A bit more about the NIST Center for Nanoscale Science and Technology

Robert Celotta, Director

The NIST Center for Nanoscale Science and Technology

VCAT Meeting

March 6, 2007

(http://cnst.nist.gov)

Outline

- CNST Structure
- CNST Mission
- Nanofab Use
- Setting the CNST Research Agenda
- CNST Program Areas
- Staffing Progress

CNST Structure

- The CNST consists of a Research Program and the CNST Nanofab
  - The Research Program
    - Enabling nanotechnology with measurement solutions
  - The Nanofab
    - A National User Facility with state-of-the-art ***measurement*** and ***fabrication*** capabilities

CNST Mission

- CNST will:
  - provide **measurement methods**, standards and technology to support all phases of nanotechnology development from discovery to production,
  - develop and maintain a national facility, **the Nanofab**, with state-of-the-art, nanoscale fabrication and measurement capabilities
  - apply a **multidisciplinary** approach to problem solving that involves partnering with industry, academia, and other government agencies,
  - serve as a hub to **link the external nanotechnology community** to the vast measurement expertise that exists within the NIST Laboratories, and
  - help to **educate** the next generation of nanotechnologist.

Nanofab User Policy (Draft)

- The Nanofab is a nanofabrication and nanoscale measurement facility
  - Fee based, shared use
- Open to all users
  - NIST site access restrictions apply
- Fees are based on operating costs
  - Similar to the full cost recovery fees of the NSF nanocenters
- External users may apply to have a portion of their fee waived
  - For research supportive of CNST goals
  - Net charges similar to NNIN “academic” rates
- The Nanofab will train users in tool use
  - Alternatively, the process can performed by a process engineer at an additional cost
- User can maintain IP rights under certain circumstances
- For information about use of the Nanofab
  - Contact Dr. Gerard Henein, the Nanofab Manager (gerard.henein@nist.gov)
  - Contact Dr. Alex Liddle (alex.liddle@nist.gov), if a joint research project is more appropriate

Steering CNST's Research Agenda

- Program areas reflect the measurement needs of emerging nanotechnologies
- Identification process is thorough and continuous
  - US Measurement System Survey
  - Government Reports (NNI, European, Asian, etc.)
  - Direct Industrial Contacts (GE, Motorola, Intel, SIA, TIA, Zyvex, Agilent, etc.)
  - Research Community Input (Meetings, workshops, reports, advisors, NRC Panel, VCAT, SRC, etc.)
  - NIST Laboratory Staff (NanoSWG, and direct contact)
  - CNST Research Staff (Leading experts in their fields)

New Programs Under Construction

Developing measurement capabilities for:

- **Post-CMOS Electronics**
  - Devices, architectures, interconnects
- **Nanomanufacturing and Nanofabrication**
  - Top-down and bottom-up fabrication and assembly
- **Energy**
  - Conversion, storage, and transport

- Complementary to and interactive with strong, existing NIST Laboratory programs
- Hiring scientific leaders to build programs
- Areas of concentration will, of necessity, change with needs

Developing Measurement Capabilities for Post-CMOS Electronics

- Characterization of Transport in Nanoscale Devices
  - Establishing a method and facility for nanoscale transport measurements
- 3D Measurement of Dopants and Defects
  - Application of atom probe and other methods to get a full 3-D picture of nanostructures
- Characterization of Nanophotonic Devices
  - Establishing the near range and far range interactions of nanostructures with light
- Spin Metrology
  - Detect spins with greater sensitivity and spatial resolution

(Hire made, interviewing, advertising)

Developing Measurement Capabilities for Nanomanufacturing and Nanofabrication

- Scanned Force Microscopy for Detection and Quality Control
  - Increase the speed, selectivity, and applicability of SFM
- Coupling Nanoscale Properties to Macroscopic Behavior
  - Computational framework to allow coupling nanodevices to the macro world
- Assembly of Nanoparticles
  - Measurement of the forces between nanoparticles in assembly
- Simultaneous Multi-function Nano-probe Measurement
  - Use of MEMs technology to establish multiprobe capability
- Tools for Manipulating Material on the Nanoscale
  - Integration of a variety of approaches to provide a nano-toolbox

(Hire made, interviewing, advertising)

Developing Measurement Capabilities for Energy Conversion, Storage, and Transport

- Nanoscale carrier dynamics
  - New probes of fast processes on the nanoscale to improve solar conversion devices
- Imaging catalysis at the atomic scale
  - New high temperature, high pressure imaging methods to allow the development of catalysts with greater efficiency in conversion and use of materials

(Hire made, interviewing, advertising)

Staffing

The following researchers have either arrived or accepted an offer to work at CNST

• Andrew Berglund.	Physics, Ph.D.	Caltech
• Marc Cangemi*	Process Engineering, B.S.	RIT, Photronics
• Seok-Hwan Chung	Physics, Ph.D.	University of Maryland, ANL
• Nathan Guisinger	Physics, Ph.D.	University of Illinois
• James Hanssen	Physics, Ph.D.	Rice University
• Christian Heiliger	Physics, Ph.D.	Martin Luther University, Halle
• Emily Jarvis	Chemistry, Ph.D.	UC Los Angeles
• Richard Kasica*	Material Science, M.S.	Bell Labs, Oak Ridge NL
• Henri Lezec (8/07)	Electrical Engineering, Ph.D.	MIT, CNRS (Strasbourg), CalTech
• Alex Liddle	Materials Science, Ph.D.	Oxford, Lawrence Berkeley NL
• Matthew McMahon	Physics, Ph.D.	Vanderbilt University
• Gregory Rutter	Physics, Grad Student, B.S.	Georgia Tech
• Young Jae Song	Physics, Ph.D.	Seoul National University, Seoul
• Kartik Srinivasan (8/07)	Physics, Ph.D.	CalTech
• Gila Stein	Chemical Engineering, Ph.D.	UC Santa Barbara

*Nanofab appointment made (2 more in process)

More about the NIST Center for Nanoscale Science and Technology

Robert Celotta, Director

The NIST Center for Nanoscale Science and Technology

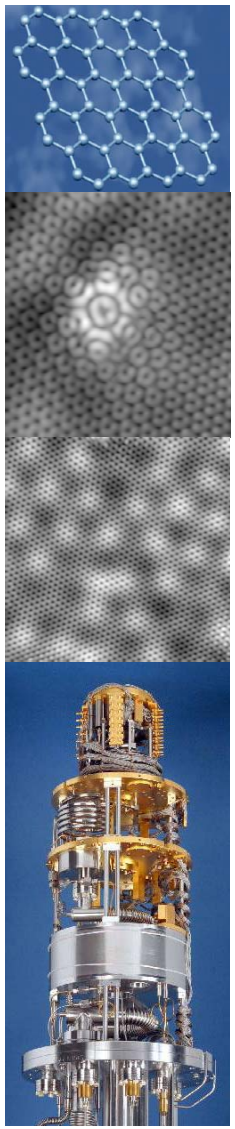
VCAT Meeting

March 6, 2007

(http://cnst.nist.gov)

NIST-Wide Four-Year Nanotechnology Program Development Plan

FY2007	FY2008	FY2009	FY2010	Theme
Nanomanufacturing - reliability and standards	Mechanical properties of nanostructures	3D Fabrication & assembly of nanostructures	Nanomanufacturing of post-CMOS electronics	Manufacturing
Advanced 2D structural imaging & characterization	3D imaging and characterization	Atomic scale measurement & characterization	Bottom-up assembly of nanostructures	Characterization
Nanomagnetics – high frequency & high resolution metrology	Simulation & modeling of nanostructures	Measurements and standards in support of nanophotonics	Standards for nanobiological & nanomedical devices	Devices
Advanced lithography – novel nanofabrication & soft matter	Measurements & standards in support of ultimate CMOS	Measurements & standards in support of post-CMOS electronics I	Measurements & standards in support of post-CMOS electronics II	Electronics

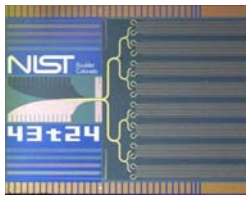


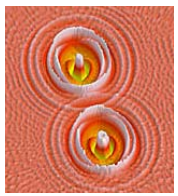
Present:

- Post - CMOS electronics
  - Graphene: A potential path for integration with Si
  - Defect and interface states imaged by scanning tunneling spectroscopy
  - Major spectrometer improvement underway (20 mK, 15 Tesla)
- Nanomanufacturing and Nanofabrication
  - Directed assembly of nanostructures
  - Tracking nanoparticles in liquids near patterned surfaces
  - Collaborative development of novel ultrahigh resolution focused ion beam system (*tour stop*)

Future:

- Post – CMOS electronics
- Nanomanufacturing and nanofabrication
- Energy: Conversion, transport and storage



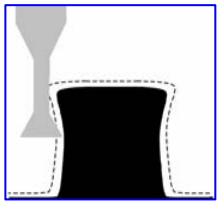


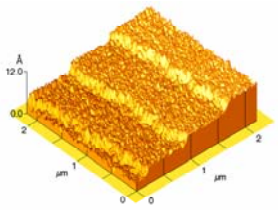
Present:

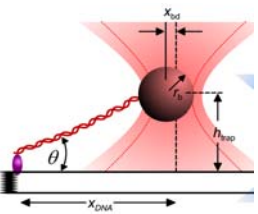
- Nanofabricated electrical standards
  - Quantum dots for single photon sources
  - State-of-the-art Josephson voltage standards.
- Nanoelectronics
  - Si-based nanoelectronics and molecular electronics
  - Measurements of molecular crossbar switching devices
- Nanomagnetic devices
  - Spin-torque nano-oscillators

Future:

- Hybrid compound semiconductor nanostructures
  - Nanophotonics





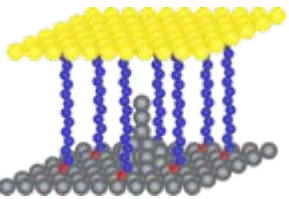


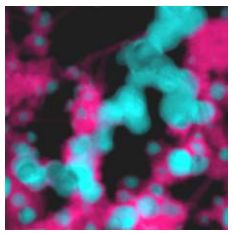
Present:

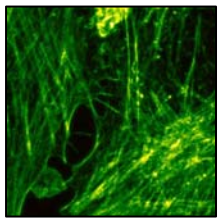
- Nanometer scale length metrology
  - Critical dimensions by AFM & SEM
  - Linewidth to 1 nm uncertainty
- Calibration standards
  - Atom-based step-heights
  - Physical and documentary standards
- Ultra-low force metrology
  - Traceable low force measurements
  - Calibration of AFM micro-cantilevers

Future:

- Intrinsic force standards
  - DNA stretching





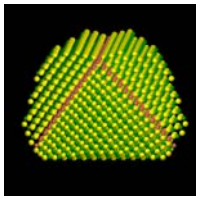


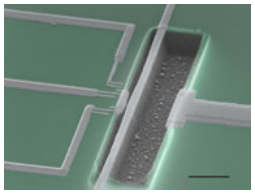
Present:

- Molecular level electronics
  - Insulating molecular monolayer with propagating Ag filament
- High resolution imaging with chemical contrast
  - Goal: In the analyzed volume, identify each atom and its location
- Super resolution optical imaging
  - Structured illumination microscopy based on a the epi-fluorescence microscope principle

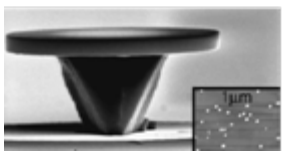
Future:

- Methods to characterize a nanomaterial's spatio-chemical composition, purity, and heterogeneity





C. BURKE/UNIV. MICHIGAN

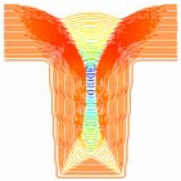


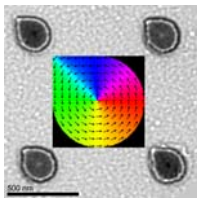
Present:

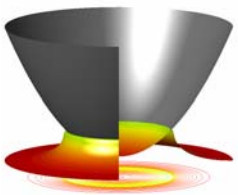
- Atomic scale simulations of nanosystems
- Nanomechanical systems
  - Precision metrology and quantum science with nanomechanical systems
- Nanotechnology enabled biosensing
  - Semiconductor quantum dots and metallic nanoparticles

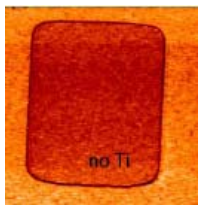
Future:

- Quantum optics
  - Single photon sources
  - Nanooptical communication with quantum dots and nanocavities







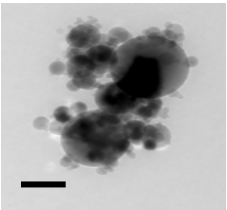


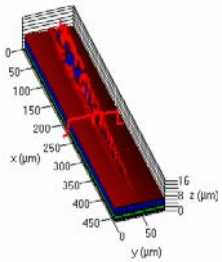
Present:

- Nanoelectronic materials
  - Sub-60nm on-chip interconnects
  - Critical dimension SAXS metrology
- Nanomagnetic materials
  - Magnetic film edge & nano-array metrology
  - Magnetic nanoparticle metrology
- Nanomechanical materials properties
  - Reference cantilever array SRM
  - Quantitative nanomechanical imaging

Future:

- Reliability & manufacturability
  - Reliability of MEMS/NEMS
  - Directed assembly of functional materials



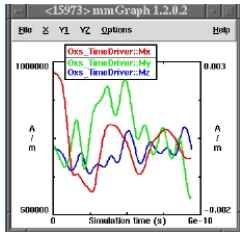


Present:

- Combustion synthesis of tailored carbon nanoparticles
  - Well-stirred reactor method
- Nanoparticle properties
  - Photoreactivity of nanoparticles used in architectural and aerospace coatings
- Nanocomposites
  - Methodologies for mechanical property measurements

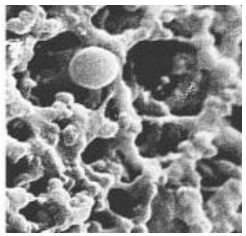
Future:

- Measurement of degradation
  - Nano-composite building materials
  - Flame retarded polymers
- Dispersion of nanoparticles within buildings



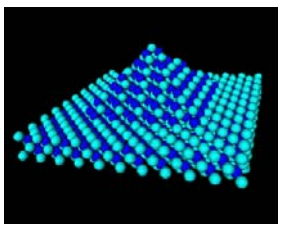
Present:

- Magnetic nanostructures
  - OOMMF system for nanoscale magnetic modeling



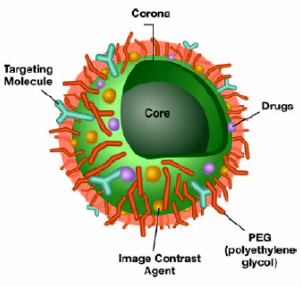
- Nanostructure imaging
  - Poisson singular integral method for real-time blind image deconvolution: deblurring of SEM microscopy

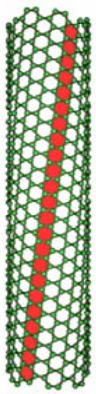
Future:

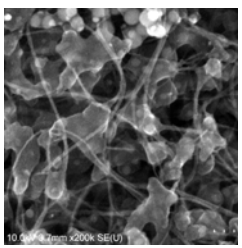


- Modeling and simulation
  - Improved algorithms and tools for multi-scale modeling and simulation of nanoscale phenomena

Nanoparticle Health and Safety – All NIST







Present:

- Nanoparticles
  - Characterization of the physical properties of engineered nanoparticles
    - Solution mediated nanoparticles
  - Observation of where nanoparticles go in cells
    - Surface functionalization of quantum dots
- Nanotubes
  - Production of “gold standard” nanotubes through solution processing
    - Characterization of fundamental optical and electronic properties
  - Production of a Reference Material for residual catalyst content in carbon nanotubes
  - Removal of nanotubes from waste water (tour stop)

Future:

- Development of analytical methods for quantifying the type and amount of nanomaterials in biological matrices, the environment, and the workplace

How can VCAT best help the NIST Nanotechnology Program?

- Help us identify the research most important to the Nation, adding an critical long-term component to our strategic planning process
  - Important measurement needs not being met
  - Consistent with NIST's vision
  - Leveraging our core competencies
    - CNST
    - CNST Nanofab
  - An effective method of knowledge transfer exists or can be established
- Help us understand the impact our contributions might have
  - Allows us to set priorities
  - Allows us to defend important, but sometimes less appreciated, infrastructural support work

Thank you!

Nanotechnology at NIST: Present and Future

Thanks to:

Clare Allocca
Ron Boisvert
Garnett Bryant
Rich Cavanagh
Jason Crain
William Grosshandler
Ted Vorburger
David Wollman

for providing information about their Laboratory's program.

Since we met last…

- CNST
  - Staffing continues; scope is expanding
  - Reorganization nearly complete
  - Space allocation plan is in place
  - Partnership with the University of Maryland has started
    - NanoDay is May 11, 2007

- Nanofab
  - Has grown to 150 NIST users
  - Staffing continues; capabilities are expanding
  - Vistec VB-300 (formerly Leica) e-beam writer has arrived
    - Install going normally; estimated completion: May 1st.
  - Zeiss dual-beam focused ion system to arrive by May 1st
  - Procedures for hosting outside users are under development
    - May 14th is the target date for accepting external users