UNIVERSITY OF CALIFORNIA, LOS ANGELES
Henry Samueli School of Engineering and Applied Science

UCLA Department of Materials Science and Engineering Newsletter

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Special Points of Interest:

- Prof. King-Ning Tu is stepping down as Chairman on July1, 2004. He will be succeeded by Prof. Mark S. Goorsky
- Our graduate program moved from unranked to 23rd in the nation
- On March 12, the Department held its annual External Advisory Board meeting
- The Department added one new faculty member
- UCLA will be the site for the 13th International Workshop on Sol-Gel Science and Technology, to be held August 21 – 26, 2005. The Chairs for the meeting include Profs. Dunn, Mackenzie and Bescher

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Chair's Message - Challenges in Materials Education

Chair, Prof. King-Ning Tu

I am delighted to report to you that in the last six months, the Department has had several exciting events.

We have taken on a new faculty member, Dr. Qibing Pei, who will be joining us from the Stanford Research Institute in July. He is a renowned scientist working on electromechanical properties of polymers and artificial muscles. Please read the special story on him in this Newsletter.

On March 22, the Department hosted an Open House to welcome potential freshman students we have already admitted. Prof. Mark Goorsky supervised the event, with the help of many fervent alumni, students and several faculty members. It was a very successful event and we expect a good sized freshman class in the fall.

On March 12, the Department held its annual External Advisory Board meeting. Twelve Board members attended. A group picture and brief introduction of these members are presented in this Newsletter. While the agenda was very tight, several of our joint appointment faculty made presentations about their research accomplishments and their interactions with the Department. At lunch time, 16 students' research posters were displayed and our students had the opportunity of talking with the Board members. In the feedback session, the Board commented on the importance of exposing our students' success stories to the outside world.

In this Newsletter, we have added a section to report the honors, accomplishments, and activities of our students. For a special mention, a group of Prof. Bruce Dunn's students joined the UCLA March Science Extravaganza, teaching and promoting materials science and engineering to the local community. Please read the exciting story about the event.

In the latest *U.S. News and World Report* Graduate Program Rankings for 2005, our Department was ranked No. 23 among all Dept. of MSE in the country. We were unranked a year ago. With momentum, we should be able to make it within the top 20 shortly. It is within our striking distance and I am confident we can achieve this objective.

I would like to announce that I shall step down as Chair and Prof. Mark S. Goorsky will be the new Chair of our Department on July 1st, this year. I would like to thank all of our faculty, staff and students for your kind support and I urge you to give our new Chair the same support as you have given me. No doubt, under the new leadership the Department will excel in teaching, research and service.

Finally, I would like to share with you a thought on Materials education. Our quality of life depends on many things, among which a crucial one is the application of materials to improve our lives. Successful materials must have real utility. We have come a long way from the stone-age to the silicon-age (or information-age), in a relatively short amount of time, and have potentially entered the "nano-age." At this moment, after the turn of the millennium, we must reflect on our role in the education of materials science and engineering. Why? Nano materials are the hot topics of research now. There are many opportunities, but also many challenges. Nano science and technology have brought together chemists, life scientists, mathematicians, physicists and all walks of engineers into collaborative work. There is no doubt that together they can do what we are doing. This is the new challenge, we must not lose our identity and allow our core values to be diluted. On the other hand, we must regard this as a good opportunity for us too. We will have very close interactions with scientists and engineers of other disciplines in the field of nano materials. With our ongoing excellence, our contributions will be recognized. We cannot be static. We need to educate our students for the new opportunities and give them a broader field of learning in other disciplines in order to achieve more in the field of materials science and engineering.

Have a nice summer! King-Ning Tu

Research Review

Prof. Mark S. Goorsky

The research programs in my group focus on the relationship between defects in solid state electronic materials and their effect on the performance of devices fabricated from these materials. The 10 graduate students and four undergraduate students in my current research group study materials ranging from AlGaAs to ZnCdTe. Much of our research includes collaboration with industrial and government laboratories; these collaborations provide a synergistic environment to study advanced electronic materials. In particular, we use X-ray scattering techniques, including diffraction imaging (topography) and reciprocal space mapping in all of our research programs. Transmission electron microscopy and atomic force microscopy are also widely used.

One area of particular interest is wafer bonding. This effort stemmed from research on defects in III-V materials funded by the NSF through the CAREER Program. Wafer bonding is well known for certain types of semiconductor applications and it provides a novel way to integrate materials. Both silicon-on-insulator (SOI) structures and post-epitaxy device processing of III-V structures, for example, employ wafer bonding. One of our main interests is with composite III-V substrates, which include a high resistivity bulk component and a large lattice parameter template layer for subsequent epitaxial deposition. This kind of application has not been developed; we address the present weak understanding of the strain state for many III-V composite structures in terms of the wafer bonding and processing conditions. An example of a composite substrate is an InP layer transferred to a GaAs substrate with intermediate silicon nitride layers for bonding. Our effort is funded through Northrop Grumman. Other examples of our research into "alternative substrates" include InAs template layers on InP substrates, templates for GaN epitaxy and CdZnTe layers on silicon substrates. We have also developed III-V virtual substrates for low power, high speed applications. These technologies depend on plasma processing, ion implantation and chemical-mechanical polishing. In addition to the Nanoelectronics Facility in the UCLA Henry Samueli School of Engineering and Applied Science, my research group runs and operates a 250 sq. ft. class 10 / 100 clean room dedicated to wafer bonding and composite substrate formation. Our success in dealing with defect issues in these materials has led to many recognitions, the most noteworthy of which involve recent awards for my students, including Dr. Petra Feichtinger, who won the "Norman Hackworth Young Author Award" from the Electrochemical Society, and Mr. Calin Miclaus, who won the "Best Student Presentation" award at the US Workshop on the Physics and Chemistry of II-VI Materials.

New Faculty Profile

Electroelastomer roll actuators function as the muscles for an artificial arm

After 10 years of R&D with diverse commercial and contract organizations, Professor Qibing Pei is establishing a soft materials laboratory at UCLA to study electronic polymers and related materials and devices. His laboratory will focus on molecular design and nano-scale engineering for the development of new polymers and nano-structures with desired electronic and/or mechanical properties. The applications of these materials are many, including organic displays, flexible electronics, artificial muscles, and biologically-inspired systems, to name a few. For instance, conducting polymers undergo a small volume change when they are electrochemically or chemically oxidized, converting a portion of the input energy into mechanical work. Such energy transduction is attractive for constructing meso, micro and even nanometer-size electromechanical devices. On the other hand, electroelastomers based on soft dielectric rubbery films exhibit electrically-induced strains as high as 400%. A number of actuators such as roll actuators (shown in the figure) have been fabricated to replace electric motors and gears. The advantages that the soft actuators provide are quiet operation compliance (thus shock resistant), high efficiency (compared to motors at small sizes), light weight and low cost. The performance of the electroelastomers is comparable to natural muscles. One particularly attractive application is as the muscles in prosthetic, orthotic and other biomimetic devices. Walking robots using a roll actuator as each of the robots' 6 legs were demonstrated to mimic cockroach and dog locomotion. A series of rolls were linked together head to tail, each bowing by as much as 90 degrees, to produce an artificial snake. Obviously, there are numerous other exciting possibilities with electroelastomers. Our laboratory focuses on the materials and actuator aspects of the whole story.

UCLA MSE in the Community

Are you surprised to learn that many Southern California middle and high school students have to share school books? Did you know that their test scores are below the national average, and that classrooms sometimes hold more than 35 students?

There are many unfortunate situations in our school districts in Southern California. This is the driving force behind academic outreach. As part of the outreach effort, the Society of Mexican American Engineers and Scientists (MAES) promotes science and engineering with its Science Extravaganza[SM] event, which is a part of their nation-wide outreach effort. The Science Extravaganza[SM] (SE) is a full-day, hands-on experience for middle school students with the purpose of exposing, encouraging and attracting them to science and engineering fields. The SE is held in many cities throughout the country. Students rotate through several fun-filled demonstrations that introduce them to biology, robotics, chemistry, physics, computer science, materials science, astronomy, mathematics and the many engineering fields. This year, the 4th annual Southern California SE was held in March at California State University, Long Beach.

The presence of UCLA MSE at this year's SE was invaluable. Four of our graduate students were presenters: Paul

Tang showed the concept of phase changes in materials (in the picture Paul and Lorenzo Guidolin are making ice cream as the children watch intently), Jimmy Lim demonstrated design and use of new energy sources in "thermo-electrics," Lorenzo made glass in his "sol-gel" demonstration, and Norma Sosa Cortes presented "It's Super Cool, it's Superconductivity!" Jing Zhou and Dr. Tanya Faltens also contributed greatly to the event.

For many of the 300 students at the SE, it was the first time they heard about materials science or alternative power sources—every 30-minute demonstration was a new door opening to them. There was excitement coming from the kids and our UCLA MSE team. "Outreach programs have always taught me more than what I try to teach. The Science Extravaganza was one of the best outreach experiences that I ever had," said Jimmy Lim about his day at SE. Everyone had a great time.

While there are many issues to resolve in our school system, each of us can make a contribution. The contributions from scientists and engineers are ever so important to the future of technology and society. This event is a prime example of how we can help. Ultimately, the UCLA MSE team was able to communicate the importance of learning, critical thinking and higher education to what we hope will be the next generation of scientists.

Advisory Board Meeting

From left to right: Chairman Fred F. Lange, Materials Dept., University of California, Santa Barbara; Mr. Terry Morris, Manager, Materials & Process Group, Honeywell Aerospace (Replacement for Dr. Dave Kotchick, Director, Shared Engineering, Honeywell); Dr. Daoqiang Lu, Sr Packaging Engineer, Components Research, Intel (Replacement for Dr. Gilroy Vandentop, Program Manager, Packaging Research, Intel); Professor William D. Nix, Dept of Materials Science and Engineering, Stanford University; Dr. Mike James, Executive Director, Rockwell Scientific; Dr. Darrel Frear, Program Manager, Green Technology, Motorola; Dr. Dwight Streit (Vice Chairman), Vice President, Space Technology, Northrop Grumman; Dr. John A. Halchak, Director, Materials Applications, Rocketdyne Propulsion and Power, The Boeing Company; Dr. Charles G. Wade, Manager, Materials Analysis and Characterization, IBM Almaden Research Center; Dr. Wei H. Kao, Director, Materials Science Dept., The Aerospace Corporation; Dr. Ed Rice (Chairman), Chairman, CTS Cement; Dr. Leslie Momoda, Director, Sensors and Materials Laboratory, Hughes Research Labs.

Open House for Potential Freshman Students

The UCLA Henry Samueli School of Engineering and Applied Science held the annual Open House for prospective first year students on Sunday, March 28th. A general session with all of the students in the School was followed by department sessions. Twenty-five high school senior students and their families attended the MSE Open House. A buffet lunch included discussions among high school students, parents, UCLA MSE graduate and undergraduate students (17 hardworking students!), several department faculty and even alumni. Next, undergraduate Vice Chair Mark Goorsky described many of the department's assets and answered questions from the students and parents. This was followed by a tour of the laboratories in the Department. The effort and time put in by all was well worth it: at the time of this writing, eleven of the 25 students at the Open House have decided to join us this year and a total of 18 new first year students (with a few more likely) will join us next fall. Because of our recent recruiting efforts, the undergraduate population has risen significantly and the Department is now home to about 105 undergraduate students.

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Highlights of Students' Achievements

• Student Presentations on 7th International Symposium on Aerogels, Alexandria, VA Nov. 2003:
- Synthesis and Properties of Conductive Mesoporous Thin Films—**Lorenzo Guidolin**, (Co-Authors: P. Sierocki, C. Sassoye, J.I. Zink, B. Dunn)
- Insertion of Multivalent Ions into Vanadium Pentoxide Ambigels—**Paul E. Tang**, (Co-Authors: B. Dunn)

• **Albert Wu** spent six months (July 2003 to January 2004) at Intel, Santa Clara, CA as an intern to work on electromigration.

• **Rajat Agarwal** is spending six months (March to September 2004) at Intel, Santa Clara, CA to work on electromigration.

• **Emily Ou** presented a talk on "Precision optical packaging of fiber array in V-grooved chips joined by Pb-free solder" at the 2004 TMS Annual Meeting at Charlotte, NC, March 16. She also presented the talk in our Departmental Seminar on April 9.

• **Joanne Huang** (one of our undergraduate students) received a two-year scholarship from Semiconductor Research Corporation (SRC) sponsored by National Semiconductor Corporation (NSC) to pursue M. Sc. degree in our Department. Her thesis will be on interconnects. She will spend the coming summer as an intern at NSC, Santa Clara, CA.

• **Jiaxing Huang** earned a prestigious Miller Postdoctoral Fellowship to carry out research at UC Berkeley. Huang is also a finalist for the 2004 ICI Student Award in Applied Polymer Science and will give an award presentation on his research at the next National Meeting of the American Chemical Society in Philadelphia in August. Huang earned a silver medal last spring from the Materials Research Society.

• **S.H. Lee** presented a paper on "Morphological evolution of III-V semiconductor and SiO_2 during Low Energy Electron Enhanced Etching (LE4)," at the American Vacuum Society National Symposium, Baltimore MD, November 2003.

Recent Publications

• J.Z. Zhu, T. Wang, A.J. Ardell, Z.K. Liu and L.Q. Chen, "Phase-field Modelling of Microstructural Evolution in Ni-Al Binary Alloys," *Acta Materialia* 52 (2004) 2837-2845.

• Y. Ma, J. Joshi and A.J. Ardell, "Coarsening of γ (Ni-Al Solid Solution) Precipitates in a γ' γ(Ni_3Al) Matrix: Preliminary Results," *Materials Science Forum* 442 (2003), Eds. H.A. Calderon and J.J. Cabañas-Moreno, Trans Tech Publications, Switzerland, 1-6.

• J.C. Zhou, M.H. Chuang, E.H. Lan, B. Dunn, P.L. Gillman and S.M. Smith, "Immunoassays for Cortisol using Antibody-Doped Sol-Gel Silica," *J. Mater. Chem.* 14 (2004), (Advance Article) DOI: 10.1039/b401902d.

• R. Yokokawa, J.-A. Paik, B. Dunn, N. Kitazawa, H. Kotera and C.-J. Kim, "Mechanical properties of aerogel-like thin films used for MEMS," *J. Micromech. Microeng.* 14 (2004) 681.

• J.J. Gilman, "Direct Evidence of Chemical Reactions Induced by Shear-Strain," *Mat. Res. Symp. Proc.* 800 (2004) 287-297.

• S. Hayashi, D. Bruno, R. Sandhu and M.S. Goorsky, "Wafer bonding for III-V on insulator structures," *IEEE Journal of Electronic Materials* 32 (2003) 877-881.

• S. Hayashi, B. Poust, B. Heying and M. Goorsky, "Exfoliation of GaN layers using hydrogen implantation," (Conference Paper) 2003 International Symposium on Compound Semiconductors, Piscataway, NJ (Cat. No.03TH8675), 106-107.

• S.H. Lee, R.M. Ho, M.S. Goorsky, H.P. Gillis, D.I. Margolese, M.A. Demine and S.J. Anz, "Morphological evolution of III-V semiconductor and SiO_2 during Low Energy Electron Enhanced Etching (LE4)," *J. Vac. Sci. Technol. A* (In Press, July 2004).

• J. Huang, S. Virji, B.H. Weiller, R.B.S. Virji, R.B. Kaner and B.H. Weiller, "Polyaniline Nanofibers as Gas Sensors: Response to Classes of Vapors and Comparison to Thin Films," *Nano Letters* 4 (2004) 591.

• J. Huang and R.B. Kaner, "A General Chemical Route to Polyaniline Nanofibers," *J. Am. Chem. Soc.* *126* (2004) 851.

• K.N. Tu, A.M. Gusak and M. Li, "Physics and materials challenges for Pb-free solders," *J. Appl. Phys.* 93 (2003) 1335-1553. (Invited Applied Physics Review).

• W.J. Choi, T.Y. Lee, K.N. Tu, N. Tamura, R.S. Celestre, A.A. MacDowell, Y.Y. Bong and L. Nguyen, "Tin whiskers studied by synchrotron radiation micro-diffraction," *Acta Mat*, 51 (2003) 6253-6261.

• Y.F. Chou, W.A. Chiou, Y. Xu, J.C.Y. Dunn and B.M.Wu, "The Effect of pH on Structural Evolution of Accelerated Biomimetic Apatite Formation," *Biomaterials* 25 (2004) 5323-5331.

• Y.F. Chou, W. Huang, J.C.Y. Dunn, T. Miller and B.M. Wu, "The Effect of Biomimetic Apatite Structure on Osteoblast Viability, Proliferation, and Gene Expression," *Biomaterial*, (In Press, Available Online).

• C.M. Cowan, S. Shi, O.O. Alami, Y.F. Chou, R. Thomas, C. Marie, N. Quarto, B.M. Wu and M.T. Longaker, "Adipose-derived Mesenchymal Stromal Cells Tissue Engineer Bone in Critical Sized Mouse Calvarial Defects," *Nature Biotechnology* (In Press, Available Online).

• H.J. Kim, Z.M. Zhao, J. Liu, V. Ozolins and Y.H. Xie, "A novel technique for the measurement of surface diffusion coefficient and activation energy of Ge adatom on Si (001)," *J. Appl. Phys.* 95 (2004) 6065.

• K. Lai, W. Pan, D.C. Tsui and Y.H. Xie, "Observation of the apparent metal-insulator transition of high-mobility two-dimensional electron system in a Si/SiGe heterostructure," *Appl. Phys. Lett.* 84(2) (2004), 302.

• J. Wu, L. Ma and Y. Yang, "Single-band Hubbard model for transport properties in bistable organic/metallic nanoparticle/organic devices," *Physical Review B* 69 (2004) 115321.

• Y. Shi, J. Liu and Y. Yang, "Polymer Morphology and Device Performance in Polymer Electronic Devices," Book Chapter in "Organic Electroluminescent Devices: A survey," Editor: J. Shinar, Spring-Verlag, (October 2003) 155-185.