability and failure analysis. Dr. Muray has published over 30 papers and holds 13 patents and patents pending relating specifically to MEMS devices and electron beam columns.