11th International Symposium on MEMS and Nanotechnology

Organized by:

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Microelectromechanical systems (MEMS) and nanotechnology are revolutionary enabling technologies (ET). These technologies merge the functions of sensing, actuation, and controls with computation and communication to affect the way people and machines interact with the physical world. This is done by integrating advances in various multidisciplinary fields to produce very small devices that use very low power and operate in many different environments. Today, developments in MEMS and nanotechnology are being made at an unprecedented rate, driven by both technology and user requirements. These developments depend on micromechanical and nanomechanical analyses, and characterization of structures comprising nanophase materials.

To provide a forum for an up-to-date account of the advances in the field of MEMS and nanotechnology and to promote an alliance of governmental, industrial, and academic practitioners of ET, SEM initiated a *Symposium Series on MEMS and Nanotechnology*.

The 2010 Symposium is the eleventh in the series and addresses pertinent issues relating to design, analysis, fabrication, testing, optimization, and applications of MEMS and nanotechnology, especially as these issues relate to experimental mechanics of microscale and nanoscale structures.

It is with deep gratitude that we thank the Organizing Committee, Session Chairs, Authors, Participants, and SEM Staff for making the 11th-*ISMAN* a valuable and unforgettable experience.

Thank you very much!

Keynote Presentations:

Dr. Augustine Urbas, *Air Force Research Laboratory*
Applied Metamaterials
Monday, June 7, 10:30 AM, Session 2

Dr. Jon R. Pratt, *NIST Mass and Force Group*
Nanomechanical Standards Based on the Intrinsic Mechanics of Molecules and Atoms
Monday, June 7, 11:10 AM, Session 2

Keynote Presentation:

Augustine Urbas
Air Force Research Laboratory

Applied Metamaterials

Monday, June 7, 10:30 AM, Session 2

Metamaterials redefine the fundamental properties of systems by creating artificial, meso-scale meta-atoms which dictate the system response to external fields. When assembled into complex, structured materials, these meta-atoms and their mutual interactions can yield effective property sets that natural materials are not capable of and tailor materials properties to specific needs. With access to almost arbitrary materials properties, observation of new physical phenomena is possible. A popular example is a negative refractive index composite composed of three dimensionally arranged split ring resonators and interpenetrating wire media that enables super resolution and focusing by a flat lens at RF frequencies. Researchers have proposed that closely matched and ultracompact antennas and materials for efficient signal couplers could be built with suitably engineered metamaterials. The concept of defining the response of materials with structure extends beyond electromagnetics to mechanical response as well. While the utility of acoustic metamaterials is just beginning to be explored for tuned mechanical responses, of particular interest are systems where the effective mass and modulus are designed to match the impedance of air and allow for reflectionless propagation across material interfaces for some range of frequencies. In electromagnetic metamaterials, systems with ε or μ near zero attract attention. This range of properties can result in a superluminal, nearly instantaneous, phase front propagation for electromagnetic waves traveling through these systems. Example electromagnetic metamaterials utilize meta-atoms such as split ring resonators and some acoustic metamaterials assemble shaped inclusions in matrices to achieve novel properties such as negative effective index or negative effective mass over some frequency range. While these resonant systems incur substantial loss, the incorporation of active components into metamaterials is beginning to be explored to compensate for losses and increase operational bands. Significant interest lies in the development of novel metamaterials structures and design tools for electromagnetic and mechanical systems. One key challenge is to develop capabilities to fully analyze the properties of these systems computationally and experimentally, and to extract truly representative effective properties values. Another is fabrication of metamaterials systems on a scale relevant to the proposed application, which can include large area nanofabrication and three dimensional fabrication techniques. In the midst of this rapidly evolving field, AFRL has recently embarked on a program to determine the utility of metamaterials in applications, evaluate their technological relevance and identify areas where focused efforts can enable rapid technological insertion. An overview of current research and application potential will be presented.

Dr. Augustine Urbas earned a B.A. in Physics from the University of Chicago in 1996 and a Ph.D. in Polymer Physics and Engineering from the Massachusetts Institute of Technology in 2003. His thesis research was on the optical and morphological analysis of structured materials and nanostructures fabricated from ultra-high molecular weight block copolymers. As a post doctoral researcher at the Air Force Research Laboratory, Dr. Urbas expanded this work by investigating responsive patterned optical materials, holographic fabrication and HPDLCs with periodic and non-periodic structures. Dr. Urbas then moved on to study the nonlinearities and molecular photophysical properties of high performance chromophores as the Agile Limiters research group leader at the Air Force Research Lab, Materials Directorate, Hardened Materials Branch. Dr. Urbas is currently the Applied Metamaterials Research Lead for the Materials Directorate of AFRL. Research in this area encompasses; structured materials, self assembled optical composites, nanophotonics, adaptable/responsive materials, nonlinear materials properties and enhancements, EM properties of composite and structured media and the design and characterization of structured electromagnetic materials. His expertise includes laser spectroscopy, structured optical materials, holography and morphological characterization. Dr. Urbas has over 25 refereed publications.

Keynote Presentation:

Jon R. Pratt
NIST Mass and Force Group

Nanomechanical Standards Based on the Intrinsic Mechanics of Molecules and Atoms

J.R. Pratt, G.A. Shaw, III, D.T. Smith, *National Institute of Standards and Technology*

Monday, June 7, 11:10 AM, Session 2

For more than a decade, instruments based on local probes have allowed us to "touch" objects at the nanoscale, making it possible for scientists and engineers to probe the electrical, chemical, and physical behaviors of matter at the level of individual atoms and molecules. In principle, physical interactions on this scale are characterized by fixed, unique values that need only be reliably measured in terms of accurately realized units of force and length to serve as standards. For example, the silicon lattice spacing is often used as a convenient ruler for estimating length in atomic scale images, since this lattice spacing has been independently measured using x-ray interferometery. Recently, the force induced failure of DNA, often referred to as the overstretch condition, has been proposed as both a standard of force and length in single-molecule bio-physics experiments. Still other nanomechanical researchers have suggested that the rupture force of a single atom chain is unique to a given metal,

and that this intrinsic force can be used to calibrate atomic break junction experiments. In both these examples, a fundamental assumption is that the irreducible nature of nanoscale experimentation, in this case tensile load testing, yields consistency befitting a standard. This paper will review efforts underway at NIST to develop the instruments and capabilities to examine this fundamental assumption. We will describe new test platforms, techniques, and calibration procedures that allow us to bring accurate picoscale measurements of both length and force to bear on the problems of single molecule and single atom tensile testing.

Dr. Jon R. Pratt received the B.S. and M.S. degrees in engineering science and mechanics from Iowa State University in 1984 and 1993, respectively, and the Ph.D. degree in engineering mechanics from Virginia Polytechnic Institute and State University in 1997. His dissertation work on the nonlinear dynamics of machine tool vibrations garnered the Paul E. Torgersen Research Excellence award, one of three given annually by the Virginia Tech College of Engineering. He completed a National Research Council postdoctoral fellowship at the National Institute of Standards and Technology (NIST) before joining its Manufacturing Engineering Laboratory as a full-time staff member in 1999. He is currently the founder and principal investigator of NIST's Small Force Metrology Laboratory. His work to develop instruments and methods for the accurate calibration of nanoscale forces has been recognized by a Presidential Early Career Award for Scientists and Engineers in 2003, a Department of Commerce Silver medal in 2004, and a Nano50 award in 2008 as one of the 50 most significant technologies impacting the commercialization of nanotechnology. Dr. Pratt's general interests are in the areas of instrumentation, precision engineering, and mechanical design.