Nanoengineered Assemblies and Advanced Micro/Nanosystems
Nanoengineered Assemblies and Advanced Micro/Nanosystems

Symposia held April 13–16, 2004, San Francisco, California, U.S.A.

EDITORS:

David P. Taylor
The Aerospace Corporation
El Segundo, California, U.S.A.

Jun Liu
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

David McLlroy
University of Idaho
Moscow, Idaho, U.S.A.

Lhadi Merhari
Ceranec
Limoges, France

J.B. Pendry
Imperial College London
London, United Kingdom

Jeffrey T. Borenstein
Charles Stark Draper Laboratory
Cambridge, Massachusetts, U.S.A.

Piotr Grodzinski
Los Alamos National Laboratory
Los Alamos, New Mexico, U.S.A.

Luke P. Lee
University of California-Berkeley
Berkeley, California, U.S.A.

Zhong Lin Wang
Georgia Institute of Technology
Atlanta, Georgia, U.S.A.
CONTENTS

Preface: Symposium O ................................................................. xiii
Preface: Symposium R: ................................................................. xv
Materials Research Society Symposium Proceedings ................................ xvii

SYMPOSIUM O

SELF-ASSEMBLED MATERIALS

* The Fabrication of Self-Assembling Peptides Into Nanofiber Scaffolds Through Molecular Self-Assembly .................................................... 3
  Xiaojun Zhao, Jessica Dai, and Shuguang Zhang

INTERFACIAL SCIENCES AND NOVEL MICROSYSTEMS/MICRODEVICES

* Magnetic and Electric Manipulation of a Single Cell in Fluid .................. 17
  Hakho Lee, Tom P. Hunt, and Robert M. Westervelt

* Actin Nanotacks for Hybrid Nanodevices Based on Linear Protein Molecular Motors ................................................................. 25
  G.S. Watson, C. Cahill, J. Blach, S. Myhra, Y. Alexeeva,
  E.P. Ivanova, and D.V. Nicolau

Covalent Immobilization of DNA and Hybridization on Microchips by Microsecond Electric Field Pulses ............................................. 37
  F. Fixe, H.M. Branz, D.M.F. Prazeres, V. Chu, and J.P. Conde

Optoelectronic Detection of DNA Molecules Using an Amorphous Silicon Photodetector ................................................................. 43
  F. Fixe, D.M.F. Prazeres, V. Chu, and J.P. Conde

*Invited Paper
NANOPARTICLE SYNTHESIS AND APPLICATIONS

Characterization of Alumina and Silica Sol-Gel Encapsulated Fe/Co/Ru Nanocatalysts in Microchannel Reactors for F-T Synthesis of Higher Alkanes ................................................................. 51
D. Kuila, V.S. Nagineni, S. Zhao, H. Indukuri, Y. Liang,
A. Potluri, U. Siriwardane, N. Seetala, and J. Fang

Reaction and Diffusion Dynamics in a Microfluidic Format .............................. 57
Dietrich Kohlheyer, Rob G.H. Lammertink,
Stefan Schlautmann, Geert A.J. Besselink, Paul Vulto,
and Richard B.M. Schasfoort

Targeting Magnetic Nanoparticles in High Magnetic Fields for Drug Delivery Purposes ................................................................. 63
Ramazan Asmatulu, Richard O. Claus, Judy S. Riffle,
and Michael Zalich

Photophysical Properties of CdS Nanoparticles in Thin Films for Opto-Chemical Sensing ................................................................. 69
Elena A. Guliants, Barbara A. Haruff, James R. Gord,
and Christopher E. Bunker

Decoration of Carbon Nanotubes With Gold Nanoparticles for Catalytic Applications ................................................................. 75
Wei Lü, Xicheng Ma, Ning Lun, and Shulin Wen

NANOMATERIALS AND NANOFABRICATIONS IN MICROSYSTEMS AND MICRODEVICES I

Carbon Nanotube-Based Permeable Membranes ............................................. 83
Jason K. Holt, Hyung Gyu Park, Olgica Bakajin,
Aleksandr Noy, Thomas Huser, and David Eaglesham

* Experimental Study of Filling Carbon Nanotubes With Nucleic Acids ................................................................. 89
Daxiang Cui, Cengiz S. Ozkan, Yong Kong, and
Huajian Gao

Control of Doping and Electronic Transport in Nanowires .......................... 101
Jianxin Zhong and G. Malcolm Stocks

*Invited Paper
Integrating Carbon Nanotubes for Atomic Force Microscopy
Imaging Applications ............................................................... 107
Qi Ye, Alan M. Cassell, Hongbing Liu, Jie Han, and Meyya Meyyappan

TISSUE ENGINEERING

Use of Soft Lithography for Multi-Layer MicroMolding
(MMM) of 3D PCL Scaffolds for Tissue Engineering ...................... 115
Yang Sun, Nicholas Ferrell, and Derek J. Hansford

Design and Fabrication of a Constant Shear Microfluidic
Network for Tissue Engineering .................................................. 121
E.J. Weinberg, J.T. Borenstein, M.R. Kaazempur-Mofrad,
B. Orrick, and J.P. Vacanti

* NanoLiterBioReactor: Monitoring of Long-Term Mammalian
Cell Physiology at Nanofabricated Scale ...................................... 127
Ales Prokop, Zdenka Prokop, David Schaffer, Eugene Kozlov,
John Wikswo, David Cliffel, and Franz Baudenbacher

Development of Self-Assembled Muscle-Powered Microdevices .......... 139
Jianzhong Xi, Jacob J. Schmidt, and Carlo D. Montemagno

NANOMATERIALS AND NANOFABRICATIONS IN
MICROSYSTEMS AND MICR DEVICES II

Novel Chemical Approach to Achieve Advanced Soft
Lithography by Developing New Stiffer, Photocurable
PDMS Stamp Materials .................................................................. 147
Kyung M. Choi and John A. Rogers

Liquid Phase Deposition of Poly(ethylene terephthalate) Films .......... 155
Robert M. Bryce, Hue T. Nguyen, Rik R. Tykwinski,
Ray G. DeCorby, Mark R. Freeman, and Ying Y. Tsui

INTEGRATED MICROANALYSIS

Ion Channel Sensor on a Silicon Support ....................................... 163
Michael Goryll, Seth Wilk, Gerard M. Laws,
Stephen M. Goodnick, Trevor J. Thornton, Marco Saraniti,
John M. Tang, and Robert S. Eisenberg

*Invited Paper
POSTER SESSION

Rapid Prototyping of Glass Microfluidic Devices Using Femtosecond Laser Pulses .................................................. 171
Myung-Il Park, Jun Rye Choi, Mira Park, Dae Sik Choi,
Sae Chae Jeoung, and Chong-Ook Park

Optimization of Mechanical Properties of Thin Free-
Standing Metal Films for RF-MEMS .............................................. 177
Jaap M.J. den Toonder and Auke R. van Dijken

Microstructural Design and Evaluation of Porcelain/
Mullite/Alumina Layered Structure for Dental Application ........................................... 183
Hyung-Jun Jang, Dong-Ho Park, Yeon-Gil Jung, and
Hee-soo Lee

Low Coherence Interferometric Metrology for Ultra-Thin
MEMs Structures ................................................................. 189
Wojciech Walecki, Frank Wei, Phuc Van, Kevin Lai,
Tim Lee, Vitali Souchkov, S.H. Lau, and Ann Koo

Tuning the Mechanical Properties of Poly-Silicon Film by
Surface Modification Using Plasma Treatment ........................................... 195
Wang-Shen Su, Weileun Fang, and Ming-Shih Tsai

Fabrication and Characterization of Platinum-Iridium
Electrodes With Micro-Structured Surfaces for Neural
Stimulation Applications ............................................................. 201
Sachin S. Thanawala, Daniel G. Georgiev, Afzal Khan,
Ronald J. Baird, and Gregory Auner

Electroactive Polymer Deformable Micromirrors (EAPDM)
for Biomedical Optics ............................................................. 207
Cheng Huang, Bo Bai, Baojun Chu, Jim Ding, and
Q.M. Zhang

A Multi-Layer Technology for Biocompatible Polymer
Microsystems With Integrated Fluid and Electrical
Functionality ................................................................. 215
Eileen D. Moss, Arum Han, and A. Bruno Frazier

Synthesis and Characterization of Ag Nanoparticle,
Ag-TiO₂ Nanoparticle and Ag-TiO₂-Chitosan Complex
and Their Application to Antibiosis and Deodorization ........................................... 221
Young Hwan Kim and Young Soo Kang
A Study of the Growth Curves of C. xerosis and E. coli Bacteria in Mediums Containing Cobalt Ferrite Nanoparticles

Marjorie Flores, Nanell Colón, Omayra Rivera, Nicole Villaalba, Yahira Baez, David Quispitupa, Javier Avalos, and Oscar Perales

NANO AND BIO MICROSYSTEMS AND DEVICES

Integrating Biomaterials Into Microsystems: Formation and Characterization of Nanostructured Titania

Zuruzi Abu Samah, Blaine C. Butler, Emily R. Parker, Ayesha Ahmed, Heather M. Evans, Cyrus R. Safinya, and Noel C. MacDonald

Impedance-Based Biosensors

X. Huang, D.W. Greve, I. Nausieda, D. Nguyen, and M.M. Domach

* From an Integrated Biochip Detection System to a Defensive Weapon Against the SARS-CoV Virus: OBMorph


SYMPOSIUM R

PHOTONIC STRUCTURES

* Polariton-Enhanced Near Field Lithography and Imaging With Infrared Light

Gennady Shvets and Yaroslav A. Urzhumov

* Fabrication of 2D and 3D Photonic Bandgap Structures Using Laser-Assisted Imprinting of Self-Assembled Particles


Synthesis and Self-Assembly of Metal-Coated Nanoparticles

W. Park and T. Borsa

*Invited Paper
Fabrication of Two-Dimensional Photonic Structure of Titanium Dioxide With Sub-Micrometer Resolution by Deep X-ray Lithography

Koichi Awazu, Makoto Fujimaki, Xiaomin Wang, Akihide Sai, and Yoshimichi Ohki

Fabricate Photonic Crystals Based on ZnS/Opal System via Solvothermal Method

Jieming Cao, Xin Chang, Lijia Pan, Hongmei Ji, Jinsong Liu, Jie Feng, Fang Zhang, Haiyan Wang, Jie Tao, and Guoyue Xu

PHOTON, ELECTRON AND ION BEAM APPROACHES TO NANOFABRICATION

* Implanted 3D Micro/Nano-Structure Fabrication: New Processing Techniques for the Creation of Nanoscale Opto-Mechanical Machines in Silicon Dioxide on a Silicon Wafer

Meg Abraham

Ion Beam Lithographic Fabrication of Ordered VO_2 Nanoparticle Arrays


Patterning and Reactive Ion Etching of Diamond Films Using Light Coupling Masks

Patrick W. Leech, Geoff K. Reeves, and Anthony S. Holland

SELF-ASSEMBLY: FABRICATION AND CHARACTERIZATION

Morphologically Well-Defined Gold Nanoparticles Embedded in Thermo-Responsive Hydrogel Matrices

Chun Wang, Nolan T. Flynn, and Robert Langer

Fabrication of Ordered Sub-Micron Topographies on Large-Area Poly(Urethane Urea) by Two-Stage Replication Molding

Keith R. Milner, Mallory Balmer, Henry J. Donahue, Alan J. Snyder, and Christopher A. Siedlecki

*Invited Paper
Investigation of the Layer-by-Layer Assembly of Colloid Crystals on a Templated Substrate ......................................................345
Sonia Grego, Thomas Jarvis, Brian Stoner, and Jay Lewis

Influence of H2 Preconditioning on the Nucleation and Growth of Self-Assembled Germanium Islands on Silicon (001) .........................351
Gabriela D.M. Dilliway, Nicholas E.B. Cowern, Lu Xu,
Patrick J. McNally, Chris Jeynes, Ernest Mendoza,
Peter Ashburn, and Darren M. Bagnall

Formation of Three-Dimensional Ni Nanostructures for Large Area Catalysts .................................................................357
J.D. Carey, S.J. Henley, E. Mendoza, C.E. Giusca,
A.A.D.T. Adikaari, and S.R.P. Silva

Anatase Inverse Opal: Preparation and Electrochemical Properties ..........................................................363
Marketa Zukalova, Martin Kalbac, and Ladislav Kavan

DESIGN, APPLICATION, CHARACTERIZATION AND SIMULATIONS OF NANOSTRUCTURED MATERIALS

* Atomic Force Microscopy Applications to Neuroscience .................................................................371
Helen A. McNally

* Microfluidics and Beyond—Devices for Applications in Biotechnology ...........................................................381
Martina Daub, Rolf M. Kaack, Oliver Gutmann,
Chris P. Steinert, Remigius Niekrawietz, Peter Kolay,
Bas de Heij, and Roland Zengerle

* Three-Dimensional Representation of Curved Nanostructures ...........................................................393
Z. Huang, D.A. Dikin, W. Ding, Y. Qiao, Y. Fridman,
and R.S. Ruoff

Ab Initio Structural Properties and Stress-Deformation Analysis by Rheological Modeling of Diamonds-Containing Nanocarbon Nanotubes .........................................................401
Maksim V. Kireitseu and Liya Bochkaryova

*Invited Paper
PREFACE

SYMPOSIUM O

Nanotechnology holds the promise of an entirely new class of materials and a new generation of microdevices with superior properties and performance. Governments world-wide are now investing an estimated $2.0 billion dollars a year to explore this new area of science and technology. The successful integration of nanotechnology and microtechnology is expected to have enormous technological and economic benefits. Microsystems, including microelectromechanical systems (MEMs), bioMEMs, nanoelectromechanical systems (NEMs), optical, electronic, and electrochemical microsystems, have great potential for many applications ranging from advanced computing, chemical and biological analysis/detection, drug delivery/discovery, tissue engineering, chemical and materials synthesis, to energy conversion and storage. New advanced microsystems with integrated nanometer scale structures and functions present a multidisciplinary challenge. The performance of such microsystems also depends on the understanding of the properties on both the nano- and micro- scales. Therefore, advanced microsystems provide an ideal platform to bridge the “top-down” approach that has been widely used in industry for microdevices, and the “bottom-up” approach that has been widely investigated for new materials and devices. Recently, the Review Committee of the National Nanotechnology Initiatives recommended: “Revolutionary change will come from integrating molecular and nanoscale components into high order structures. ... To achieve improvements over today’s systems, chemical and biologically assembled machines must combine the best features of the top-down and bottom-up approaches.”

Many symposia had been organized on synthesis and characterization of nanomaterials, and on microfluidic and microelectronic systems. Symposium O, “Advanced Microsystems—Integration with Nanotechnology and Biology,” held April 13–16 at the 2004 MRS Spring Meeting in San Francisco, California, was unique because it provided an international forum to focus on integration of advanced microsystems with biomaterials, and also provided the latest developments in nanomaterials and nanotechnology. This symposium addressed scientific and technology challenges in materials science for advanced nano- and microsystems, novel concept, design, devices or systems/architectures with functions and structures spanning many length scales, integration and development of multiscale fabrication tools and methodologies, integration of biological and synthetic materials and control of the interface between biological and non-biological components, control of optical and electronic energy transfer coupled across multiple length scales, coupling of mechanical forces across nano-, micro- and larger scales, including the control of fluidic transport, and understanding and predicting fundamental behavior and reliabilities of materials and systems. Experts in materials sciences, chemistry, biology, and microtechnology participated in this symposium. The first half of this proceedings contains most of the exciting results presented at Symposium O, which we hope will become valuable references to scientists and engineers who work in these areas.

Jun Liu
Jeffrey T. Borenstein
Piotr Grodzinski
Luke P. Lee
Zhong Lin Wang

June 2004
PREFACE

SYMPOSIUM R

Both of the three-dimensional nanoengineered assemblies symposia that have been held by the Materials Research Society were intended to bring together researchers from a wide range of fields. The conference topic is not focused on a particular area of research, but on a goal that is being pursued by many groups approaching from diverse directions. There were only a handful of papers that presented true "3D nanoengineered assemblies" at the first meeting in the Fall of 2002. It was anticipated that most of the papers would be either "not quite truly 3D" or "3D but not quite on the nanoscale." The first symposium was directed at both the fabrication methods for creating these structures in materials as well as understanding the phenomena that make possible unique applications for these materials. By the time of the second symposium, Symposium R, "Three-Dimensional Nanoengineered Assemblies II," held April 12–16 at the 2004 MRS Spring Meeting in San Francisco, California, there had been significant progress in realizing these materials and many of the most interesting phenomena have become the focus of very active areas of research.

There are many approaches with the ability to fabricate or assemble three-dimensional structures with nanoscale precision. These approaches to making 3D structures range from lithography, through beam based direct write methods, through "soft lithography" contact printing, through various pick and place methods to self-assembly. Self-assembly includes biological and biomimetic based methods which generated significant interest in "3D Nano I" and this thread has continued through the "3D Nano II" symposium. If biological processes can be understood and controlled or mimicked, then there is potential to build structures starting on the nanoscale. The directed self-assembly and the bottom-up approach to processing implicitly offers some 3D control from the nanoscale all the way to large structures. A "3D Nano II" session (with Morley Stone, Mark Hildebrand, and Ken Sandhage) explored chemical conversion of biologically created calcium carbonate structures, which may be a particularly direct path to producing useful materials.

One of the most interesting aspects of nanotechnology is the ability to access physical phenomena that occur on the nanoscale. Many of these phenomena have become prototypical examples of the promise of new technology, from catalysis and fluidics to energy storage. Photonic systems are also an important and well-known class of 3D nanoengineered systems.

A focus topic of the first "Three-Dimensional Nanoengineered Assemblies" symposium was the emerging field that has been called "plasmonics." Rufus Ritchie coined the term "plasmons" in 1957 to describe the particle-like behavior of plasma oscillations in materials. There has been an ongoing interest in these surface or bulk plasmons that run as longitudinal charge density waves inside materials or at interfaces. John Pendry has been one of the main proponents of the view that photonics and plasmonics are related on a fundamental level and that it is possible to model photonic crystals and other systems in terms of their plasmon resonances. Plasmon-related phenomena include light funnels, perfect lenses, magnetic properties from non-magnetic materials, and left-handed index materials. It may have been Harry Atwater that coined the term "plasmonics" to make the analogy between plasmon applications and electronics. The light funnel (transmission through subwavelength apertures) session with Francisco Garcia-Vidal, Tineke Thio, and Han Woerdman was one of the most active MRS sessions in our memory. The "perfect lens" talk of Gennady Shvets and the "left-handed materials" talk of David R. Smith exemplified the rapid development of this exciting area that seems very rich with applications. Many of the invited speakers were in this area of photonics and plasmonics, including a particularly inspiring talk by Eli Yablonovitch. It also seems clear from recent work in this area (particularly from the work of John Pendry and Eli Yablonovitch) that many of the future applications in the area of plasmonics will involve 3D nanoengineered assemblies.
The above commentary does not span very many of the areas presented in the symposium. In the area of microfluidics, Juan Santiago and Stephen Turner presented the tutorial session. Martina Daub presented an approach to building accurate dispensing arrays for biological applications. Meg Abraham, Richard Haglund, Hans Loeschner, Albert Polman, Z.F. Ren, and Prakash Koonath all presented beam based fabrication methods. Y.F. Lu, Paul Alivisatos’ group, and Chun Wang presented papers on nanoparticle assemblies. In addition to those already mentioned, Harry Atwater, Axel Scherer’s group, Chris Berven, Naomi Halas, Vladimir Shalaev, and Anand Gopinath presented plasmonics/photonics talks. A number of approaches were presented for using contact fabrication methods, including John Rogers’ lead off talk on soft lithography. Armand Rosenberg and Robert Rudd presented the results of their simulations. Pick and place assembly schemes ranged from Helen McNally’s AFM manipulation of biological species to Rodney Ruoff’s nanorobots.

A large number of excellent talks presented interesting work in this symposium. Part of the success of this symposium is that it touches on a presently topical aspect of research. However, the real strength of this meeting was the multidisciplinary character of the entire symposium. This symposium succeeded in presenting a snapshot of the current work in this topic to researchers, in keeping with the best traditions of the Materials Research Society Meetings. Finally, the success of the symposium is a direct result of the generous support we received from the Air Force Office of Scientific Research and the National Science Foundation. The co-organizers thank the many participants who contributed by giving talks and by their presence and we look to the future to see what advances evolve from the cross-disciplinary exchange provided by this excellent symposium on three-dimensional nanoengineered assemblies.

David P. Taylor
David McLlroy
Lhadi Merhari
J.B. Pendry

July 2004
SYMPOSIUM O