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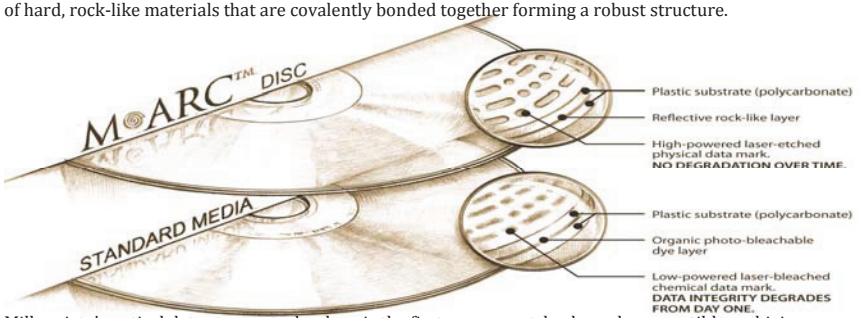


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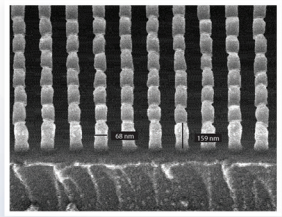

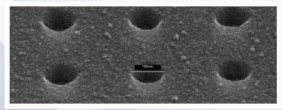

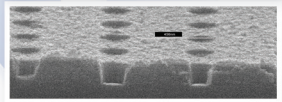

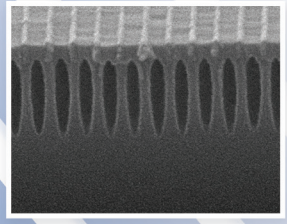

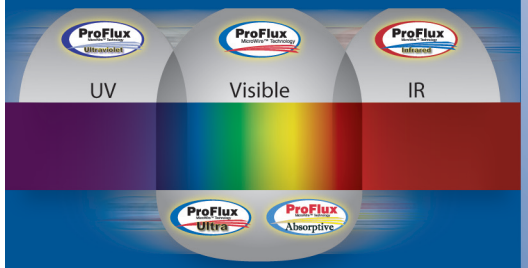


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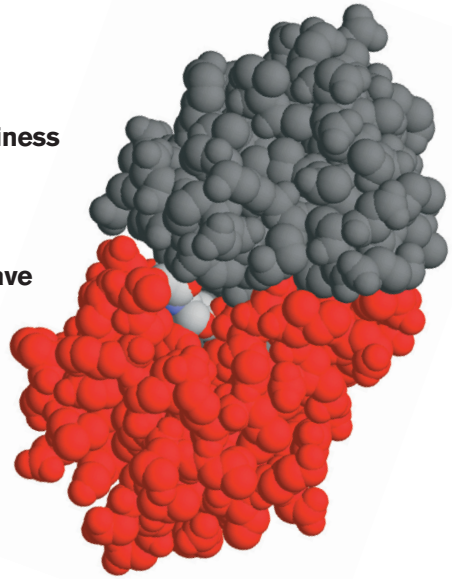

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# Welcome from the Conference Organizers

Welcome to Utah's fifth nanotechnology conference, the first of which was held in 2003 to enable conference attendees to share in the latest research and development in nanotechnology among academic, industrial, and government sectors in the state of Utah. This year's conference highlights key advances in nanobiotechnology, nanoparticles, nanomaterials and characterization, devices and sensors, nanomedicine, and energy. Keynote and other invited speakers are distinguished colleagues from industry, academia, and government agencies who will present overviews of advances in all fields of nanotechnology. Over eighty oral and poster presentations from across the state will provide an opportunity to foster pivotal interactions in these highly dynamic emerging fields of science.

We are proud to partner with the Nano Institute of Utah for this year's nanoUtah Conference. The Nano Institute of Utah, supported in part by the Utah Science Technology and Research (USTAR) initiative, was established to enable Utah researchers from disciplines such as chemistry, physics, biology, engineering, medicine, and pharmacy to create synergistic alliances driving higher levels of collaborative research, education and commercialization. The Nano Institute of Utah strives to position Utah as a global leader in nanoscience and technology distinguished by interdisciplinary collaboration and entrepreneurial excellence.

We are especially pleased that nanoUtah 2009 is being held at the beautiful Salt Lake City Marriott City Center, which will provide easy access to the conference venue while allowing conference attendees to freely interact with other nanoscience, nanoengineering and biomedical researchers and clinicians, while also permitting folks to continue their discussions in a relaxed setting after the formal portions of the program conclude.

We are particularly grateful for the generous support of the sponsors and for the hard work of our dedicated staff, without whom this conference would not have been possible. We hope you enjoy the conference.

With best wishes,

The nanoUtah 2009 Organizing Committee

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# THURSDAY – OCTOBER 15, 2009

## The Marriott City Center – Capital Ballroom

3:00 p.m. Open Registration:
Poster & Exhibition setup

4:00 p.m. **Welcome:**
Lorris Betz
Office of Health Sciences, University of Utah

David W. Pershing
Office of Academic Affairs, University of Utah

John L. Valentine
Utah State Senate

4:30 p.m. **Keynote Speakers:**
*"Nanoscale based emerging science and technology"*
Mihail C. Roco
National Science Foundation and
National Nanotechnology Initiative

*"Building Functional Electronic Devices from Molecular Components"*
Richard L. McCreery
Department of Chemistry, University of Alberta and
National Institute for Nanotechnology

6:00 p.m. Dinner Reception:
Student Poster & Exhibition

# FRIDAY - OCTOBER 16, 2009

## The Marriott City Center – Capital Ballroom

7:30 a.m. Open Registration

8:00 a.m. **Opening Remarks:**
Thomas N. Parks
Office of Research, University of Utah

8:15 a.m. **Conference Speakers:**
*"Manipulating Interfacial Chemistry for Design of Highly Selective and Sensitive Total $NO_x$ Sensors"*
Prabir K. Dutta
Department of Chemistry, The Ohio State University

*"Designer DNA Architectures for Nanobiotechnology"*
*Hao Yan*
The Department of Chemistry and Biochemistry, and
The Biodesign Institute, Arizona State University

9:30 a.m. Break

9:40 a.m. **Parallel Sessions:**
Devices & Sensors - Capital Ballroom

"Patterning & Imaging Nanostructures with Light"
Rajesh Menon
University of Utah

15 minute Research Introductions (8)

Materials & Characterization - Olympus Ballroom

*"Nanoparticle Blood Substitutes"*
*Agnes Ostafin*
Department of Materials Science & Engineering,
University of Utah

15 minute Research Introductions (8)

12:15 p.m. Lunch:
Poster Session & Exhibition

1:00 p.m. **Conference Speakers:**
*"Multifunctional Pharmaceutical Nanocarriers: Promises and Problems"*
Vladimir Torchilin
Department of Pharmaceutical Sciences and Center for Pharmaceutical Biotechnology and Nanomedicine, Northeastern University

*"Structure Control in Carbon Nanotube Synthesis and Applications"*
Lisa Pfefferle
Yale University

2:15 p.m. Break

2:25 p.m. **Parallel Sessions:**
nanoMedicine - Capital Ballroom

*"Nanotechnology in Biomedical Innovation"*
David Grainger
Departments of Pharmaceutics and Pharmaceutical Chemistry, and Bioengineering, University of Utah

15 minute Research Introductions (8)

Energy, Catalysis, & Environment - Olympus Ballroom

*"Theory and Simulation of Charge Transport in Energy Capture, Conversion, and Storage"*
Jessica Swanson
Center for Biophysical Modeling and Simulation, University of Utah

15 minute Research Introductions

5:00 p.m. Student Poster Awards & Closing Remarks

# Session Presentations- At a Glance

| | |
|---|---|
| T=Talk | Check schedule for location of each session |
| P= Poster | Poster displays will be in the Capital Ballroom |

**Devices & Sensors- Capital Ballroom**

9:40 AM (DS-T1) **Rajesh Menon**, U of U, *"Patterning & Imaging Nanostructures with Light"*

10:10 AM (DS-T2-P9) **Robert C. Davis**, BYU, *"Nano Infiltration Fabrication (NIF) of Carbon Nanotube Microstructures"*

10:25 AM (DS-T3) **Matthew R. Linford**, BYU, *"Progress Towards DNA-Based Nanocircuits"*

10:40 AM (DS-T4-P10) **Bruce K. Gale**, U of U, *"A Fully Integrated Nucleic Acid Identification System for Bacteria Monitoring"*

10:55 AM (DS-T5) **Genyao Lin**, U of U, *"Novel Miniaturized Piezoresistive Glucose Sensors Based On Osmotic Swelling Pressure Response of Smart Hydrogels"*

11:10 AM (DS-T6-P11) **Nitesh Madaan**, BYU, *"Chemically Stable High-Resolution Surface Patterning by Thiolated DNA for Self-Assembly of Nanocircuits"*

11:25 AM (DS-T7) **Sang H. Yoon**, U of U, *"Nano Deposition and Etching Using Electric-Field Assisted Atomic Force Probe Directed Chemical Vapour Deposition"*

11:40 AM (DS-T8) **Jung Hoon Yang**, U of U, *"Ultrafast, Small Footprint, Low Voltage Nano-Electro-Mechanical Switches For VLSI Power Management and Harsh-Environment Processors"*

11:55 AM (DS-T9) **Arun Tejusve**, U of U, *"Very Sensitive Electric-Field Sensors Using Nano-Scale J-FETs"*

**Materials & Characterization- Olympus Ballroom**

9:40 AM (MC-T10) **Agnes E. Ostafin**, U of U, *"Nanoparticle Blood Substitutes"*

10:10 AM (MC-T11) **Michael H. Bartl**, U of U, *"Low-Temperature Synthesis of High-Quality Colloidal Semiconductor Nanocrystals"*

10:25 AM (MC-T12-P24) **Jon Paul Johnson**, U of U, *"Electronic trap states in dielectric films imaged by Dynamic Tunneling Force Microscopy and characterized by Single Electron Tunneling Force Spectroscopy"*

10:40 AM (MC-T13-P25) **Shan Lu**, U of U, *"Modulation of Polyaromatic Hydrocarbon Toxicity by Carbon Nanomaterials Assess the Rescue Effects by Nano-Carbon Materials on Phenanthrene Toxicity in Solution"*

10:55 AM (MC-T14-P26) **Landon Wiest**, BYU, *"Use of Nanodiamond for Creating Core-shell Diamond Particles for Use in SPE and HPLC"*

11:10 AM (MC-T15-P27) **Aleksander Skardal**, U of U, *"Reversibly Crosslinked Gold Nanoparticle - Hyaluronan Hydrogels for Vessel Construct Bioprinting"*

11:25 AM (MC-T16-P28) **Clinton F. Jones**, U of U, *"Utilizing Zebrafish to Elucidate in vivo Nanomaterial Trafficking"*

11:40 AM (MC-T17-P29) **William Niedermeyer**, NLC Laboratories, "*Stable Biocidal Nanospheres in Common and Adverse Condition Environments"*

11:55 AM (MC-T18-P30) **Vishal Gupta**, U of U, *"Anisotropic Surface Chemistry Features of Kaolinite Particles as Revealed by AFM Surface Force Measurements"*

**nanoMedicine- Capital Ballroom**

2:25 PM (NM-T19) **David W. Grainger**, U of U, "Nanotechnology in Biomedical Innovation"

2:55 PM (NM-T20-P38) **Alexander Malugin**, U of U, *"Cellular Uptake and Toxicity of Silica Nanoparticles in Epithelial and Phagocytic Cells"*

3:10 PM (NM-T21-P39) **Cassandra Deering-Rice**, U of U, *"Human Endothelial Cells Display Inflammatory Markers to Cache Valley Particulate Pollution"*

3:25 PM (NM-T22-P40) **Giridhar Thiagarajan**, U of U, *"PAMAM-Camptothecin Conjugate Inhibits Proliferation and Induces Apoptosis in Colorectal Carcinoma Cells"*

3:40 PM (NM-T23-P41) **Hemang Patel**, USU, *"Effect of MWCNT exposure on cellular toxicity in dynamic airway epithelial cell culture models"*

3:55 PM (NM-T24-P42) **Rena Baktur**, USU, *"Effects of Exposure Time, Size, Concentration of Nano-structured Particles on Cellular Toxicity in the Lung"*

4:10 PM (NM-T25-P43) **Natalya Rapoport**, U of U, *"Multifunctional Nanoparticles for Ultrasound Tumor Imaging and Targeted Chemotherapy"*

4:25 PM (NM-T26-P44) **Yufeng Huang**, U of U, *"Anti-thy-1-nanoparticles for Renal Mesangial Cell-targeted Delivery of siRNA Therapeutics"*

4:40 PM (NM-T27-P45) **Vijayalakshmi Nirmalkumar**, U of U, *"PAMAM Dendrimer–SN38 Conjugates: Synthesis, Characterization and In Vitro Evaluation"*

**Energy, Catalysis, & Environment- Olympus Ballroom**

2:25 PM (EC-T28) **Jessica M. J. Swanson**, U of U, *"Theory and Simulation of Charge Transport in Energy Capture, Conversion, and Storage"*

2:55 PM (EC-T29-P48) **Jesus Paulo L. Perez**, U of U, *"Synthesis of Air-stable, Unoxidized, Hydrocarbon Dispersible Boron Nanoparticles Using Ball Milling Method"*

3:10 PM (EC-T30-P49) **Elizabeth Lund**, U of U, *"Plasmonic Nanorod Enhanced Thin Film Si Solar Cells"*

3:25 PM (EC-T31-P50) **James R. Nagel**, U of U, *"Simulated Performance of Plasmon-Enhanced Thin-Film Silicon Solar Cells"*

3:40 PM (EC-T32) **Richard K. Watt**, BYU, *"Ferritin As A Photocatalyst in an Artificial Photosynthesis System"*

3:55 PM (EC-T33-P51) **Jeremy D. Bergeson**, National Renewable Energy Laboratory, *"Single-Walled Carbon Nanotube Transparent Electrodes"*

4:10 PM (EC-T34-P52) **Nathan Bair**, BYU, *"Bifunctional Thiophene Molecules Coordinated to Ruthenium and Bound to CdSe Nanoparticles"*

4:25 PM (EC-T35-P53) **William A. Kunkel**, U of U, *"Pd Electronic Structure Controls Reactivity of Size-selected $Pd_n/TiO_2$ Catalysts"*

4:40 PM (EC-T36-P54) **Christian Dimkpa**, USU, *"Metallic Nanoparticle Interactions with Environmentally Beneficial Pseudomonads"*

# Welcome / Opening Remarks

**A. Lorris Betz**

Dr. Betz received his B.S. degree in Chemistry in 1969 from the University of Wisconsin. He entered the Medical Scientist Training Program at the University of Wisconsin and was awarded M.D. and Ph.D. (biochemistry and physiology) degrees in 1975. Dr. Betz spent the next four years at the University of California, San Francisco, completing his pediatric residency and a research fellowship in pediatric neurology. In 1979, he joined the faculty at the University of Michigan as an Assistant Professor in the Departments of Pediatrics and Neurology. Other administrative appointments at the University of Michigan included Associate Dean for Faculty Affairs, Senior Associate Dean for Academic Affairs, Executive Associate Dean, and Interim Dean.

In June of 1999, Dr. Betz was named Senior Vice President for Health Sciences, Dean of the School of Medicine, and Chief Executive Officer of the University of Utah Health System at the University of Utah. He holds faculty appointments in the Department of Pediatrics (Professor with tenure) and the Department of Neurobiology and Anatomy (Adjunct Professor). In January of 2004, Dr. Betz was named Interim President of the University of Utah and served until August 1, 2004.

Dr. Betz's research focus has been on solute transport across the blood-brain barrier, brain ion homeostasis, and the biochemical mechanisms which lead to brain injury and edema formation in stroke and intracerebral hemorrhage. He has published over 150 scientific papers and chapters and has presented his work at numerous international symposia. Dr. Betz's research has been supported by grants from the National Institutes of Health and he has been an Established Investigator of the American Heart Association. He has served on the Board of Directors and as Secretary for the International Society of Cerebral Blood Flow and Metabolism. He has chaired the Utah Medical Education Council, served on the Board and Executive Committee of the Utah Hospitals and Health Systems Association, and is a member of the American Association of Medical Colleges Executive Council and the Council of Deans Administrative Board.

### Thomas N. Parks

A native of Fullerton, California, Dr. Thomas N. Parks earned an undergraduate degree in biology at the University of California, Irvine, followed by a Ph.D. in psychobiology at Yale University and postdoctoral work at the University of Virginia. He joined the University of Utah faculty in 1978.

During 1985-1993, Dr. Parks directed an interdepartmental Ph.D. program in neuroscience. He chaired the Department of Neurobiology and Anatomy in the School of Medicine during 1992-2007, and has served as executive director of the Brain Institute since 2004.

In 1986, he co-founded NPS Pharmaceuticals and served on its board until 2006. He also took primary responsibility for recruiting three of the professors hired for USTAR.

Since June of 2008, Dr. Parks has served as the Vice President for Research at the University of Utah.

### David W. Pershing

Distinguished Professor David W. Pershing, Senior Vice President for Academic Affairs, earned his B.S. degree in Chemical Engineering from Purdue University in 1970 and his Ph.D. in the same field from the University of Arizona in 1976.

Dr. Pershing joined the University of Utah as an Assistant Professor in Chemical Engineering in 1977. He was named a Presidential Young Investigator by the National Science Foundation in 1984 and became Dean of the College of Engineering in 1987. He has had a brilliant career in academia, government, industry and consulting. He has more than 80 peer-reviewed publications, more than 20 research grants, and five patents to his credit.

Dr. Pershing has won both the Distinguished Teaching and Distinguished Research Awards and is the 1997 recipient of the Rosenblatt Prize for Excellence. He is the director of the U's Center for Simulation of Accidental Fires and Explosions, fueled by a $20 million grant from the U.S. Department of Energy.

## John L. Valentine

John L. Valentine is a member of the Utah State Senate, representing the state's 14th Senate district since 1998. Prior to being appointed to the Utah Senate, he served in the Utah House of Representatives from 1988. Valentine obtained a B.S. in Accounting and Economics from Brigham Young University (BYU) in 1973 and a J.D. from BYU's J. Reuben Clark School of Law in 1976. Upon graduating from Brigham Young University with a law degree, Valentine joined the law firm of Howard, Lewis & Petersen where he currently is employed as a managing partner. Valentine currently serves as the Chairman of Higher Education Appropriations and the Business Labor Standing Committee and is a member of the Revenue and Tax Standing Committee and Senate Ethics Committee. Valentine is also an Adjunct Professor of Law at Brigham Young University.

# Invited Speakers

### Prabir K. Dutta

Prabir K. Dutta received his Ph.D. in Chemistry from Princeton University. After a year of post-doctoral study at Princeton and four years of industrial research at Exxon Research and Engineering Company, he joined The Ohio State University, where currently he is the Robert K. Fox Professor of the Department of Chemistry. His research interests are in the area of microporous materials, including their synthesis, structural analysis, hosts for chemical and photochemical reactions and their toxicity. He is the principal author of more than 190 papers and his current research is supported by grants from NIOSH, DOE, NASA, NSF and DOD. His most recent edited books are Handbook of Zeolite Science and Technology and Handbook of Layered Materials, published by Marcel Dekker in 2003 and 2004. Dutta is also leading a NSF-supported Ohio-wide effort to alter the curriculum of undergraduates taking chemistry courses with the goal of increasing the number of Science and Engineering graduates in the State of Ohio.

### David W. Grainger

David W. Grainger is the George S. and Dolores Doré Eccles Presidential Endowed Chair in Pharmaceutics and Pharmaceutical Chemistry, Chair of the Department of Pharmaceutics and Pharmaceutical Chemistry, and Professor of Bioengineering at the University of Utah. He received his Ph.D. in Pharmaceutical Chemistry from the University of Utah in 1987, with Humboldt Fellow postdoctoral research under Prof. Helmut Ringsdorf, Germany. With over 25 years of experience with "materials in medicine", Grainger's research expertise is focused on polymer films for medical device modification, drug delivery of proteins and live vaccines, and diagnostic devices based on DNA capture.

Grainger has published over 114 full research papers at the interface of materials innovation in medicine and biotechnology. Current areas of active research include the implant foreign body response, diagnostic materials and bioassay designs, drug delivery of siRNA, proteins and live vaccines, and anti-microbial approaches to biomaterials. He has won research several awards, including the 2007 Clemson Award for Basic Research, Society for Biomaterials, and the 2005 APhRMA award for "Excellence in Pharmaceutics". He has also received several teaching awards for outstanding undergraduate teaching service. Grainger is an elected Fellow of both the American Association for the Advancement of Science (AAAS) and the American Institute of Medical and Biological Engineering (AIMBE).

Grainger has organized 21 international scientific symposia, presented over 120 invited symposia lectures, and serves on editorial boards for 4 major journals in the biomedical materials field, reviewing over 50 manuscripts annually. He is a standing member of Emerging Bioanalytical Technologies scientific review group (SRG) at NIH, past standing member on Surgery and Bioengineering SRG, and has served on over 20 other NIH and NSF review panels, some as chair. Additionally, he serves on the Scientific Advisory Boards of the Univ. Wisconsin-Madison NSF

MRSEC on High Performance Nanostructured Materials, the NIH P41 National Research Center at the University of Washington (NESAC/Bio) for surface analysis for biomedical problems, NSF Harvard/New Mexico NSF PREM MRSEC, several international research foundations (AO Foundation, Davos, Switzerland, Swiss Center for Materials Competence, Julius Wolfe Musculoskeletal Research Institute of the Berlin Charité Research Center, Germany, Waseda University ASMeW Research Center, Japan), 4 biomedical companies, and actively consults internationally with industries in applications of materials in biotechnologies and medicine.

### Rajesh Menon

Professor Menon has pioneered several technologies that will enable far-field optics to manipulate and image matter with nanoscale resolution, something that was thought impossible until a few years ago. His research has spawned over 40 publications, patents, and a spin-off company. He led several projects in nanopatterning and nanoscopy with support from DARPA, NSF and the MIT Deshpande Center for Technological Innovation.

Prior to joining the University of Utah in August 2009 as a USTAR faculty, Prof. Menon was a research engineer at MIT's Research Laboratory of Electronics. He graduated with S.M (2000) and Ph.D (2003) degrees from the Department of Electrical Engineering and Computer Science at MIT. In addition, he served as the Chief Technology Officer of LumArray, Inc., a company he co-founded with colleagues at MIT.

### Richard L. McCreery

Richard L. McCreery is currently Professor of Chemistry at the University of Alberta, with a joint appointment as a Senior Research Officer at the National Institute for Nanotechnology. Until 2006, he was Dow Professor of Chemistry at the Ohio State University. He received his B.S. in chemistry from the University of California, Riverside, in 1970, and Ph.D. under Ralph Adams at the University of Kansas in 1974. His research involves spectroscopic probes of electrochemical processes, the electronic and electrochemical properties of carbon materials, and carbon-based molecular electronics. Much of his research involves collaborations with materials scientists and engineers, as well as surface scientists and electrochemists. He leads an effort at NINT and UofA to investigate hybrid devices for molecular electronics, which combine existing CMOS technology with new electronic and optoelectronic devices containing active molecular components. McCreery has written over 200 refereed publications, including one book; he also has eight U.S. Patents, three of which are extended to Europe and Japan.

### Agnes E. Ostafin

Dr. Ostafin earned a Ph.D. from University of Minnesota in the Division of Chemical Physics, Department of Chemistry, in 1994, and two B.S degrees from Wayne State University in the Department of Chemistry and in the Biophysics Program, in 1987 and 1988. She is currently Associate Professor at the University of Utah in the department of Materials Science & Engineering and Adjunct Associate Professor

in Bioengineering. Dr. Ostafin teaches undergraduate and graduate courses in Nanobiotechnology, Biomaterials, Polymer Science and Kinetics. Prior to 2006, she was Assistant Professor, Department of Chemical & Biomolecular Engineering, University Notre Dame. Dr. Ostafin completed postdoctoral training at University of Chicago, Department of Chemistry, from 1996-1999, and at Argonne National Laboratory, Department of Chemistry, from 1994-1996. She has 7 patents/patent pending applications, 42 book chapters/publications, and > 100 presentations or invited talks. Her research interests focus on the use of nanoreactors and supporting technologies in biosensing, medicine, and energy applications.

### Lisa D. Pfefferle

Lisa Pfefferle, a Professor of Chemical Engineering at Yale University received a B.S. in ChE from Princeton University and a Ph.D. in ChE from the University of Pennsylvania. Her Ph.D. advisor was S.W. Churchill, leading to her early work in soot precursor chemistry developing new techniques for analysis of large molecules including VUV-photoionization and analysis methodology for interpretation of spectrometric and spectroscopic data. Pfefferle's current main research thrust is the synthesis, characterization and functionalization of nanostructures and their tailoring for energy and biomedical applications. The nanostructures of current focus are carbon, bismuth, pure boron and GaN nanotubes (the only lab in the world able to produce single-walled pure boron and GaN nanotubes.) The boron nanotubes are metallic and when doped, show potential for high temperature superconductivity. The GaN nanostructures are being developed for incorporation into a new hybrid organic/inorganic solar cell design. The synthesis of carbon nanotubes emphasizing structure control is also a major focus of the work. The use of these materials as a platform for antibody stimulation of T-cells is a promising recent application.

### Mihail C. Roco

Dr. Mihail C. Roco is the Senior Advisor for Nanotechnology at the National Science Foundation (NSF) and a key architect of the National Nanotechnology Initiative. Dr. Roco is the founding Chair (in August 2000) of the U.S. National Science and Technology Council's Subcommittee on Nanoscale Science, Engineering and Technology (NSET). Prior to joining National Science Foundation, he was Professor of mechanical and chemical engineering. Dr. Roco is credited with thirteen patents and has contributed over two hundred articles and sixteen books including "Nanostructure Science and Technology" (Kluwer Acad., 1999), "Societal Implications of Nanoscience and Nanotechnology" (Springer/Kluwer, 2001 and 2006), "Managing Nano-Bio-Info-Cognition Innovations" (2007) and "Mapping Nanotechnology Knowledge and Innovation: Global and Longitudinal Patent and Literature Analysis" (2009). Under his stewardship as NSET chair, the nanotechnology federal investment has increased from about $0.27 million in 2000 to about $1.4 billion in fiscal year 2006. Dr. Roco is a corresponding member of the Swiss Academy of Engineering Sciences. He is a Fellow of ASME, Fellow of AIChE and Fellow of the Institute of Physics, and leads the Nanotechnology Group of the International Risk Governance Council. Dr. Roco was elected as Engineer of the Year by the U.S. Society of Professional Engineers and NSF in 1999 and again

in 2004. He was awarded the National Materials Advancement Award from the Federation of Materials Societies in 2007 "as the individual most responsible for support and investment in nanotechnology by government, industry, and academia worldwide".

### Jessica M.J. Swanson

Jessica M.J. Swanson is a NIH NRSA Postdoctoral Fellow in the Center for Biophysical Modeling and Simulation and a recently appointed Assistant Research Professor in the Department of Chemistry at the University of Utah. She received her B.S. in Biochemistry from the University of California, Davis in 2000 and her Ph.D. training in Physical Chemistry from the University of California, San Diego in 2006 under the supervision of J. Andrew McCammon. In 2006, she was awarded an NIH NRSA fellowship to study the proton pumping mechanism in cytochrome c oxidase. Her research interests are the theory and simulation of coupled charge transport processes in photosynthesis and photocatalysis.

### Vladimir P. Torchilin

Vladimir P. Torchilin, Ph.D., D.Sc. is a Distinguished Professor of Pharmaceutical Sciences and Director, Center for Pharmaceutical Biotechnology and Nanomedicine, Northeastern University, Boston, Mass. He graduated from the Moscow University with a M.S. in Chemistry, where he also obtained his Ph.D. and D.Sc. in Polymer Chemistry, Chemical Kinetics and Catalysis, and Chemistry of Physiologically Active Compounds in 1971 and 1980, respectively. In 1991 Dr. Torchilin joined Massachusetts General Hospital and Harvard Medical School as the Head of Chemistry Program, Center for Imaging and Pharmaceutical Research, and Associate Professor of Radiology. Since 1998 Dr. Torchilin has been at Northeastern University, where he was the Chair of the Department of Pharmaceutical Sciences in 1998-2007. His research interests have focused on biomedical polymers, polymeric drugs, immobilized medicinal enzymes, drug delivery and targeting, pharmaceutical nanocarriers for diagnostic and therapeutic agents, and experimental cancer immunology. He has published more than 300 original papers, more than 100 reviews and book chapters, wrote and edited 10 books, including Immobilized Enzymes in Mecicine, The Handbook on Targeted Delivery of Imaging Agents, Liposomes: A Practical Approach, Nanoparticulates as Pharmaceutical Carriers, Multifunctional Pharmaceutical Nanocarriers, Biomedical Aspects of Drug Targeting, Delivery of Protein and Peptide Drugs in Cancer. He also holds more that 40 patents. He is Editor-in-Chief of Current Drug Discovery Technologies, and Co-Editor-in-Chief of Drug Delivery; he also serves on the Editorial Boards of many leading journals in the field including Journal of Controlled Release (Review Editor), Bioconjugate Chemistry, Advanced Drug Delivery Reviews, European Journal of Pharmaceutics and Biopharmaceutics, Journal of Drug Targeting, Molecular Pharmaceutics, Journal of Biomedical Nanotechnology, and others. Among his many awards, Professor Torchilin was the recipient of the 1982 Lenin Prize in Science and Technology (the highest scientific award in the former USSR). He was elected as a Member of European Academy of Sciences. He is also a Fellow of The American Institute of Medical and Biological Engineering and of The American Association of Pharmaceutical Scientists (AAPS), and has received the

2005 Research Achievements in Pharmaceutics and Drug Delivery Award from the AAPS and 2007 Research Achievements Award from the Pharmaceutical Sciences World Congress. In 2005-2006 he served as a President of the Controlled Release Society.

**Hao Yan**

Hao Yan got his Ph.D degree from the Department of Chemistry at New York University in 2001. He then moved to the Department of Computer Science at Duke University as a Research Assistant Professor. He joined the Department of Chemistry and Biochemistry and The Biodesign Institute at Arizona State University in 2004. He is currently a Professor of Chemistry and Biochemistry at ASU. His research interests focus on molecular self-assembly and directed self-assembly using DNA as a structural building block.

# Keynote Speaker Abstracts

## OCTOBER 15, 2009

### 4:30 PM

"Nanoscale Based Emerging Science and Technology"

Speaker: Mihail C. Roco
National Science Foundation and National Nanotechnology Initiative

Nanotechnology R&D has changed its research focus, main domains of industrial relevance, governance, education outreach and public perception since 2000 when it was proposed as a key development for the 21st Century under the National Nanotechnology Initiative (NNI). This initiative has already powerful implications in knowledge foundation, advanced materials, electronics, nanomedicine and energy conversion. The presentation will outline changes from 2000 to 2009 in nanoscale based science and engineering and their relevance to emerging technologies. The long-term view of National Nanotechnology Initiative and several research frontiers will be outlined in the global context. Partnerships with industry and translational research supported by NSF and NNI will be discussed.

Upstream and broad-ranging investments are made by the National Science Foundation (NSF) in supporting fundamental research, balanced infrastructure and education across all disciplines of science and engineering. Priorities and illustrations of recent results will be discussed. An increased focus is on sustainable resources including water, food, energy, materials and clean environment. The convergence of nanotechnology, modern biology, the digital revolution and other areas are expected to bring about tremendous improvements in transformative tools and societal outcomes.

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### 5:15 PM

"Building Functional Electronic Devices from Molecular Components"

Speaker: Richard L. McCreery
University of Alberta: Department of Chemistry and National Institute for Nanotechnology

The prospect of using molecules as components in electronic circuits has both enormous potential and enormous challenges. It is possible that molecular circuits will enhance silicon-based microelectronics, yielding faster, denser, and cheaper electronic devices with possibly new functions not possible with conventional semiconductors. Our approach to the problem is based on a layer of molecules covalently oriented between a conducting substrate and a metallic top contact {Bergren, 2008 #3687; Wu, 2007 #2815; McCreery, 2006 #2587}. We use Raman and UV-Vis spectroscopy to probe the structure of the molecules in live molecular junctions, in which molecules are subjected to unusually large electric fields (e.g. $10^7$ V/cm){Nowak, 2004 #1775; Bonifas, 2008 #3627}. The behavior of molecules as circuit components is strongly dependent on temperature, molecular structure and bonding to the contacts, and it is possible to monitor chemical changes in molecular junctions during operation. Progress toward the central objective of rational design of molecular electronic circuits will be described, as applications in nonvolatile memory and novel electron transport mechanisms {Wu, 2009 #3858; Barman, 2008 #3688}.

# Conference Speaker Abstracts

## OCTOBER 16, 2009

### 8:15 AM

"Manipulating Interfacial Chemistry for Design of Highly Selective and Sensitive Total $NO_x$ Sensors"

Speaker: Prabir K. Dutta
The Ohio State University: Department of Chemistry

Solid-state electrochemical devices composed of stabilized zirconia electrolytes (YSZ), e,g, oxygen sensors, are used extensively for sensing in combustion environments. However, sensors for detecting other gases have not been as forthcoming. We will present our work in the area of total $NO_x$ sensors based on YSZ and catalysis research. In the presence of oxygen, the heterogeneous catalytic reactions occurring on the surface of metal-oxide electrodes and electrolytes compete with electrochemical reactions. We find that the heterogeneous catalytic activity of $WO_3$, yttria-stabilized zirconia (YSZ), and Pt containing zeolite Y (PtY) have a significant influence on the performance of solid-state potentiometric gas sensors. Pt electrodes covered with PtY and $WO_3$ are used as the reference and working electrodes because of the significant reactivity difference, with $WO_3$ being largely inactive toward catalytic $NO_x$ equilibration. Using highly catalytic active PtY to filter incoming gas mixtures can effectively remove interferences from 2000ppm CO, 800ppm propane, 10ppm $NH_3$, as well as minimize effects of 1~13% $O_2$, $CO_2$, and $H_2O$. In addition, the results from TPD, diffuse-reflectance FT-IR, and catalytic activity measurements also show that the reactions between $WO_3$ and YSZ dramatically reduces the $NO_x$ catalytic activity of YSZ by suppressing the formation of surface nitrates. From XRD and Raman scattering, it is shown that $WO_3$ reacts with segregated surface $Y_2O_3$ and subsurface $Y_2O_3$ of YSZ during the heat treatment, forming less catalytically active yttrium tungsten oxides and monoclinic $ZrO_2$. These two phases suppressed the non-electrochemical reactions around the triple-phase boundary before charge-transfer occurred, leading to stronger sensor signal. New ways of deposition of electrodes as well as increasing sensitivity to ppb levels using a series of sensors will be presented.

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### 8:55 AM

"Designer DNA Architectures for Nanobiotechnology"

Speaker: Hao Yan
Arizona State University: Department of Chemistry & Biochemistry and The Biodesign Institute

Naturally existing biological systems, from the simplest unicellular diatom to the most sophisticated organ such as human brain, are functional self-assembled architectures. Scientists have long dreamed about building artificial nanostructures that can mimic such elegance in nature. Structural DNA nanotechnology, which uses DNA as a blueprint and building material to organize matter with nanometer precision, represents an appealing solution to this challenge. Based on the knowledge of helical DNA structure and Watson-Crick base pairing rules, we are now able to construct DNA nanoarchitectures with a large variety of geometries, topologies and periodicities with considerably high yields. Modified by functional groups, those DNA nanostructures can serve as scaffolds to control the

positioning of other molecular species, which opens opportunities to study inter-molecular synergies, such as protein-protein interactions, as well as to build artificial multi-component nano-machines. In this talk, I will introduce the principle of DNA self-assembly, describe our recent progress in designing and implementing designer DNA architectures for directed self-assembly, biosensing and molecular robotics, and discuss some potential applications of structural DNA nanotechnology.

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## 1:00 PM

"Multifunctional Pharmaceutical Nanocarriers: Promises and Problems"

Speaker: Vladimir Torchilin
Northeastern University: Department of Pharmaceutical Sciences and Center for Pharmaceutical Biotechnology & Nanomedicine

Various pharmaceutical nanocarriers, including liposomes and polymeric micelles, are frequently used for the delivery of a broad variety of both soluble and poorly soluble pharmaceuticals. Using nanoparticulate pharmaceutical carriers to enhance the in vivo efficiency of many drugs is now well established. Now, within the frame of this concept, it is important to develop multifunctional stimuli-responsive nanocarriers, i.e., nanocarriers, that, depending on the particular requirements, can circulate long; target the site of the disease via both non-specific and/or specific mechanisms, such as enhanced permeability and retention effect (EPR) and ligand-mediated recognition; respond to local stimuli characteristic of the pathological site by, for example, releasing an entrapped drug or deleting a protective coating under the slightly acidic conditions inside tumors facilitating the contact between drug-loaded nanocarriers and cancer cells; and even provide an enhanced intracellular delivery of an entrapped drug. Additionally, these carriers can be supplied with contrast moieties to follow their real-time biodistribution and target accumulation. Among new developments to be considered in the area of multifunctional pharmaceutical nanocarriers are: drug- or DNA-loaded delivery systems additionally decorated with cell-penetrating peptides for the enhanced intracellular delivery; "smart" multifunctional drug delivery systems, which can reveal/expose temporarily hidden functions under the action of certain local stimuli characteristic for the pathological zone; new means for controlled delivery and release of siRNA; and nanocarrier-based new targeted contrast agents for diagnostic imaging.

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## 1:40 PM

"Structure Control in Carbon Nanotube Synthesis and Applications"

Speaker: Lisa Pfefferle
Yale University: Department of Chemical Engineering

Most synthesis processes for single walled carbon nanotubes (SWNT) result in a wide range of diameters and chiralities. This is a problem because the properties of these tubes vary greatly and have precluded widespread use of nanotubes commercially. In this talk we outline applications in biological systems, as catalyst supports and for superconductivity, and how tube characteristics affect performance. Most of the talk will focus on synthesis techniques for achieving a narrow diameter and chirality distribution

in synthesis. One method discussed is the stabilization of small domains on nm sized SWNT growth catalyst particles using a second metal which does not participate in nanotube nucleation but either alloys with the growth metal or is not fully reduced, and acts to anchor sub-nm sized catalysts. For example chromium addition to a Co catalyst anchors Co particles. X-ray absorption analysis of the catalyst in-situ during the SWNT synthesis, shows that the use of the less reducible oxide (chromium oxide) to anchor clusters of a nanotube growth catalyst (cobalt clusters) is an important general tool for engineering the resultant nanotube properties. The addition of chromium has been seen to affect both the reducibility of the cobalt ions and the size of the resultant particles during the SWNT synthesis process. For this system smaller SWNT are favored by chromium addition and mod 1 semiconducting tubes predominate. Other synthesis systems will be discussed as well as a new regrowth process that reproduces a seed population. A short summary of interesting non carbon nanotubes will also be given.

# Session Speaker Abstracts

## Devices & Sensors- Capital Ballroom

### 9:40 AM (DS-T1)

"Patterning & Imaging Nanostructures with Light"

Speaker: Rajesh Menon
University of Utah: Department of Electrical & Computer Engineering and Laboratory for Optical Nanotechnologies

A technique for creating deterministic structural complexity is essential to achieving high functionality at the nanoscale, whether in electronics, photonics, or molecular biology. Scanning-electron-beam lithography (SEBL) is the most widely used method in research, but it has a number of drawbacks. SEBL tends to be slow, expensive, prone to placement errors, and not compatible with organics and biological material. Ideally one would prefer to employ benign photons in the visible or near IR range for such patterning. However, the so-called far-field diffraction barrier limits the smallest feature achievable by wavelength, l to ~ l/4. In this presentation, I will describe a technique that circumvents this barrier by means of wavelength-selective chemistry. I call the technique Absorbance Modulation. Absorbance modulation is limited to surface (2-D) patterning. I will also describe an alternative approach that exploits unique combinations of spectrally-selective reversible and irreversible photochemical transitions to achieve single-molecule resolution in 3 dimensions.

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### 10:10 AM (DS-T2-P9)

"Nano Infiltration Fabrication (NIF) of Carbon Nanotube Microstructures"

Speaker: Robert C. Davis

David N. Hutchison, Nicholas B. Morrill, Brendan W. Turner, and Richard R. Vanfleet, Quentin Aten, Larry L. Howell, and Brian D. Jensen

Brigham Young University: Departments of Physics & Astronomy, and Mechanical & Engineering

Carbon nanotube (CNT) composite structures were developed to take advantage of the precise three-dimensional shapes obtained by patterned, vertical CNT growth. These patterned forests were rendered mechanically robust by chemical vapor infiltration and were used to fabricate a diverse variety of functional MEMS devices, including comb drives, cantilevers, bi-stable mechanisms, and thermomechanical actuators. A wide range of chemical vapor depositable materials can be used as fillers, including materials that have previously been difficult to pattern in 3-D including oxides, nitrides and carbides. Porous 3-D microstructures were also fabricated by this technique for applications where high surface area is desirable.

## 10:25 AM (DS-T3)

"Progress Towards DNA-Based Nanocircuits"

Speaker: Matthew R. Linford

Robert C. Davis, John N. Harb, Adam T. Woolley
Brigham Young University: Departments of Chemistry, Physics, and Chemical Engineering

Helmut Schlaad
Max Planck Institute of Colloids and Interfaces, Germany

Two years ago a group from the departments of chemistry, physics, and chemical engineering at Brigham Young University received four years of funding from NSF to develop DNA-based nano-circuits. Tasks that needed completing for this project included surface patterning and modification, alignment of carbon nanotubes on surfaces, design, synthesis, and purification of DNA origami, and metallization of surface immobilized DNA and silanes. In this presentation we describe progress in these areas, which includes surface patterning and gold nanodot deposition with block copolymers and by e-beam lithography, surface modification of gold and silicon dioxide with polybutadiene and polyoxazolines using thiol-ene chemistry for DNA attachment (work done in collaboration with the Max Planck Institute), synthesis and surface deposition of DNA origami in a variety of shapes and sizes to serve as future circuit elements, and electroless metallization of solution and vapor deposited silane films, surface aligned DNA, and DNA origami.

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## 10:40 AM (DS-T4-P10)

"A Fully Integrated Nucleic Acid Identification System for Bacteria Monitoring"

Speaker: Bruce K. Gale

Jungkyu Kim, John Elsnab, Michael Johnson, Rahul Sonkul, Cory Shorr, Cody Gehrke
University of Utah: Departments of Bioengineering and Mechanical Engineering

Prabhu Arumugam, Hua Chen
Center for Nanobiotechnology, NASA Ames

This presentation describes a totally integrated microfluidic system for detecting nucleic acids obtained directly from real biological samples. The microfluidic system was fabricated out of molded PDMS parts and consisted of a series of valves and chambers for control and reaction. Each microvalve and pump was sequentially controlled to extract the nucleic acid and deliver the sample to the sensor chip for electrochemical (EC) detection. A microfluidic cell for EC sensing, including counter and reference electrodes, was manufactured by sputtering Pt and printed Ag/AgCl paste onto a glass slide. The multiwalled carbon nanotube (MWCNT) sensing electrodes were fabricated by patterning Ni nanodots using e-beam evaporation, followed by carbon nanotube growth using CVD. The microfluidic system, silica cartridge, microfluidic cell, and MWCNT-EC sensor were integrated into a mounting setup for validation testing using E-coli. Sample preparation, including reagent and sample volume metering, were accomplished using the microfluidic system to control the chemical reactions required for cell

lysis and nucleic acid extraction. Using the integrated microfluidic EC cell, three Differential Pulse Voltammetery (DPV) scans were consecutively performed before and after hybridization. From the peak potential of each scan, guanine oxidation was measured for identifying genetic information. With this integrated system, nucleic acid was extracted within 30 minutes, and bacteria were detected and identified within 2 hours using an EC sensor, compared to several days for current tests. This μTAS system could potentially be used for point-of-care, environment assessment or food analysis.

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## 10:55 AM (DS-T5)

"Novel Miniaturized Piezoresistive Glucose Sensors Based On Osmotic Swelling Pressure Response of Smart Hydrogels"

Speaker: Genyao Lin

Michael Orthner, Florian Solzbacher, Jules J. Magda

University of Utah: Department of Materials Science & Engineering, Electrical & Computer Engineering, and Bioengineering

Two types of "smart" glucose sensitive hydrogels (GSH) have been synthesized at the University of Utah. The first type swells with increase in glucose concentration whereas the second type shrinks with increase in glucose concentration. Both types of GSH have been evaluated for their potential use in a novel continuous piezoresistive glucose sensor. In this sensing modality, a thin film of glucose sensitive hydrogel is restricted between a rigid porous membrane and the diaphragm of the piezoresistive transducer. A change of analyte concentration, as transported through the porous membrane, is detected by measuring the pressure exerted by the hydrogel on the diaphragm of the piezoresistive pressure transducer. The custom-designed piezoresistive sensor measures about 1×1mm in size and can detect glucose concentration changes on the order of 1 mg/dl by measuring the pressure originating from the swelling of the smart hydrogel. With further miniaturization of the GSH, the sensor response time could be reduced from its current value of about 50 minutes and could potentially be used as a real-time continuous implantable glucose sensor for diabetic patients.

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## 11:10 AM (DS-T6-P11)

"Chemically Stable High-Resolution Surface Patterning by Thiolated DNA for Self-Assembly of Nanocircuits"

Speaker: Nitesh Madaan

Matthew Linford, Robert Davis
Brigham Young University: Department of Chemistry & Biochemistry, and Physics

Helmut Schlaad
Max Planck Institute of Colloids and Interfaces, Germany

Nanocircuits should be able to perform complex functions at faster speed using less energy than conventional approaches. But, the need of complex interconnections in circuits makes the complete bottom-up approach quite unfeasible for nanocircuits. In our research group, we are combining bottom-up and top-down approaches. The DNA templated segments (circuit elements) of a bigger circuit made with DNA origami will be self-assembled to form a complete nanocircuit on a surface patterned by complementary DNA. In this regard, the literature shows that DNA-SH can be patterned on gold surfaces by DPN. And while the Au-S bond is strong, sulphur is subject to oxidation and weakens this linkage. An alternative approach is self assembly of dithiol monolayers onto Au(111) followed by reaction with 1,4-polybutadiene (thiol-ene chemistry). Although the dithiol monolayer is also prone to oxidation, the presence of many oxidized thiol linkages in an assembly gives it good stability. That is, reaction with 1,4 -polybutadiene will reinforce the robustness of the entire structure. Such a surface will also have many surface double bonds which can be used to subsequently attach complementary thiolated DNA required for surface patterning/surface nanocircuit immobilization. The rest of the unpatterned surface can be covered with another thiol that contains phosphate end groups that could limit nonspecific adsorption. The attachment of polybutadiene to the dithiol monolayer on the surface double bonds has been successfully achieved, and the reaction with thiolated DNA will be performed shortly. Contact angle goniometry, ellipsometry, time-of-flight secondary ion mass spectrometry, and X-ray photoelectron spectroscopy are used for surface characterization.

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## 11:25 AM (DS-T7)

"Nano Deposition and Etching Using Electric-Field Assisted Atomic Force Probe Directed Chemical Vapour Deposition"

Speaker: Sang H. Yoon

Massood Tabib-Azar

University of Utah: Departments of Electrical & Computer Engineering and Bioengineering

Near-field microwave can be used for depositing materials in addition to their well developed applications in sensing and imaging. Here we report for the first time electric-field assisted decomposition of gas molecules near a conducting AFM tip to directly deposit, etch and pattern nano-scale silicon structures. In our approach, near-fields are used to decompose $SiCl_4$ molecules for depositing Si, and $SF_6$ molecules for etching. The deposition and etching rates vary with gas flow rate, power and the type of the tip. The process is potentially very fast since gas molecules at 1 atmosphere have around 60 nm mean-free-path and are readily available on demand. Owing to relatively large curvature of our current AFM tip apex ~ 20 nm, the smallest feature size we could pattern was around 30 nm. We discuss kinetics of formation of these dots and propose a reaction mechanism that is being evaluated to improve the spatial resolution of this unique technique. We also discuss the role of thermal decomposition that can deteriorate the spatial resolution of tip-based CVD processing. To avoid thermal contribution and spreading, the tip voltage should be pulsed. We are currently adding electrodes directly on the AFM probe to eliminate any need for conducting substrate. With excitation completely contained in the tip, the AFM-based nanofabrication will become versatile and can be used as a 3-D mask-less nanofabrication on any material from polymers to diamond to clays to bio-materials.

This work was supported by DARPA MTO Office under Dr. Thomas Kenny.

## 11:40 AM (DS-T8)

"Ultrafast, Small Footprint, Low Voltage Nano-Electro-Mechanical Switches For VLSI Power Management and Harsh-Environment Processors"

Speaker: Jung Hoon Yang

Sri Ramya Venumbaka, Massood Tabib-Azar
University of Utah: Departments of Electrical & Computer Engineering and Bioengineering

Khawla Alzoubi, Daniel Saab
Case Western Reserve University: Department of Electrical Engineering & Computer Science

Micro-Electromechanical Switches have very low "on" (micro- to milli-Ohm), very high "off" (Mega- to Giga-Ohms) resistances and are currently used in RF switches. Their switching voltages, however, are usually high (5-50 Volts), their switching speeds are usually low (~0.1-10 MHz) and their footprints tend to be large as well (many $um^2$). We have designed and fabricated small footprint (<1 $um^2$), low voltage (~1V) and very high speed (>1GHz) nano-electro-mechanical switches using a tuning fork geometry compatible with silicon IC fabrication technologies. The tuning fork geometry consists of a ground plane that is also a cantilever beam. Upon actuation, both the ground plane and the switches main flexural beam move towards each other enabling the center-of-mass to be stationary during switching and resulting in doubling the switching speed. This unique switch geometry also results in lower actuation voltage by a factor of 1.4. Fabricated of all metallic parts, the tuning fork NEMS can be readily incorporated in VLSI circuits to manage leakage power. They can also be used as complementary switching structures to design processors for very harsh environments where ionization or thermal conductivity of semiconductor switches render them useless. Our presentation will describe the NEMS device structures, their fabrication and characteristics along with their many potential applications in 45 nm-node VLSI power management, FPGA's, and harsh environment processors.

This work was partially supported by DARPA MTO Office under Dr. Amit Lal.

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## 11:55 AM (DS-T9)

"Very Sensitive Electric-Field Sensors Using Nano-Scale J-FETs"

Speaker: Arun Tejusve R. R.
Abhishek Mathur, Massood Tabib-Azar

University of Utah: Departments of Electrical & Computer Engineering and Bioengineering

Very sensitive electric-field sensors using a micro-to-nano geometrical adaptor and nano-scale JFETs are designed and implemented using sub-micron silicon JFETs to prove feasibility. The coupling strength with external field is determined by the exposed plate area of the micro-nano adaptor while the ability to sense the field is determined by the gate area of the JFET and its transconductance. JFETs are more suitable for low-noise detection of low (<mV/cm) electric fields than MOSFETs. The input JFET is part of a relaxation oscillator at 1.1 MHz unperturbed frequency that changed to 0.2 MHz when an electric field of 10 V/cm was applied. The rms fluctuation in the oscillator frequency was around 100 Hz resulting in

a minimum detectable signal (MDS) of better than $10^{-3}$ V/cm. By reducing the JFET gate area to around 10 $nm^2$, the MDS can be improved by a factor of $10^{-3}$ resulting in $10^{-6}$ V/cm minimum detectable electric field. We will discuss our electric field sensor and its applications in mapping biological signals (EEG and EKG) as well as detection of hidden and concealed objects.

This work is partially supported by the USTAR Program in the University of Utah.

# Materials & Characterization- Olympus Ballroom

## 9:40 AM (MC-T10)

"Nanoparticle Blood Substitutes"

Speaker: Agnes E. Ostafin
University of Utah: Department of Materials Science & Engineering

As supplies of fresh, donated blood continue to decline, and the dangers of immunological mismatch, fear of disease and contamination persist, the need for artificial oxygen carriers (AOC), or blood substitutes for surgery, traumatic injury, chronic anemia, and combat remains strong. Several decades of extensive academic and industrial effort has lead to two major classes of AOCs, polymeric hemoglobins and emulsified perfluorocarbons. While both are able to deliver oxygen in significant quantities to tissue, they have faced an uphill battle in U.S. clinical trials due to side effects related to the presence of AOC components and their breakdown products in the bloodstream after clinical urgency has subsided. These side effects have included acute nitric oxide related vasoconstriction, stroke, flu-like symptoms and longer term chemical toxicity. In our work we are developing new kinds of nanoparticle-based AOC and blood chemistry sensors, and methods to apply them in circulation in ways that aim to avoid these complications.

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## 10:10 AM (MC-T11)

"Low-Temperature Synthesis of High-Quality Colloidal Semiconductor Nanocrystals"

Speaker: Michael H. Bartl

Jacqueline T. Siy, Eric M. Brauser

University of Utah: Department of Chemistry

Semiconductor nanocrystals display unique size and shape-related properties as a result of quantum size effects and strongly confined excitons. These phenomena have not only stimulated new concepts in physics, but promise novel applications in biological labeling and imaging, nanoelectronics, solar energy conversion and light-emitting diodes (LEDs) technologies with a combined projected market growth from about $30 million in 2008 to over $720 million by 2013. In contrast to this multitude of emerging applications, fabrication of high-quality nanocrystals still relies on high-temperature (e.g., 240-350 °C for CdSe nanocrystals) small-batch methods developed some 20 years ago. These small-batch methods limit mass production and therefore are a major barrier for widespread use of nanocrystals. In this talk I will present a low-temperature (50-130 °C) synthesis method for high-quality CdSe nanocrystals. The fabricated CdSe nanocrystals possess narrow size distribution, tunable electronic and optical properties, and bright luminescence behavior. First promising up-scaling experiments of our reaction will also be presented.

## 10:25 AM (MC-T12-P24)

"Electronic trap states in dielectric films imaged by Dynamic Tunneling Force Microscopy and characterized by Single Electron Tunneling Force Spectroscopy"

Speaker: Jon Paul Johnson

Dustin W. Winslow, Clayton C. Williams

University of Utah: Department of Physics & Astronomy

The Scanning Tunneling Microscope (STM) has shown the power of quantum tunneling for nanoscale characterization and manipulation since its invention in the 1980s. Dynamic Tunneling Force Microscopy (DTFM) and Single Electron Tunneling Force Spectroscopy (SETFS) are new scanning probe techniques based on quantum tunneling which were developed to image and characterize electronic states in completely non-conducting films with sub-nanometer spatial resolution. In DTFM and SETFM, single electrons are induced to tunnel between a metallic tip (a metal-coated Atomic Force Microscope probe) and localized electronic states in an insulating dielectric film, while the tunneled charge is measured by monitoring its electrostatic force on the oscillating probe. The DTFM signal provides an atomic scale map of individual electronic "trap" states within tunneling range of the surface. SETFS provides information about the relative energies of the states seen by DTFM in the dielectric film. Also discussed is a method to independently determine not just the lateral position of the states, but also their energy and depth—on a sub-nanometer scale. This atomic scale method provides the means to study atomic scale defects in semiconductor device materials (gate oxides and flash memory).

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## 10:40 AM (MC-T13-P25)

"Modulation of Polyaromatic Hydrocarbon Toxicity by Carbon Nanomaterials
Assess the Rescue Effects by Nano-Carbon Materials on Phenanthrene Toxicity in Solution"

Speaker: Shan Lu

Clint Jones, David Grainger

University of Utah: Department of Bioengineering

Nanomaterials are researched and used increasingly in consumer products, technological applications, and medical treatments. However, in many cases the toxicological implications of these new materials lag behind the application of these materials. Carbon nanomaterials (CNM) represent what is possibly the most-studied class of nanoparticles, but much disagreement exists concerning their toxicity and much work remains in their toxicological assessment. Since many CNMs have intrinsically high specific surface area and all CNMs have much molecular commonality with ubiquitous organic pollutants, there is some concern over the ability of CNMs to interact with and modify the effects of such toxicants. This project focuses on assessing the impact of a variety of CNMs on the toxicity of phenanthrene—a common, mutagenic, polyaromatic hydrocarbon (PAH). The zebrafish embryo (ZFE) model was employed to examine both mortality and sub-acute, developmental abnormalities arising from phenanthrene exposures and the effect of CNMs upon the occurrence and severity of toxic endpoints. Distinct forms

of CNM, including multi-walled carbon nanotubes (MWNT), fullerenes ($C_{60}$), and carbon black (CB), were found to distinctly modify phenanthrene toxicity in ZFE. Subsequently, CNM surface areas, morphologies, and intramolecular bonding characteristics were assessed to elucidate the source of the observed modulation of phenanthrene toxicity in the presence of CNMs.

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## 10:55 AM (MC-T14-P26)

"Use of Nanodiamond for Creating Core-shell Diamond Particles for Use in SPE and HPLC"

Speaker: Landon Wiest

Gaurav Saini, David Jensen, Matthew Linford
Brigham Young University: Department of Chemistry & Biochemistry

Michael Vail, Andrew Dadson
US Synthetic Corporation, Orem, UT

We have created new high-performance liquid chromatography (HPLC) stationary phases using nano- and microdiamond. The use of nanodiamond has allowed us to sufficiently increase the surface area of our diamond-based chromatographic phases so that we will be able to retain chemicals and perform chemical separations. Core-shell HPLC particles have been created using a non-porous diamond core (2 um) which is subsequently coated with poly(allylamine) (PAAm) and nanodiamond bilayers until the desired surface area and thickness has been achieved. Thus far we have created particles with a surface area of $>30 m^2/g$ of diamond which is equivalent to $\sim 40 m^2/g$ of silica. The HPLC phases have been characterized via XPS, DRIFT, BET Isotherm measurements, RBS and NRA. The benefits of diamond-based materials for chromatography are as follows: they are stable under extreme pH conditions (less than pH 1 and greater than pH 14), have high thermal conductivity, do not swell when exposed to organic solvents and do not need to be restored in between experiments. They can also be functionalized in a variety of ways to give different selectivities.

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## 11:10 AM (MC-T15-P27)

"Reversibly Crosslinked Gold Nanoparticle - Hyaluronan Hydrogels for Vessel Construct Bioprinting"

Speaker: Aleksander Skardal

Jianxing Zhang, Lindsi McCoard, Siam Oottamasathien, and Glenn D. Prestwich

University of Utah: Departments of Bioengineering, Medicinal Chemistry, and Center for Therapeutic Biomaterials

Bioprinting, or organ printing, is a new field that has significant potential to further tissue engineering. While medical needs for viable organs and tissues are increasing, development of functional organs in the laboratory remains a distant goal. The complexity of cell and tissue organization in an organ has proven to be difficult to mimic, but bioprinting can address this. By using a 3-axis analogue of an inkjet printer,

a device can deposit cells and cell aggregates – the "bioink", and hydrogels – the "biopaper", building a three-dimensional construct. Within bioprinting, the hurdle has been interfacing between hardware and the printable materials. Standard hydrogels pose design problems because they are either printed as fluid solutions, limiting mechanical properties, or printed as crosslinked hydrogels and destroyed during the extrusion process. Despite the recent advances in nanotechnology, there has been little fusion between it and true tissue engineering. Here, we show that hyaluronic acid-based hydrogels crosslinked with gold nanoparticles gain new properties, making them more suitable for bioprinting procedures than other hydrogels we have worked with. They do not break apart during extrusion, they continue to crosslink after printing, stabilizing the construct, and they can be degraded after tissue maturation. We use these biocompatible hydrogels to bioprint hydrogels and cells into viable vessel-like constructs, that after culture, stained positive for procollagen and collagen, indicating endogenous matrix production. This proof of concept system can likely be expanded to allow construction of multi-layered vessel constructs and other organ structures, turning engineered organs into an attainable goal.

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## 11:25 AM (MC-T16-P28)

"Utilizing Zebrafish to Elucidate in vivo Nanomaterial Trafficking"

Speaker: Clinton F. Jones

David W Grainger

University of Utah: Department of Pharmaceutics

The growing usage of nanomaterials in consumables and technology, together with the growth of nanomedicine research has prompted many to call for more rigorous assessments of nanoparticle toxicities and interactions with living systems. Nanoparticles are known to traffic readily between many compartments in the body, but the details concerning their transport and movement within living systems are still mostly unknown. Vertebrates possess an immune system comprised of several cell types with an overall purpose of responding to injury and non-self entities within the organism. Little is known concerning the response of this very complex system to foreign materials in the nano-size range. Accordingly, we evaluated the cellular uptake and trafficking of nanoparticles within a living vertebrate system through time-lapse imaging of zebrafish embryos exposed via a variety of modes and points of administration. Time for nanoparticle uptake and phagocyte localization in vivo were observed to be dependent upon mode of administration and initial dose. The zebrafish can provide real-time, contextual information on nanomaterial interactions with a living system.

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## 11:40 AM (MC-T17-P29)

"Stable Biocidal Nanospheres in Common and Adverse Condition Environments"

Speaker: William Niedermeyer

Bryon Tarbet

NLC Laboratories, Inc. and Protium Plus Technologies, LLC, West Jordan, UT

NLC Laboratories, Inc., a Utah company, was created in 2005 with the intent to produce nanoparticles to be studied within the fundamentals of the physical sciences, and to discover phenomena not known of the host materials used in their manufacture. The critical factor of stability negated all methods of production known at the time due to contamination of chemical components and low zeta potential of the nanomaterial. In 2006 research into production methods for spherical nanoparticles, all of the same size, with controllable sizes from 6-35 nanometers, with high zeta potentials for stability, proved successful. The production methods were scaled to provide large quantities for use in collaborative research and industry. A focus on the bio-science was encouraged by the unique ability of specific stable nanomaterials, trademarked as Attostat, in removing bio-burden from wounds, and effecting the life cycles of fungus, bacteria (including MRSA), and some viruses by nonionic mesomechanical methods. Successful Usage of Attostat by patient permission for wound care brought about continued application research into the use of stable nanospheres in other medical applications. Industrial applications in water treatment have recently been added. In 2008 NLC Laboratories, Inc., began application for membership in the Nano Materials Stewardship Program from the EPA. Currently nanomaterials are being produced for local universities in their research programs. A collaborative program from NLC Laboratories, Inc., encourages the study of these highly characterized materials by providing them free of cost to legitimate research programs.

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## 11:55 AM (MC-T18-P30)

"Anisotropic Surface Chemistry Features of Kaolinite Particles as Revealed by AFM Surface Force Measurements"

Speaker: Vishal Gupta

Jan D. Miller

University of Utah: Department of Metallurgical Engineering

Kaolinite is a 1:1 layer of alumino-silicate clay mineral. The 001 basal plane consists of a silica tetrahedral layer, and the 00$\underline{1}$ basal plane consists of an alumina-hydroxide octahedral layer. Kaolinite naturally exists as sub-micron, pseudo-hexagonal shaped, platy particles. The two largest applications of kaolinite are the coating of paper and the production of high grade ceramic products. Many newer applications include: paint, rubber, plastics, fiberglass, cosmetics and pharmaceuticals. Many of these products and their properties are governed by the surface chemistry of kaolinite, more importantly their electrokinetic characteristics. The electrokinetic characteristics are generally explained without consideration of the difference in the face surfaces (basal plane surfaces). In order to provide more detailed surface chemistry information, atomic force microscopy is being used to measure surface forces at the two faces of kaolinite. The interaction forces between a silicon nitride tip and the basal planes of kaolinite particles (~500 nm in size) are being studied at varying solution chemistry conditions (ionic strength and pH). Also, potentiometric titration is being conducted to study the surface charge properties of the kaolinite. The surface force measurements reveal the difference between these two basal plane surfaces and will be discussed in the context of interfacial water structure and electrokinetic behavior.

# nanoMedicine- Capital Ballroom

## 2:25 PM (NM-T19)

"Nanotechnology in Biomedical Innovation"

Speaker: David W. Grainger
University of Utah: Departments of Pharmaceutics & Pharmaceutical Chemistry and Bioengineering

Through past decades, materials engineered into nanotechnology have moved from an exotic research pursuit to inclusion in hundreds of mainstream consumer products, with nanomaterials markets exceeding billions of dollars annually. Specialized nanoparticle chemistries (e.g., metals, ceramics, and carbon allotropes) are produced in metric tons annually for commercial ventures. Many medical innovations under assessment now claim benefits from nanotechnology. Nanosystems under biomedical development comprise nanoparticles as functional building blocks. Drug delivery systems by their very nature are prime for such use: several polymer nanophase formulations are approved for human use, and dozens more nano-therapeutics are in clinical trials. Medical imaging and diagnostic systems using nanotechnology are also abundant, some marketed. Nonetheless, less sophisticated consumer products dominate current nanotechnology applications. With entry of engineered nanomaterials and products into nearly every aspect of life come increasing calls for prudent assessment of new safety and exposure risks. Human exposure to environmental non-engineered, natural sources of nanomaterials is by far the most significant. By contrast, deliberate exposure to human-made nanosystems is a relatively recent phenomenon, yet substantial enough to warrant clear safety or hazard assessments. Every possible result is published for a given nanomaterial in biological tests: from "overt toxicity" to "no observable toxicity". Hence, a classic "cup is either half-full or half-empty" analogy with regard to nanotechnology's promise exists where exaggerated commercial benefit forecasts are offset by equally extreme, adverse human health impact scenarios.

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## 2:55 PM (NM-T20-P38)

"Cellular Uptake and Toxicity of Silica Nanoparticles in Epithelial and Phagocytic Cells"

Speaker: Alexander Malugin

Heather Herd, Hamid Ghandehari

University of Utah: Departments of Bioengineering, Pharmaceutics & Pharmaceutical Chemistry, Utah Center for Nanomedicine, and Nano Institute of Utah

The objective of this study was to evaluate the influence of size and surface characteristics of silica nanoparticles (SNPs) on cellular toxicity and uptake by epithelial and phagocytic cells. Commercial anionic SNPs of 50, 100, 200, and 500 nm in diameter were prepared in cultured medium immediately before use from a stock dispersion and vortexed before applying to cells. Confocal microscopy and flow cytometry revealed that fluorescently labeled plain SNPs regardless of their size were internalized by RAW264.7 macrophages to a higher extent and with faster kinetics than by epithelial DU145 (prostate)

and HCT116 (colorectal) cancer cells. Neither plain nor surface modified SNPs affected the proliferation of epithelial cells in concentrations as high as 500 mg/ml. All tested SNPs showed toxicity ($IC_{50}$ values from 15 to 630 mg/ml) toward RAW 264.7 macrophages. Plain and carboxyl-functionalized 50 nm particles were more toxic than larger counterparts. The toxicity of amine-functionalized particles increased with size. Carboxyl-functionalized SNPs were significantly less toxic than plain and amine-functionalized particles. Cells treated with plain SNPs caused leakage of plasma membrane, and manifested characteristics of necrotic cells. Neither carboxyl- nor amine-functionalized SNPs induced plasma membrane leakage. Both apoptotic and necrotic cells were found after treatment of macrophages with surface modified SNPs. Longer incubation times were required for carboxyl-functionalized particles to induce similar changes when compared to amine-functionalized particles. These results suggest that functional groups on the surface of SNPs play an important role in the interaction of nanoparticles with macrophages and that cellular uptake and toxicity is cell-dependent. *Financial Support was provided by NIH R01 DE19050 and the Utah Science Technology and Research (USTAR) Initiative.

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## 3:10 PM (NM-T21-P39)

"Human Endothelial Cells Display Inflammatory Markers to Cache Valley Particulate Pollution"

Speaker: Cassandra Deering-Rice

Garold Yost, Teresa Hole
University of Utah: Departments of Pharmacology & Toxicology

Roger Coulombe, Randy Martin
Utah State University: Departments of Veterinary Sciences and Civil and Environmental Engineering

Surrounded by mountains, Cache Valley is prone to strong winter inversions arising from motor vehicle emissions, and ammonia gas from animal excreta. These inversions caused the highest $PM_{2.5}$ levels in the nation. Epidemiological studies from diverse geographical areas have linked exposures to particulate air pollution with stroke and Alzheimer's disease and to early mortality from cancer and cardiopulmonary diseases, but studies to determine causal relationships between exposure to Cache Valley Particulate Matter (CVPM) and poor health outcomes have not been reported. To determine potential adverse consequences of exposures to CVPM on respiratory and cardiovascular organs, human bronchial epithelial cells (BEAS-2B) and human umbilical vein endothelial cells (HUVEC) were cultured with CVPM that was collected from various locations in the Cache Valley. CVPM was only slightly cytotoxic in BEAS-2B (>1,000 µg/ml), while HUVECs were substantially more susceptible (>200 µg/ml). CVPM at a low concentration of 4 µg/ml in HUVECs produced a 2.5-fold increase in expression of IL-6 and a moderate increase in BEAS-2B cells of C-reactive protein (CRP), a prototype marker of inflammation and cardiovascular disease. These results indicate that CVPM is particularly cytotoxic to endothelial cells, and the particles upregulate signaling processes for inflammatory events in both airway and endothelial cells. Thus, it is plausible that CVPM could produce substantial adverse effects associated with inhalation of fine particulate matter during pollution episodes. Supported by a grant from the Marriner S. Eccles Foundation, and a pilot grant from the National Children's Study through Utah State University.

## 3:25 PM (NM-T22-P40)

"PAMAM-Camptothecin Conjugate Inhibits Proliferation and Induces Apoptosis in Colorectal Carcinoma Cells"

Speaker: Giridhar Thiagarajan

Abhijit Ray, Alexander Malugin, Hamid Ghandehari

University of Utah: Departments of Bioengineering, Pharmaceutics & Pharmaceutical Chemistry, Utah Center for Nanomedicine, and Nano Institute of Utah

The purpose of this work was to synthesize a novel conjugate of camptothecin (CPT) with poly (amido amine) (PAMAM) generation 4 dendrimers and subsequently evaluate its in vitro activity. The attachment of CPT to PAMAM was facilitated through a succinic acid-glycine linker. The conjugate was characterized by size exclusion chromatography and high performance liquid chromatography for purity, spectrophotometrically for drug loading, and dynamic light scattering for hydrodynamic volume. The stability of the conjugate in PBS (pH 7.4) and growth media (pH 7.4, with 10% FBS) was studied. Results indicate that the conjugate was stable under these conditions with approximately 4% and 6% release of camptothecin at 48 hrs respectively. A WST-8 based cytotoxicity assay performed on human colorectal carcinoma HCT-116 cells demonstrated the ability of PAMAM-CPT conjugates to inhibit cell proliferation which was evident from an $IC_{50}$ of 1.6 ± 0.3μM. Analysis of DNA content in cells stained with propidium iodide revealed that about 60% of cells were arrested in the G2 phase of the cell cycle for PAMAM-CPT treatment. To visualize the manifestation of apoptotic cell death as a consequence of the cell cycle block, these cells were stained with DAPI and images captured on a confocal laser-scanning microscope. Image analysis suggests apparent nuclear fragmentation leading to formation of apoptotic bodies. Our findings suggest high potency of the dendrimer-based delivery system. Coupled with the ability to target macromolecular therapeutics to the tumors, these conjugates show promise for increased efficacy and reduced toxicity of cancer chemotherapy with CPT. Acknowledgments: NIH R01 EB007470 and Utah Science Technology & Research (USTAR) for their funding support.

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## 3:40 PM (NM-T23-P41)

"Effect of MWCNT exposure on cellular toxicity in dynamic airway epithelial cell culture models"

Speaker: Hemang Patel

Soonjo Kwon

Utah State University: Biological Engineering Program

Rapid advancement in the field of nanotechnology has given birth to various types of nanomaterials with unique mechanical, thermal, and electrical properties. Despite their great use for engineering and medical applications, nanomaterials may have adverse consequences upon accidental exposure and medical application due to their nanoscale size and composition. The carbon nanotube (CNT) has been well explored for many proven applications, but very little explored to understand its potential

toxic effects. It is crucial to develop viable alternatives to in vivo tests to evaluate the toxicity of engineered CNTs. Our objective is to study and characterize the molecular mechanism of multi-walled carbon nanotube (MWCNT)–induced cytotoxicity in a novel dynamic in vitro model, which can simulate cyclic breathing condition. Different MWCNT concentrations (5, 10, and 20 μg/ml) in combination with different exposure times (24, 48, and 72 hours) were used to simulate different exposure conditions. The levels of pro-inflammatory, oxidative stress and cytotoxic mediators were monitored, following exposure of MWCNTs with different concentrations, and exposure time. Diffusion and/or uptake of MWCNTs were monitored using 5-(4,6-dichlorotriazinyl) aminofluorescein labeled MWCNTs. Level of diffusion or uptake of MWCNTs were related to variations of cellular toxicity and inflammatory responses. The outcome of this study would help us to understand the cellular response of MWCNT exposure to human airway and the mechanism of progression of inhaled MWCNTs in the respiratory system.

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## 3:55 PM (NM-T24-P42)

"Effects of Exposure Time, Size, Concentration of Nano-structured Particles on Cellular Toxicity in the Lung"

Speaker: Rena Baktur

Hemang Patel, and Soonjo Kwon

Utah State University: Biological Engineering Program

The "nanostructured particles" are potentially of concern if they can deposit in the respiratory system and have nanostructure influenced toxicity (e.g., high surface area, high aspect ratio, unusual morphology, small diameters, or disaggregation into smaller particles once deposited). Accidental exposure to nanoparticles might have adverse consequences to health, although the physicochemical determinants of these effects are not well characterized. Especially, the effect of concentration, exposure time, size, and aggregation of nanoparticles on cellular toxicity and its mechanisms have not been well defined. Human alveolar epithelial cell monolayers were exposed to single-walled carbon nanotubes (SWCNT) and multi-walled carbon nanotubes (MWCNT) with the different levels of concentrations (2, 4, and 8μg/ml), size (long/10-30μm dia.and short/0.5-20μm), and exposure times (1, 3, 6, and 24 hr). Cell viability, inflammatory response, particle aggregation, and pulmonary barrier function were monitored. Different exposure times induced the different levels of inflammatory responses. Short exposure time suppressed inflammatory responses, while longer exposure time enhanced inflammatory responses. In the presence of serum, more CNTs were translocated into the cells.

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## 4:10 PM (NM-T25-P43)

"Multifunctional Nanoparticles for Ultrasound Tumor Imaging and Targeted Chemotherapy"

Speaker: Natalya Rapoport

Poster Presenter: Kwon-Ho Nam

Anne M. Kennedy, Jill Shea, Courtney Scaife

University of Utah: Department of Bioengineering

Multifunctional nanoemulsion/microbubble nanoparticles that combined properties of drug carriers, ultrasound imaging contrast agents, and enhancers of ultrasound-mediated drug delivery have been developed. At room temperature, the formulations comprised perfluoroalkane nanoemulsions stabilized by biodegradable block copolymers or their mixture. The drug doxorubicin (or paclitaxel) was localized in the droplet/bubble walls. As indicated by biodistribution and ultrasound imaging, drug-loaded micelles and nanobubbles extravasated selectively into the tumor interstitium. In vivo, the drug was tightly retained by nanodroplets but was released in response to sonication by therapeutic ultrasound. Acoustic properties of droplets and corresponding bubbles depended on the type of the bubble stabilizing copolymer. Nanodroplets converted into nano/microbubbles upon ultrasound irradiation. Droplet-to-bubble transition and stable cavitation of formed nano/microbubbles has been implicated as a cause of ultrasound-induced drug release. Upon injection of perfluoropentane nanoemulsions, a long-lasting, strong and selective ultrasound contrast was observed in the tumor volume thus confirming tumor accumulation of nanoparticles. Tumor sonication by therapeutic ultrasound resulted in a significant degree of drug tumor-targeting and effective tumor chemotherapy. Efficient regression of breast, ovarian and pancreatic tumors was achieved using this approach. In addition, ultrasound irradiation combined with nanodroplet encapsulated paclitaxel appeared to suppress metastasizing of pancreatic cancer. Current efforts are directed to suppression of tumor recurrence. Potential applications of these systems include image-guided chemotherapy, diagnostic ultrasound imaging, and gene delivery.

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## 4:25 PM (NM-T26-P44)

"Anti-thy-1-nanoparticles for Renal Mesangial Cell-targeted Delivery of siRNA Therapeutics"

Speaker: Yufeng Huang

Liang Xu, Jiandong Zhang, Youhan Bae, Frderic Clayton, Wayne A. Border and Nancy A. Noble.

University of Utah: Department of Internal Medicine

Small interfering RNA (siRNA) that silences specific diseased-related genes holds great promise. However, delivery to specific cells remains a major obstacle. Here we describe a novel nanoparticle-based system comprised of siRNA in cationic liposomes coated with the anti-thy-1 antibody that selectively targets rat renal mesangial cells (MCs). At the optimized ratio of components, these nanoparticles form a compact nanostructure with close to neutral surface charge and relatively uniform size (80.98±4.73nm). Nanoparticle-delivered fluorescent siRNA was observed in cytoplasm of cultured MCs from 4h to at least 72h after transfection and in glomeruli from rats injected with these particles from 2h to at least 6h. No fluorescence was seen in glomeruli from control rats injected with untargeted siRNAs. Targeted delivery of siRNA specific to the (pro)renin receptor ((p)RR) gene reduced glomerular (p)RR mRNA expression and protein production more than 90%, both in rat MCs at 72h and in cortical glomerular tissue for up to 5 days. No effect was seen in untargeted renal medulla. The success of this nanoparticle system suggests that targeted siRNA delivery to glomeruli is achievable, which holds promise as a novel therapeutic approach for glomerular disease.

## 4:40 PM (NM-T27-P45)

"PAMAM Dendrimer–SN38 Conjugates: Synthesis, Characterization and In Vitro Evaluation"

Speaker: Vijayalakshmi Nirmalkumar

Abhijit Ray, Alexander Malugin, Hamid Ghandehari

University of Utah: Departments of Bioengineering, Pharmaceutics & Pharmaceutical Chemistry, Utah Center for Nanomedicine, and Nano Institute of Utah

SN38 is the active metabolite of the camptothecin analog irinotecan (CPT-11) and is 100-1000 fold more active compared to CPT-11 against its cellular target topoisomerase I in the treatment of colorectal carcinoma. Conjugation of SN-38 to poly amido amine (PAMAM) dendrimers can increase the drug's solubility, target it to cancer cells, and potentially improve oral bioavailability. Carboxyl-terminated PAMAM G3.5 was covalently conjugated to SN38 via two different spacers, namely glycine and beta alanine linkers. The average number of SN38 molecules attached per dendrimer conjugate system was three for the glycine linker (G3.5-gly-SN38) and four for the beta alanine linker (G3.5-betaala-SN38) systems respectively. Size exclusion chromatography confirmed the absence of small molecular weight impurities. Stability of the conjugates was evaluated in phosphate buffer (pH = 7.4) and in cell culture media. The HPLC analysis revealed that up to 4% of free drug can be released from G3.5-gly-SN38 in PBS and up to 5.5% in cell culture media within the first 10 h. G3.5-betaala-SN38 showed a similar profile with about 2% release in PBS and 5% release in cell culture media. Both conjugates inhibited proliferation of human colorectal cancer HCT-116 cells and the order of activity was SN38 > G3.5-gly-SN38 > G3.5-betaala-SN38. Similar to SN38, both conjugates were capable of arresting the cell cycle in the G2/M phase. These results indicate that SN38 conjugated with PAMAM dendrimers can be employed for targeted therapy of colorectal carcinoma. *Financial Support was provided by the NIH (R01 EB007470) and Utah Science Technology and Research (USTAR).

# Energy, Catalysis, & Environment-Olympus Ballroom

## 2:25 PM (EC-T28)

"Theory and Simulation of Charge Transport in Energy Capture, Conversion, and Storage"

Speaker: Jessica M. J. Swanson
University of Utah: Center for Biophysical Modeling and Simulation

Redox-coupled charge transport is nature's primary mechanism of energy capture, conversion, and storage. It is the process that enables plants to convert sunlight into biomass (photosynthesis) and our bodies to convert organic nutrients into high energy ATP (oxidative respiration). In this talk, the use of theory and computer simulation to describe charge transport processes will be discussed. A multi-configurational molecular dynamics model will be presented as a useful tool to study proton transport in condensed phase and biological systems. Results for both wild type and mutant forms of the proton pump cytochrome c oxidase (CcO) will be presented, highlighting the role of charge transfer and the complexity of proton solvation and transport.

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## 2:55 PM (EC-T29-P48)

"Synthesis of Air-Stable, Unoxidized, Hydrocarbon Dispersible Boron Nanoparticles Using Ball Milling Method"

Speaker: Jesus Paulo L. Perez

Brian R. Van Devener, Scott L. Anderson

University of Utah: Department of Chemistry

Boron's high energy density makes it a prime candidate as a next generation energy source. When burned, it generates an amount of energy four times that produced per unit volume of gasoline. However, boron's refractory nature proves to be a hindrance in efficiently harvesting this energy. In our research, nanometer size boron particles were produced and coated with a surfactant in a one-pot synthesis process – ball milling. Tungsten carbide balls and jar were used to grind amorphous boron powder to nanometer size particles. The oleic acid surfactant coats these nanoparticles as fresh, unoxidized boron surfaces are formed. It covalently binds with the boron atom through its carboxyl functional group, allowing the long chain hydrocarbon tail to freely interact with the liquid hexane forming a stable dispersion. SEM images of the boron nanoparticles left in the suspension after centrifugation showed distinct aggregated particles with ~50 nm diameter. This is further confirmed by DLS which gave a mean size less than 100 nm. X-ray photoelectron spectra of boron powder milled with oleic acid showed a significant decrease in the intensity of the oxide peak as compared with samples milled without oleic acid. This suggests that oleic acid served as a passivating layer preventing oxidation of the boron particles once expose to atmosphere. We have shown that a top-down approach for engineering surface functionalized boron nanoparticles is feasible. Ball milling is an ideal method for its simplicity and ease of up scaling.

## 3:10 PM (EC-T30-P49)

"Plasmonic Nanorod Enhanced Thin Film Si Solar Cells"

Speaker: Elizabeth Lund

Michael Scarpulla
University of Utah: Departments of Materials Science & Engineering, Electrical & Computer Engineering, and Chemical Engineering

Kirstin Alberi
National Renewable Energy Resources Laboratory, Golden, Colorado

Plasmonic nanoparticles deposited on optically-thin photovoltaic cells are emerging as a viable option for increasing efficiency. The surface plasmon resonances induced by incident electromagnetic waves forward scatter light preferentially into the cell absorber material, thereby increasing the photogeneration of electron-hole pairs. This project aims to investigate the viability of gold nanorods in increasing the efficiency of thin film silicon solar cells. Si solar cells have been obtained from NREL (National Renewable Energy Resources Laboratory) and consist of 60 nm ITO (indium tin oxide), gold nanorods, 15 nm ITO, 15 nm $p^+$ hydrogenated amorphous silicon (a-Si), 3 nm intrinsic hydrogenated a-Si, 2 μm epitaxially deposited crystalline silicon (c-Si), an electronically dead $n^+$ c-Si wafer, and a metal back contact. The external quantum efficiency of this cell peaks around 600 nm, with poor absorption above ~700 nm. Gold nanorods 41 nm in length and 10 nm in diameter were selected because of their longitudinal surface plasmon resonance at 808 nm, which is in the poorly-absorbed wavelength range of the cell. The nanorods are randomly distributed on the surface of the ITO via hydrogen bonding between a covalently bonded monolayer of (3-aminopropyl)triethoxysilane (APS) on the ITO and the carboxylic acid functionality on the nanoparticle surface. Characterization tests of reflectivity, resistance, SEM images, and photocurrent generation will be discussed.

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## 3:25 PM (EC-T31-P50)

"Simulated Performance of Plasmon-Enhanced Thin-Film Silicon Solar Cells"

Speaker: James R. Nagel
University of Utah: Department of Electrical & Computer Engineering

Thin-film solar materials are much cheaper to manufacture than ordinary silicon solar cells, but are unfortunately also much lower in efficiency. This problem can has been partially alleviated through the use of light-trapping via surface excitations in metal nanoparticles on the surface of a thin film solar cell, but much work still remains before an ideal solution is realized. This work presents analytical and finite-difference time-domain simulations of light scattering and absorption in plasmon-enhanced silicon solar cells using metal nanoparticles embedded within a surface layer of indium-tin-oxide (ITO). The efficiency gains due to nanoparticle shape (sphere vs. rod), particle material (Au vs. Ag), diameter, size, aspect ratio, density, and arrangement will all be discussed in relation with this work.

## 3:40 PM (EC-T32)

"Ferritin As A Photocatalyst In An Artificial Photosynthesis System"

Speaker: Richard K. Watt

Robert J. Hilton, Jeremiah D. Keyes

Brigham Young University: Department of Chemistry & Biochemistry

Alternate fuel sources are becoming increasingly important as the reserve of fossil fuels decrease. We describe a bio-photo-catalyst based on the iron storage protein ferritin. The ferritin protein naturally sequesters ferrihydrite as nanoparticles of about 6-8 nm inside a spherical 12 nm protein shell. Ferrihydrite is a semi-conductor material that functions as a photo-catalyst. The protein shell surrounding the ferrihydrite allows this normally insoluble nanoparticle to be soluble in aqueous solutions. The solubility of the ferritin/ferrihydrite nanoparticle complex increases the quantum yield of light absorption and allows substrate molecules greater access than if ferrihydrite was not available in solution. Using this reaction, ferritin has been shown to photo-reduce Au(III) and Cu(II) ions to form soluble 10-30 nm Au(0) and Cu(0) nanoparticles. In this reaction, citrate acts as a sacrificial electron donor to supply electrons for the photo-reduction. This talk will describe efforts to: 1) maximize the catalytic efficiency of the ferritin photocatalyst; 2) synthesize ferritin-containing mineral cores of other transition metals and test these other metals for photo-catalytic activity; 3) test inorganic colloids for photochemical catalytic capability; 4) examine alternate substrates as electron donors; 5) characterize the metal nanoparticles that form from photo reduction; and 6) identify alternate electron acceptors.

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## 3:55 PM (EC-T33-P51)

"Single-Walled Carbon Nanotube Transparent Electrodes"

Speaker: Jeremy D. Bergeson

Jeffrey L. Blackburn, Robert C. Tenent, Brian A. Larsen, Matthew O. Reese, and Teresa M. Barnes

National Renewable Energy Laboratory, Golden, Colorado

Transparent conducting electrodes made from thin-film networks of single-walled carbon nanotubes (SWCNTs) have great potential for use in photovoltaics (PV), flat-panel displays, and touch screens. Traditionally, transparent conducting oxide (TCO) electrodes are used in such devices; however, SWCNTs provide mechanical flexibility with good hole-transport properties, low-temperature processibility and potentially reduced material costs. Improvements in optical transparency and electrical conductivity are still needed for these materials to compete effectively with traditional TCOs. One potential pathway to improvement is to change the distribution of metallic or semiconducting tube types within the SWCNT network. We report the use of SWCNT networks with enriched metallic or semiconducting tube content as transparent electrodes. Through density gradient ultracentrifugation, we separate out semiconducting and metallic nanotubes, which can then be deposited to make thin-film nanotube networks with percentages of metallic tubes varying from 4-98%. We will discuss the characterization of these enriched nanotube transparent electrodes through optical transmission and electrical transport measurements,

as well as their performance in both organic and inorganic thin-film PV devices.

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## 4:10 PM (EC-T34-P52)

"Bifunctional Thiophene Molecules Coordinated to Ruthenium and Bound to CdSe Nanoparticles"

Speaker: Nathan Bair
Brigham Young University: Department of Chemistry & Biochemistry

Oligothiophenes are fluorescent molecules that are potentially applicable in photovoltaics and fluorescence sensing because of their electrical conduction and absorption properties. Oligothiophene absorption properties are easily adjusted by varying the number of thiophene subunits or type of substituents. We have made oligothiophenes with a phosphate group and bipyridine bound to opposite ends. The phosphate functional group is to bind the oligothiophenes to CdSe nanoparticles while the bipyridine complexes to ruthenium. When complexed to ruthenium, fluorescence of the thiophene chain was quenched. When the bithiophene ligand complexed to ruthenium was bound to CdSe nanoparticles, the fluorescence of the CdSe was quenched. If the ligand was not complexed to ruthenium, then the fluorescence of the oligothiophene chain remained even after binding to CdSe. These results describe the relative energy levels of the ligand and nanoparticle. Current efforts are directed toward comparing the results of binding different oligothiophene chains to CdSe nanoparticles.

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## 4:25 PM (EC-T35-P53)

"Pd Electronic Structure Controls Reactivity of Size-selected $Pd_n/TiO_2$ Catalysts"

Speaker: William A. Kunkel

William E. Kaden, Tianpin Wu, Scott L. Anderson

University of Utah: Department of Chemistry

Planar model $Pd_n/TiO_2$ (n=1,2,4,7,10,16,20,25) catalysts prepared by deposition of size-selected $Pd_n$ on rutile $TiO_2$(110) have been studied by x-ray photoemission spectroscopy, low energy ion scattering, and temperature-programmed reaction of CO with $O_2$. The Pd 3d binding energy is observed to vary non-monotonically with cluster size, and the fluctuations correlate with strong size variations in CO-oxidation activity. Taking final state effects into account, low activity is correlated with higher-than-expected Pd 3d binding energy, which is attributed to particularly stable valence electronic structure. In addition, the results suggest significant electron transfer from the $TiO_2$ support to the Pd clusters. Ion scattering shows that small clusters form single-layer islands on the surface, and that the onset of second layer formation appears to increase activity significantly.

## 4:40 PM (EC-T36-P54)

"Metallic Nanoparticle Interactions with Environmentally Beneficial Pseudomonads"

Speaker: Christian Dimkpa

Priyanka Gajjar, Joan McLean, David Britt, Anne J. Anderson

Utah State University: Department of Biology and Biological Engineering Program

Nanoparticles (NPs) of Ag, CuO and ZnO are antimicrobial for pathogenic bacteria such as Escherichia coli and Staphylococcus aureus. We are testing the effect of these ''as-manufactured" NPs on environmental bacteria with roles in bioremediation, Pseudomonas putida KT2440 (PpKT2440), and plant growth promotion, P. chlororaphis O6 (PcO6). Treatment with water-based suspensions of nano-CuO and nano-Ag at 10 $mg^{-l}$ reduced culturability of both environmental pseudomonads, whereas nano-ZnO was bacteriostatic. The surface charge of PcO6 cells as measured with a Zeta-potential meter was negative. Nano-CuO reduced the net negative charge for cells in water at pH 5 and above. Cu ions also reduced net negative charge up to 8 mg/L. With nano-ZnO, cell surface charge was less negative at pHs 4, 5 and 6, and showed little effect at pH 7 and 8. Zn ions reduced the negative charge at all pHs. Negatively charged colloids were observed with nano-Ag and these did not alter bacterial cell charge. Ag ions reduced the negative charge of the cells at pH 6, 7 and 8 but not at pH 4 and 5. Thus, the charge responses of NPs were not identical to those of the metal ions. Extracellular polysaccharide preparations from PcO6 and PpKT2440 form negatively charged colloids; their interaction with NPs is being studied.

# Poster Session Abstracts
# Devices & Sensors

## DS-P1

"Spinning Disc Platform for Digital PCR"

Presenter: Scott O. Sundberg

Bruce K. Gale, Carl T. Wittwer

University of Utah: Departments of Bioengineering, Mechanical Engineering, and Pathology

Digital PCR is capable of detecting single DNA molecules. Rare mutations within an excess of normal DNA can be detected and genetic allelic imbalance can be quantified. This process is expensive and difficult because of the thousands of reactions necessary. Although dilutions can be used to achieve single DNA copy reactions, reduction in sample volume is another solution. The spinning disc platform uses an inexpensive rotating disc to partition the sample into a thousand nanoliter-sized wells.
A PETG sheet was patterned with a spiraling channel having 1,000 wells (30 nl/well), facing radially outward and tangential along the spiral, and then laminated between two similar PETG sheets, thus creating the rotating disc. PCR solution was pipetted into an inlet port towards the center of the disc and spun at 4,000 rpm to load each well. A modified air thermal cycler was used for PCR amplification (40 cycles in 25 minutes) and the disc was interrogated using a CCD camera image to determine how many wells fluoresce for quantification.
All wells were filled with a volume CV of 20%. Single DNA molecule detection is possible with target dilution down to less than an average of 1 copy/well. The spinning disc platform is capable of partitioning and quantifying a sample and can now be applied to multiple digital PCR applications. The spinning disc platform is an improvement over other volume limiting platforms because no valving or pumping is required. Furthermore, rapid air cycle PCR is possible for increased speed and throughput.

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## DS-P2

"Parametric Finite Element Analysis of Microfluidic RNA Hybridization"

Presenter: T. Onur Tasci

Bruce Gale

University of Utah: Department of Bioengineering

In this study, finite element analysis software (Comsol 3.5) was used to simulate the hybridization of RNAs on the biosensor incorporated with a microfluidic channel. Several parameters such as target concentration, flow speed, channel height, and association rate constant were investigated, and their effect on the hybridization duration was examined. The proposed model can also be used for the hybridization analysis of other biological molecules such as DNAs, proteins etc.

RNA binding in the microfluidic channel was modeled by two governing equations. The first equation is Fick's Law, which represents the diffusion of the target molecules to the sensing region. The second equation is the affinity interaction equation, which models the hybridization of the target molecules with the probes.

According to the results, the saturation duration (i.e., duration until all the probes are hybridized) is inversely proportional to the target concentration. There is no significant effect of the flow speed on the saturation duration. But it is observed that flowing the sample results in a much faster hybridization compared to the no flow condition. Channel height has a significant effect on the hybridization duration; this effect becomes more significant as we decrease the concentration of the targets. The effect of the association rate constant on the hybridization duration is also examined.

In summary, parameters effecting the RNA hybridization in the microchannel were investigated by parametric simulations. According to the simulation results, the most effective parameters in the minimization of the hybridization time were found as the target concentration, channel height and the association rate constant of the targets

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## DS-P3

"Continuous Metabolic Monitoring using Hydrogel Based Microsensor Arrays (2×2)"

Presenter: Mahendernath Avula

Michael Orthner, Loren Rieth, Prashant Tathireddy, Florian Solzbacher

University of Utah: Departments of Mechanical Engineering and Electrical & Computer Engineering

Many hydrogels are sensitive to changes in physiological conditions (pH, ionic strength, glucose, temperature, $CO_2$) and are highly biocompatible. We report on the design, simulation, fabrication and initial testing of novel pressure sensor arrays (2×2) that incorporate perforated diaphragms for detection of various hydrogel swelling pressures. Specifically the 0.5, 1.0, 1.25, and 1.5 mm wide square diaphragm sensors were designed to have full scale pressures of 150, 50, 25 and 5 kPa, respectively. To our knowledge this is the first reporting of a sensor that uses a perforated diaphragm allowing the passage of analytes into hydrogel cavity while simultaneously measuring pressure. It was shown that pore geometry can be used modify the diaphragm mechanics and thus electrical output. The optimized geometry removed pores from along the diaphragm midline, edges, and near piezoresistors. This specific pattern was used because it significantly reduced stresses developed around the pores while maintaining mechanical integrity. It was also found that pores act as piezoresistor stress concentrators leading to increased sensitivities. The 14-step sensor fabrication process was performed using standard micro-electro mechanical systems (MEMS) and integrated circuit technologies. Diaphragm pores were created using combination of potassium hydroxide (KOH) etching and deep reactive ion etching (DRIE). Characterization was performed using a custom bulge testing system that exposes the array to a controlled pressure while measuring diaphragm deflection and electrical output. The new perforated diaphragm sensors had sensitivities from 25 to 250 μV/ V-kPa. Initial ionic strength testing using physiological buffer solution (0.05-.15M PBS) showed the sensors have sensitivities from 75 to 270 mV/V-M.

## DS-P4

"Selectivity, Stability and Repeatability of $In_2O_3$ $NO_x$ sensor at high temperature (≥ 500 °C)"

Presenter: Srinivasan Kannan

H. Steinebach, L. Rieth, and F. Solzbacher

University of Utah: Departments of Electrical & Computer Engineering, and Materials Science & Engineering

Solid state sensors ($SnO_2$, $TiO_2$, $In_2O_3$, $WO_3$, etc.) have been used extensively for detection of varied gas pollutants resulting from industrial and automotive exhaust. It is important that these exhaust sensors, besides being sensitive, need to be selective to the target gas. In addition, stability of the sensor is an important consideration since the sensor surface can be poisoned due to the harsh environment (gases, high temperature and pressure) they are operated in leading to variations in sensor performance. In this work, we have studied the selectivity, stability and repeatability of Indium Oxide ($In_2O_3$) thin film sensor to detect $NO_x$ (25 ppm) in presence of other exhaust gas pollutants (5000 ppm $H_2$, 100 ppm $NH_3$ and 1000 ppm $CO_2$) at high operating temperatures (> 500 °C). When exposed individually to 25 ppm $NO_x$, 100 ppm $NH_3$, 5000 ppm $H_2$ and 1000 ppm $CO_2$, the sensor is selective to $NO_x$ with higher sensitivity/ sensor response (S ~ 23) to $NO_x$ species. The sensor response ("S") reduces drastically when $NO_x$ is in a mixture with either $NH_3$ or $H_2$. $In_2O_3$ samples without promoter layers exhibited higher sensor response to $NO_x$ in presence of 100 ppm $NH_3$ when compared to Au promoter samples. Fourier Transform Infrared Spectroscopy (FT-IR) was employed in order to understand the gas-phase reactions between $NO_x$ and $NH_3$ or $H_2$ at high temperatures (> 500 °C). At >500 °C, $NH_3$ and $H_2$ reduce $NO_x$ to water in $N_2$ carrier gas which may explain the drastic reduction in $NO_x$ response at high temperatures (> 500 °C). Exposure to $H_2$ results in etching away of the $In_2O_3$ surface resulting in stability issues when the sensor is operated in a $H_2$ rich environment. $In_2O_3$ thin films deposited in an oxygen environment (25% $O_2$) result in a $NO_x$ sensor with higher sensor response (S ~ 46) and faster response constants ($\tau_{1response}$ ~ 5 seconds, $\tau_{1recovery}$ ~ 5 seconds) at operating temperature ≥ 500 °C in $N_2$ carrier gas. These sensors were repeatable to 25 ppm $NO_x$ exposures with overall variation in sensor response < 10%.

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## DS-P5

"Fully Integrated Wireless Neural Interface based on Utah Electrode Array"

Presenter: Asha Sharma

L. Rieth, P. Tathireddy, R. Harrison, R. Normann, G. Clark, and F. Solzbacher

University of Utah: Departments of Electrical & Computer Engineering, and Bioengineering

In the past decades implantable devices were being developed for use in prosthetics that allow physiological monitoring and functioning of certain organs that are lost due to injuries or diseases. An example of one such type of device is the wireless neural interface based on the Utah Electrode Array (UEA)/Utah Slant Electrode Array (USEA) for neural recording and stimulation. To eliminate the use of wired connections, the batteries for power supply, and lifetime limitations of the implant, our research

group at the University of Utah has recently focused on developing the fully integrated wireless interface that can transmit the data wirelessly. Here we present in-vitro results from a low-power integrated wireless recording system based on 10×10 recording USEA. The fully integrated devices consist of INI-R6 chip that is flip-chip bonded directly to the USEA. Two discrete SMD capacitors (tuning and smoothing capacitor) are connected to the chip through re-routing metallization on the back of USEA. An inductive power receiving coil made of insulated Au/Pd wire (55.9 µm dia.) is connected to the chip by wire bonding to the bond pads on the backside of USEA. Finally, the devices are hermetically sealed by coating 6 µm Parylene followed by silicone potting. In-vitro testing was performed by introducing artificial neural signal into the agarose dish from Grass SD-9 pulse stimulator. Fully integrated neural interface was inserted into agarose, then powered and configured wirelessly. The FSK modulated RF signal was received by the Utah INI receiver, demodulated, decoded and displayed in a Matlab window.

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## DS-P6

"A Wireless and Batteryless Multi-Channel Bio-Sensing Microsystem for Untethered Genetically Engineered Mice Real-Time Monitoring"

Presenter: Ondrej Novak

Nattapon Chaimanonart, Darrin J. Young
University of Utah: Department of Electrical & Computer Engineering

Peng Cong
Medtronic, Inc

Wen H. Ko
Case Western Reserve University: Electrical Engineering & Computer Science

Genetically engineered mice with in vivo real-time physiological signal monitoring are ultimately crucial for system biology research to identify genetic variation susceptibility to various diseases and to develop effective treatment methods for similar human diseases. Due to the small size of a laboratory mouse, a miniature, light-weight, wireless, batteryless, and implantable multi-channel bio-sensing microsystem is developed to capture real-time accurate biological signals from an untethered animal in its natural habitat, thus eliminating stress and post-implant trauma-induced information distortion. The prototype sensing microsystem powered by an optimized remote RF powering system with an adaptive control capability can detect three vital signals, blood pressure, electrocardiogram (EKG) and core body temperature. A miniature elastic sensing cuff filled with silicone gel is wrapped around a blood vessel to couple the vessel expansion and contraction to an immersed capacitive MEMS pressure sensor for blood pressure monitoring. An EKG signal can be measured by employing two-stainless-steel electrodes attached on a mouse chest. The core body temperature can be sensed by an on-chip temperature sensor. The integrated electronics consisting of a low-power low-noise capacitance-to-voltage converter, two ADCs, an EKG amplifier, a proportional-to-absolute-temperature (PTAT) circuit, an adaptive RF-to-DC power converter, a digital control unit and a wireless FSK transmitter, are designed and fabricated in a 1.5µm CMOS process. The wireless transmitter with a duty cycling technique is employed to further reduce the total microsystem power consumption.

## DS-P7

"Micro Hydraulic Piston Arrays for Pneumatic-less Portable Large-Scale Microfluidic Systems"

Presenter: Jungwoo Park

Hanseup Kim
University of Utah: Department of Electrical & Computer Engineering

Khalil Najafi
University of Michigan: Department of Electrical Engineering & Computer Science

We report a pneumatic-less (all-electrical) microfluidic control system that could overcome the critical hurdle in achieving fully-integrated, all-electrical, and thus portable lab-on-chips. This device obviates the need for conventional pneumatic control components (e.g. external gas tanks), and their associated problems, such as large numbers of fluidic interconnections and potential leaks, by utilizing hydraulic amplification to achieve high force and large deflection purely from electrical energy instead of pneumatic sources. Our micro hydraulic actuator array consists of a matrix of flexible Parylene membranes formed on the front side of a device, and a single driver membrane on the backside. Each flexible membrane can be electrically manipulated individually (programmable). Thus, when placed on top of a typical microfluidic chip that contains flow channels, the actuators close the channels, thus allowing valving and pumping functions. The front and back sides of the wafer are fluidically connected through a number of thru-channels formed under each of the front-side membranes. The sealed cavity between the front and back sides is filled with a hydraulic fluid. When the large driver membrane is deflected, the hydraulic fluid is compressed through the small channels to the other side, generating large deflection and high force through hydraulic amplification. When voltage is applied between these membranes and the substrate, the membrane is electrostatically latched to the substrate and does not expand, allowing electrical control of each membrane. The fabricated 3×3 array produces hydraulically-amplified (>3x) out-of-plane deflection of 35μm from each of the electrostatically latchable $2\times2mm^2$ actuators at 100V. The array functions up to a frequency of 2Hz and measures as $8.4\times8.4\times0.65mm^3$.

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## DS-P8

"Comparison of Y-Doped $BaZrO_3$ Thin Films For High Temperature Humidity Sensors by RF Sputtering and Pulsed Laser Deposition"

Presenter: XiaoXin Chen

Loren Rieth, Mark S. Miller, Florian Solzbacher

University of Utah: Departments of Electrical & Computer Engineering, Materials Sciences & Engineering, and Bioengineering

We have developed and tested a novel high temperature humidity micro sensor, based on proton ionic conduction in Y-doped $BaZrO_3$ thin films. Micro gas sensors are being developed to help monitor

emissions and provide feedback for advanced engine and emission control systems and to address more stringent restrictions on emissions from fossil fuel-fired power plants and combustion engines. The gas species of interest include CO, $CO_2$, hydrocarbons, $H_2S$, $NO_x$, $H_2O$, etc. Gas sensitivity tests from Y-doped bulk $BaZrO_3$ suggest that this material could be suitable as a highly selective humidity sensor based on proton ionic conduction. In the work presented here, thin films of $BaZrO_3$:Y were developed and investigated for their potential to significantly reduce sensor response time, increase sensitivity, and allow integration in microsensor platforms. Most solid-state humidity sensors based on chemisorption of $H_2O$ lack selectivity and are not functional at high temperatures Y-doped $BaZrO_3$ can exhibit oxygen vacancies when doped with a trivalent cation e.g. $Y^{3+}$ on a $Zr^{4+}$ site. In atmosphere, this material contains oxygen ions, protons, and electrons. The same material, when heated in an environment containing $H_2O$, allows the absorption of $H_2O$ into the lattice, lowering the oxygen vacancy concentration and releasing protons. We can conclude that PLD provides a more stable and repeatable process that yields more stoichiometric films with good sensitivity even at high temperatures with little ageing. The lower activation energy compared to sputtered films may help explain the lower sensitivity at lower temperatures, but stable sensitivity up to much higher temperatures than can be observed in the sputtered films.

# Materials & Characterization

## MC-P12

"How Does Encapsulation Affect Enzyme Activity?"

Presenter: Hsiao-Nung Chen

Morgan Fetherolf, Kenneth Woycechowsky

University of Utah: Department of Chemistry

Lumazine synthases (LS) from bacteria self-assemble into dodecahedral capsid structures that contain 60 identical subunits. The lumazine synthase from Aquifex aeolicus (AaLS) has been engineered to add extra negative charges on the inner surface of the capsid. This variant (AaLS-neg) is able to encapsulate a co-expressed target protein fused to a deca-arginine tag ($R_{10}$). In this research, a 55 kDa esterase from Geobacillus stearothermophilus is fused to a $R_{10}$ tag at the C-terminus. This mutant, PER10, can be expressed in E. coli and maintains esterase activity. Upon co-production with AaLS-neg, PER10 should become encapsulated. The esterase activity of PER10 encapsulated by AaLS-neg will be compared with the activity of free PER10 for substrates of varying size. These studies should help to define the porosity of the capsid and demonstrate how control of enzyme activity can be achieved though diffusion effects.

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## MC-P13

"Improved Perfluorocarbon Oxygen Carriers for Tissue Engineering"

Presenter: Russell M Condie

Harriet W Hopf, Glenn D Prestwich

University of Utah: Departments of Bioengineering, Medicinal Chemistry, and Chemistry

Partial oxygen pressure is emerging as a critical environmental parameter affecting cell behavior. But for many tissue engineering applications, particularly the culture of thick constructs in vitro, we lack the tools to control it. We previously reported the development of perfluorocarbon emulsions stabilized by diblock copolymers as oxygen carriers for use in perfusion bioreactors. We have since developed improved oxygen carriers of micellar construction with higher perfluorocarbon content from more economical starting materials. These exhibited a slower rate of pO2 decline from saturation upon exposure to ambient air than previous emulsions or perflubron-based emulsions extensively investigated as blood substitutes. Hyperoxic conditions were maintained for 12 hours. Average micelle diameters measured by dynamic light scattering ranged from 250 to 300 μm in solutions stored at 4º C for six weeks, and polydispersity remained below 0.25. Over the course of several hours, the dense (1.7g/ml) micelles settled without coalescing and could be resuspended by agitation.

## MC-P14

"Controlled Placement of Carbon Nanotubes using Massively Parallel Indirect Dielectrophoresis"

Presenter: Brian S. Davis

Hiram J. Conley, Lawrence Barrett, David Jones, Matthew R. Linford, Adam T. Wooley, Dean R. Wheeler, John N. Harb, Robert C. Davis

Brigham Young University: Departments of Physics & Astronomy, Chemistry & Biochemistry, and Chemical Engineering

Dielectrophoresis has been used to place nanotubes, nanorods, nanowires, and other nanostructures between surface patterned metal electrodes. This technique can deposit a varying number of nanotubes between each set of electrodes. We have developed a method to control the number of deposited nanotubes by tuning the impedance of capacitively-coupled electrodes through parameters such as electrode geometry and AC driving frequency. Controlled placement of nanotubes at high yield is a prerequisite for the use of carbon nanotube devices in modern integrated circuitry.

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## MC-P15

"Nanoreactors: Making Molecules Perform Better"

Presenter : Kyu-Bum Han

Yen-Chi Chen, Agnes Ostafin

University of Utah: Department of Materials Science and Engineering

From sensing to imaging to chemical processing, researchers and developers are faced with the limitations inherent in the molecules they use. These limitations are related to the molecular structure, interactions with the surrounding solvent, the sensitivity to contaminants, and other factors. Traditionally problems have been addressed by focusing on developing new molecules, but this process is time consuming, and is limited in terms of what can be changed while still retaining the desired characteristics of the structure. In the past, many researchers have appreciated the effects of confinement in submicron structure on molecular function. Most of these studies involved soft systems such as micelles or liposomes, supramolecular polymeric or protein cages, or larger systems such as zeolite cages. In this project, we are focused on designing solid-state nanoreactors that can withstand harsh chemical environments, mechanical stress and biological attack. The goal is to be able to extend the range of performance of molecules well beyond traditional limitations. Described are two example systems, fluorescein and SNARF molecules, both utilized extensively as fluorescent labels and pH indicators. Reliability of these materials is limited to specific pH and temperature ranges, and the absence of interfering substances which can quench their emission. Shown is how placing these molecules inside a nanoreactor can stabilize their photophysical properties even in extremely unfavorable conditions, leading to improved performance where the exposed molecule fails. Characteristics such as overall emission yield, photobleaching tendency, pH response and others are discussed and explanations for how the nanoreactor environment modulates them are discussed. This work shows that nanoreactor

approach can have important effects on molecular properties and provides an ideal test system to systematically manipulate nanoscale environments and study the effect on molecular behavior. Unlike micelles or liposomes, supramolecular polymeric or protein cages, or larger systems such as zeolite cages, the hollow particles interior can be chemically altered without changing the overall morphology of the unit.

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## MC-P16

"Binder Free Thin Layer Chromatography Plates Assembled Through Microfabrication"

Presenter: David S. Jensen

Li Yang, Jun Song, John Evans, Robert C. Davis, Richard Vanfleet, Matthew R. Linford
Brigham Young University: Department of Chemistry & Biochemistry

Michael Vail, Andrew Dadson
US Synthetic, Orem, UT

Novel silica-based thin layer chromatography plates (TLC) were prepared through microfabrication processes. The microfabrication process excludes the need for a binder to keep the silica adhered to the TLC backing. The binder free TLC plate circumvents the possible secondary interactions between the binder and the species that are to be separated. Also, not having any binder present will allow for a broader choice of solvents. The resulting normal phase microfabricated TLC plate has shown to give base line separation with the following two compounds: Sulforhodamine B and Sudan Black B in a 90% dichloromethane 10% methanol mobile phase.

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## MC-P17

"Bio-Inspired Synthesis of Novel Photonic Crystal Structures Operating in the Visible"

Presenter: Matthew R. Jorgensen

Jeremy W. Galusha, Lauren R. Richey, Matthew R. Jorgensen, Michael H. Bartl

University of Utah: Department of Chemistry

Many butterflies and beetles have developed highly elaborate exoskeleton photonic crystal structures to create their striking coloration. Since many of these structures and their associated photonic effects are not accessible through current artificial synthetic methods, they create exciting opportunities for bio-templating and bio-mimetic manufacturing routes. We will present sol-gel chemistry-based bio-replication routes for the fabrication of high-dielectric photonic crystals from biological templates. For example, using templates from beetle scales, we successfully fabricated a diamond-based photonic crystal with a high-dielectric (titanium dioxide) framework. Theoretical studies show that this bio-templated photonic crystal possesses a complete band gap in the visible. Having access to these novel photonic crystals gives us unprecedented access to fundamental experiments probing the relationship

between photon emitters and their environments. In addition, we will discuss new bio-mimetic synthesis strategies to further access and exploit the potential of biological structure engineering for advanced photonic applications.

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## MC-P18

"Thin Smooth Carbon Nanotube/polymer Composite Membranes"

Presenter: Lei Pei

Richard Vanfleet , Matthew R. Linford, Robert C. Davis

Brigham Young University: Department of Chemistry & Biochemistry

We have developed a new and straightforward method for fabricating freely suspended ultrathin carbon nanotube (CNT) membranes. A smooth transferrable CNT sheet was first made from vertically aligned carbon nanotube (VACNT) forests by placing mixed cellulose ester (MCE) filter paper on a VACNT forest and using a roller to both compress the forest and transfer the nanotubes to the filter paper. The compressed CNT film was then transferred to a solid substrate and the MCE was subsequently dissolved, leaving the CNT film on the substrate. Nanotube – polymer composite films were then fabricated by spin casting a polymer layer on top of the transferred CNT sheet. If the solid substrate was coated with a polymer film prior to CNT transfer, a polymer/CNT/polymer sandwich was created. The composite membranes were subsequently released from the substrate. Characterization of the films and membranes performed by scanning electron microscopy, atomic force microscopy, and by strength testing will be presented.

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## MC-P19

"An Engineered pH-dependent Quaternary Structure Switch for Protein Capsid Formation"

Presenter: Seth Lilavivat

Kenneth J. Woycechowsky

University of Utah: Department of Chemistry

Protein capsids are potential scaffolds for engineering drug delivery vehicles. Key to this problem is establishing precise control over quaternary assembly. We have prelimary evidence that lumazine synthase from Sacchormyces cerevisiae, a naturally-occurring homopentamer, can be modified to assemble into a 60 subunit icosahedral capsid, similar to its homolog in Aquifex aeolicus. Furthermore, the assembly and disassembly of the engineered protein is fully reversible (unlike capsid formation by its homolog from A. aeolicus). The development of a switchable protein capsid could be used as the foundation for a novel system for delivering molecules into cells or provide insight into the phenomenon of self assembly. Current work is underway to further characterize the engineered assembly.

## MC-P20

"Nano-shaving of Thin Polymer Layers on Silicon Oxide to Produce Chemically Templated Surfaces"

Presenter: Kyle A. Nelson

Brian Davis, Hiram Conley, Matthew R. Linford, Robert C. Davis, John N. Harb

Brigham Young University: Departments of Chemical Engineering, Physics & Astronomy, Chemistry & Biochemistry

AFM patterning of polymer layers has been developed as a method for chemical templating of $SiO_2$ surfaces. Nano-shaving of these polymers has been demonstrated to produce lines with a 24 nm pitch chemical patterning of the surface was achieved by depositing a monolayer of the desired chemical species on the oxide surface, depositing a polymer layer on top of that monolayer, and then selectively removing the polymer layer via AFM to expose the underlying layer. In the present study, an APTES layer was formed on a silicon oxide surface and then covered with a sacrificial layer of polystyrenesulfonate (PSS). The surface was patterned by AFM scribing using contact mode in air, and by both tapping and contact modes in water. The resulting patterned surface was analyzed to characterize the difference between the chemistry of the shaved and non-shaved areas. Such a chemically patterned surface can be used, for example, as a template for metal deposition to form nanowires or for patterned deposition of target molecules on the surface. Selective metal deposition of chemical patterns is demonstrated with a colloidal Pd seed and copper electroless plating.

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## MC-P21

"Assembly of Block Copolymer Micelles on a Lithographically Templated Surface"

Presenter: Anthony C. Pearson

Matthew R. Linford, John Harb, Robert C. Davis

Brigham Young University: Departments of Physics & Astronomy, Chemistry & Biochemistry, and Chemical Engineering

Block copolymer micelle patterning has been shown to be a versatile method of creating hexagonal arrays of metal nanoparticles with sizes less than 10 nm and spacing that can be controlled by adjusting the molecular weight of the block copolymer. To use these nanoparticles for controlled lithographic applications, registration of the nanoparticles with other surface patterns is essential. Here we exploit the self-aligned assembly of PS-P2VP block copolymer reverse micelles using both topographical and chemical surface patterning to achieve micelle registration. Specifically, e-beam lithography and plasma etching of $SiO_2$ surfaces were used to create recessed boxes and ovals correctly sized to deposit controlled numbers of micelles within the recessed regions. Chemical surface patterning has been explored to selectively place micelles in the patterned areas with low micelle adsorption in the non-patterned regions. Gold nanoparticles were formed from the micelles by adding $HAuCl_4$ to the micelle solution prior to deposition. After dip coating, an oxygen plasma etch removes the polymer, leaving an aligned array of nanoparticles. A subsequent hydrogen anneal reduces the nanoparticles to elemental

gold. Chemical functionality of the gold has been examined by attachment of octadecanethiol (ODT). Atomic force microscopy was used to verify thiol attachment by measuring a particle height increase of two nanometers following the gold-thiol reaction. This is consistent with the expected height of an ODT self-assembled monolayer. X-ray photoelectron spectroscopy has also been used to examine chemical composition of gold nanoparticles.

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## MC-P22

"One-Step Synthesis of Phosphine-Stabilized Gold Nanoparticles Using the Mild Reducing Agent 9-BBN"

Presenter: Patrick M. Shem

Jennifer S. Shumaker-Parry
University of Utah: Department of Chemistry

Rajesh Sardar
University of North Carolina at Chapel Hill: Department of Chemistry

A simple and versatile one-step approach for making triphenylphosphine (TPP) stabilized AuNPs with diameters of less than 2 nm is presented. This method is a single step procedure which uses a mild reducing agent 9-Borabicyclo [3.3.1]nonane (9-BBN). 9-BBN avails the ability to control the particle growth process. The particle size can be tuned by carefully controlling the conditions under which the reduction takes place. Since 9-BBN is a mild reducing agent, the synthesis is compatible with a wide variety of -functionalized capping ligands. These particles also are soluble in water, thereby expanding their potential applications. The chemistry of these AuNPs can be varied by way of ligand exchange reactions to obtain AuNPs stabilized with different -functionalized alkythiols, other phosphines and bipyridines. This approach is inexpensive and greener because the use of phase transfer reagents and the attendant rigorous purification steps are eliminated. We have characterized the AuNPs using transmission electron microscopy (TEM), X-ray photoelectron spectroscopy (XPS), and $^{31}P$ NMR. Thus these TPP-AuNPs can be used as precursors to gold nanoparticles functionalized with various ligands depending on their envisaged utility such as catalysis, making sensors and labeling of biological molecules and other uses. We also have shown that the synthetic method can be extended to make other noble metal nanoparticles such as Ag, Pt and Pd. The metal nanoparticles can be produced without surface functionalization (bare nanoparticles) or capped in situ as desired.

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## MC-P23

"Synthesis of Vertically Aligned and Patterned Silicon-Carbon Core Shell Nanotubes"

Presenter: Jun Song

Richard Vanfleet, Robert Davis

Brigham Young University: Department of Physics & Astronomy

Here we report the first synthesis of silicon-carbon core-shell nanotubes (SiCNTs). The SiCNTs are formed by coating a vertically aligned and patterned carbon nanotube(CNT) forest with low pressure chemical vapor deposition (LPCVD) of silicon. The carbon nanotube forests were grown from a patterned thin film Fe catalyst resulting in high aspect ratio three-dimensional microscale structures up to 500 microns tall with vertical sidewalls. The density of the nanotubes in the forests is very low; the nanotubes fill only about 1 percent of the space by volume. Silicon LPCVD layers (~30 nm thickness) are deposited conformally, coating the nanotubes and significantly increasing the mechanical strength of the structure. By adjusting the silicon deposition temperature, amorphous or crystalline silicon shells can be formed. This combination of silicon LPCVD on VACNTs yields a unique fabrication approach resulting in porous three-dimensional silicon structures with precise control over shape and porosity.

# nanoMedicine

## NM-P31

"Silk-elastinlike Protein Polymers Improve the Efficacy of Gene Therapy of Head and Neck Tumors"

Presenter: Jordan Frandsen

Khaled Greish, Stephanie Scharff, Joshua Gustafson, Hamid Ghandehari

University of Utah: Departments of Pharmaceutics & Pharmaceutical Chemistry and Bioengineering

Objective: To improve intratumoral delivery of adenoviruses encoding for thymidine kinase (Ad-TK) using recombinant silk-elastinlike protein polymer (SELP) matrices.
Methods: Recombinant liquid SELP analogues with similar silk to elastin repeat ratios but different lengths, namely SELP-47K with 4 silklike and 8 elastinlike units per block and SELP-815K with twice as many silk and elastin units per block, were mixed with Ad-TK containing a luciferase gene. Virus-SELP mixtures were directly injected into subcutaneous xenograft tumors of human head and neck carcinomas in nude mice where they formed hydrogels at body temperature. The prodrug ganciclovir was administered at 25 mg/kg body weight to the mice daily for 10 days. Anticancer efficacy was measured by tumor volume reduction. Duration and localization of gene expression were evaluated by a bioluminescent imaging system 30 minutes after injection of luciferin twice per week.
Results: SELP-815K at 4 wt% efficiently improved the duration and extent of transfection of Ad-TK in head and neck tumors for up to 5 weeks with no detectable spread to the liver. Both SELP 815K and SELP 47K resulted in a more pronounced antitumor response; however SELP 815K displayed a longer term result. About a five-fold greater reduction in tumor volume was obtained with matrix-mediated delivery compared to intratumoral injection of adenoviruses in saline.
Conclusions: With systematic control over the structure of SELPs using recombinant techniques, it is possible to design matrices that maximize the delivery of adenoviral gene vectors to head and neck tumors and minimize dissemination to nontarget sites.

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## NM-P32

"Piezoresponse Atomic Force Microscopy of Prestin-transfected HEK-293 Cells"

Presenter: Micah Frerck

Melany Moras, Massood Tabib-Azar, Richard Rabbitt

University of Utah: Departments of Bioengineering and Electrical & Computer Engineering

The proposed research will establish whether the conformational transition of prestin, the motor protein in outer hair cells of the cochlea, is responsible for both charge transfer and changes in membrane area. Debate has been put forth suggesting that the nonlinear capacitance measured in prestin transfected cells is the result of anion transport and that prestin may not be directly involved in changing the

membrane surface area. The electromechanical properties of prestin will be investigated using a new atomic force scanning technique based on piezoresponse. HEK-293 cells transfected with prestin will be influenced by an external electrical field, either whole cell or localized to the cantilever tip, and the electromechanical response of the motor protein will be measured via the deflection of the atomic force cantilever. Successful implementation of piezoresponse atomic force microscopy may enable future work to definitively identify transmembrane prestin in topography scans, measure the conformational force elicited by prestin, conclude the frequency response of prestin, investigate the conformational transition geometry, and may lead to future work revealing the conformational geometry of ion channels and transporters.

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## NM-P33

"Nanoparticle Interactions with Low-Frequency Electromagnetic Fields for Ablation Therapy"

Presenter: Scott Jensen

Timothy E. Doyle

Utah State University: Department of Physics

The in vivo ablation of malignant tumors can be significantly enhanced with nanoparticles (NPs) that absorb energy from electromagnetic (EM) waves and subsequently heat targeted regions in the body. NP excitation with low-frequency EM fields is a particularly exciting approach for ablating deep tissues where near-infrared and visible light cannot penetrate. Ohmic heating has primarily been the sole mechanism considered to date for the coupling of the EM fields to the NPs, and few quantitative analyses have been published that predict NP heating. To address this issue, this study identified and modeled four excitation mechanisms for the remote heating of NPs by low-frequency EM waves. These mechanisms included (1) ohmic heating of conductive NPs, (2) translational vibrations of charged NPs, (3) rotational vibrations of piezoelectric NPs, and (4) acoustic wave generation by piezoelectric NPs. The models used a classical approach with an incident EM field of 1.0 watt/cm$^2$, EM frequencies from $10^5$-$10^8$ Hz, a tissue viscosity equal to blood, and NP radii of 5-50 nm. Preliminary results showed that for a constant NP volume, the heating rate is independent of NP size for ohmic heating. Additionally, ohmic heating produced far lower heating rates than the other three mechanisms. The highest heating rates were produced by acoustic wave generation. The results indicate that mechanisms other than ohmic heating may significantly contribute to the low-frequency EM heating of NPs in tissues, and point to possible new NP technologies to optimize heating rates and tumor ablation in patients.

## NM-P34

"Self-Assembled Hydrogels from Poly(HPMA) with Pendant -Sheet Peptide Domains"

Presenter: Larisa Cristina Radu-Wu

Jiyuan Yang, Kuangshi Wu, Jindrich Kopecek

University of Utah: Departments of Bioengineering and Pharmaceutics & Pharmaceutical Chemistry

A new hybrid hydrogel based on a βsheet peptide conjugated as grafts on poly[N-(2-hydroxypropyl) methacrylamide] [poly(HPMA)] was proposed. For its synthesis, a de-novo undecapeptide, Beta11 (acetyl-TTRFTWTFTTT-amide), was modified at its N-terminus with CGG tripeptide spacer to form CGGTTRFTWTFTTT-amide, then coupled onto maleimido-terminated side chains of poly(HPMA), via thioether bonds. Circular dichroism and fluorescent thioflavin T (ThT) binding indicated that the strong tendency of the peptide to self-assemble into βsheets was retained after conjugation with the polymer. Moreover, poly(HPMA) had a shielding effect, decreasing βsheets sensitivity to temperature and pH variations, and favoring the preferential binding of the ThT dye. Transmission electron microscopy showed that poly(HPMA)-g-CGGBeta11 fibrils formed matrices with minimal lateral aggregation, dramatically different from the highly aggregated peptide fibrils. The tendency of the peptide to form hydrogels was preserved in the copolymer, as showed by microrheology, depending on the density of the grafts, concentration, and incubation time. Gels, depicted by plateau formation in mean square displacements and higher G' values compared to G", were formed in the peptide at concentrations as low as 0.8 wt%, whereas higher concentrations, 3 wt%, were needed for the copolymer. Investigation of networks morphology, done by scanning electron microscopy, revealed that the copolymer hydrogel was characterized by uniformly aligned lamellae, a result of the self-assembly process.

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## NM-P35

"Drug-Free Macromolecular Therapeutics: Induction of Apoptosis by Coiled-Coil Mediated Crosslinking of Antigens on Cell Surface"

Presenter: Kuangshi Wu

Jihua Liu, Russell N. Johnson, Jiyuan Yang, Jindrich Kopecek

University of Utah: Departments of Bioengineering and Pharmaceutics & Pharmaceutical Chemistry

A new paradigm was designed for apoptosis induction mediated by the biorecognition of peptide segments at the Raji B cell surface, using CD20 as the target antigen. CD20 is one of the most reliable biomarkers for B cell non-Hodgkin lymphoma (NHL). It is a non-internalizing antigen; it remains on the cell surface when bound to a complementary antibody. However, crosslinking with a secondary antibody results in apoptosis. We designed a system composed of a pair of oppositely charged pentaheptad peptides (CCE and CCK) that form antiparallel coiled-coil heterodimers, Fab' fragment of the 1F5 anti-

CD20 antibody, and N-(2-hydroxypropyl)methacrylamide (HPMA) copolymer. CCE was attached to Fab' fragment of 1F5 antibody specific for CD20 (Fab'-CCE). Multiple copies of the complementary peptide, CCK, were attached as grafts to HPMA copolymer (CCK-P). The exposure of CD20+ human Burkitt's NHL Raji B cells to Fab'-CCE resulted in the decoration of cell surface with the CCE peptide. Further exposure of the decorated Raji B cells to HPMA copolymer grafted with multiple copies of CCK resulted in the formation of CCE-CCK coiled-coil heterodimers on the cell surface. This biorecognition process induced crosslinking of CD20 receptors and triggered apoptosis of Raji B cells. The apoptosis was verified by caspase 3, Annexin V/propidium iodide, and TUNEL assays. The fact that biorecognition of coiled-coils at cell surface occurred in media containing 10% of bovine serum indicates the specificity of the CCE – CCK interaction and bodes well for future in vivo experiments and for the development of efficient drug-free macromolecular therapeutics.

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## NM-P36

"Synthesis, Characterization and Biological Evaluation of PEGylated Gold Nanorods"

Presenter: Adam Gormley

Joe Hui, Alexander Malugin, Abhijit Ray, Margit Janat-Amsbury, Hamid Ghandehari

University of Utah: Departments of Pharmaceutics & Pharmaceutical Chemistry, Bioengineering, School of Medicine, Center for Nanomedicine, and Nano Institute of Utah

Objectives: To synthesize PEGylated gold nanorods (GNRs), investigate their cellular uptake and toxicity in prostate cancer cells, and biodistribution in mice.
Methods: GNRs were synthesized using a seed-mediated growth method and surface functionalized with polyethylene glycol for stability under physiological conditions. Characterization of size, charge, concentration, and aggregation was performed by TEM, DLS, ICP-MS, and UV-Vis-NIR respectively. Cytotoxicity was evaluated using a WST-8 assay in DU145 prostate cancer cells and uptake was observed by transmission electron and dark field microscopy. In vivo biodistribution of the GNRs was assessed in Female C57BL/6 immunocompetent black mice.
Results: PEGylated GNRs were synthesized to be 10x45 nm in size. They remained stable as colloids in 3.5% NaCl. No inhibition of mitochondrial function was observed after GNR exposure to prostate cancer cells indicating no apparent toxicity. GNRs were uptaken as aggregates and ultimately transported in vesicles to the perinuclear regions. Uptake was energy dependent suggesting an endocytotic mechanism was involved. Injected GNRs were uptaken by the liver and spleen within two hours with some gold detected in the blood after 24 hours.
Conclusion: PEGylated GNRs are non-toxic and taken up by prostate cancer cells. This coupled with the ability to surface functionalize them with targeting moieties make GNRs suitable candidates for photothermal ablation and tumor therapy.
Acknowledgements: Support provided by NIH (R01DE019050), NSF (ID 0835342), USTAR and Medical Student Research Program (JH).

## NM-P37

"Synthesis and Biological Evaluation of HPMA Copolymer-docetaxel-RGDfK Conjugates"

Presenter: Alexander Malugin

Abhijit Ray, and Hamid Ghandehari
University of Utah: Departments of Pharmaceutics & Pharmaceutical Chemistry, Bioengineering, Center for Nanomedicine, and Nano Institute of Utah

Sachin Naik
The Maharaja Sayajirao University of Baroda, India: Department of Pharmacy

N-(2-hydroxypropyl)methacrylamide (HPMA) copolymers containing RGDfK in the side chains targeted to avb3 receptors have shown promise in targeted cancer therapy. In this work a monomeric derivative of docetaxel containing the lysosomally degradable tetrapeptide glycylphenylalanylleucylglycine (GFLG) spacer was copolymerized with HPMA comonomers. RGDfK was further attached to the pendant p-nitrophenyl esters of the copolymers by aminolysis. The targeteable conjugates were characterized for their molecular weight and molecular weight distribution, hydrodynamic volume, and drug and targeting peptide contents. The copolymers had drug content of 0.128 mmol/g and peptide content of 0.123 mmol/g respectively with an average molecular weight of 28 kDa. The stability of conjugates in PBS was confirmed and drug release in the presence of Cathepsin B evaluated. Conjugates, similar to free drug, inhibited proliferation of BT-20 (breast) and HCT116 (colorectal) cancer cells at nanomolar concentrations. Incubation of both cell lines with the conjugates resulted in the formation of large multinucleated cells suggesting mitosis aberration, more pronounced in slow proliferating BT-20 cells. These observations were corroborated by DNA content analysis demonstrating that up to 90% of cells from both cell lines were accumulated in G2/M phase of cell cycle after 24 h incubation with drugs showing their inability to complete the mitosis. Annexin V/PI assay revealed that over 50% of BT-20 cells were undergoing apoptosis after 48 h continuous incubation with both free and conjugated drugs. The ester bond containing conjugates demonstrated a low stability in plasma suggesting further modifications of the current design are needed for targeted delivery of docetaxel.

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# Energy, Catalysis & Environment

## EC-P46

"Ferritin as a Photocatalyst in an Artificial Photosynthesis System"

Presenter: Robert J. Hilton

Jeremiah D. Keyes, Richard K. Watt

Brigham Young University: Department of Chemistry & Biochemistry

Alternate fuel sources are becoming increasingly important as the reserve of fossil fuels decreases. We describe a bio-photocatalyst based on the iron storage protein ferritin. The ferritin protein naturally sequesters ferrihydrite inside a spherical 12 nm protein shell. Ferrihydrite is a semi-conductor material that functions as a photocatalyst in aqueous solvents. Ferritin has been shown to photoreduce Au(III) and Cu(II) ions in solution to form 10–30 nm Au(0) and Cu(0) nanoparticles. Citrate acts as a sacrificial electron donor to supply electrons for the photoreduction. We describe studies designed to understand the mechanism of this catalyst in order to improve the efficiency of the reaction. We have developed a spectrophotometric assay to simultaneously illuminate the sample and kinetically monitor the formation of products. We report that buffers containing sulfur significantly increase the rate of the reactions. The absence of salt can completely inhibit the reaction. Control reactions with colloidal ferrihydrite nanoparticles do not catalyze the photochemical reaction but produce a black magnetic precipitate indicating that the protein shell has an important function in nanoparticle formation. To substantiate this hypothesis, studies were done with H and L homopolymers of ferritin. The results show that the H homopolymers were more effective in nanoparticle formation than the L homopolymers. Interestingly, the homopolymers were more efficient than the natural heteropolymer of H & L ferritins found in horse spleen ferritin. Finally, the sacrificial electron donor citrate appears to play an additional role as an intermediate in the photochemical reaction.

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## EC-P47

"Photoreduction of Au(III) to Form Au(0) Nanoparticles Using Ferritin As a Photocatalyst."

Presenter: Jeremiah D. Keyes

Robert J. Hilton, Richard K. Watt

Brigham Young University: Department of Chemistry & Biochemistry

Gold metal nanoparticles are catalysts that have applications in bio-sensing technology, nano-tube formation, and cancer therapy, but are difficult to form reproducibly in a tight, well-defined size distribution. We describe efforts to synthesize gold nanoparticles within the ferritin cavity (8 nm) or using ferritin as a scaffold for coating gold on the outside surface (12 nm). Previously, ferritin was shown to function as a photocatalyst for the reduction of copper ions in solution. We used a Xenon-

Mercury lamp system to photo-reduce gold ions to form gold nanoparticles. A variety of buffers and salt concentrations were tested and significantly influenced the final products formed. The timing of sample illumination had a significant impact on the products formed. Using Tris buffer, gold nanoparticles formed only in the presence of light. These particles had spherical morphology and a narrow size distribution of 5.7 ± 1.6 nm. MOPS buffer by itself slowly reduces gold, whereas reactions with light occur more rapidly. Two different synthetic routes using MOPS buffer have been employed and are dependent on the timing of illumination of the sample after gold is added. When gold is added without light, a dark purple solution slowly forms with a broad size distribution of irregularly shaped particles ranging in size from 3-30 nm. When gold is added while the sample is illuminated a reddish purple solution forms with spherical particles in the 3-10 nanometer range, similar to the reaction performed with Tris buffer.