Nanotechnology at NIST: Present and Future

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The NIST Center for Nanoscale Science and Technology

VCAT Meeting

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(http://cnst.nist.gov)

Outline

- Very Brief Status Report on the CNST
- Overview of Nanotechnology Research at NIST
  - Four-Year Horizon
  - Laboratory Programs
    - Present
    - Future
- How VCAT Can Best Help Us

CNST Structure

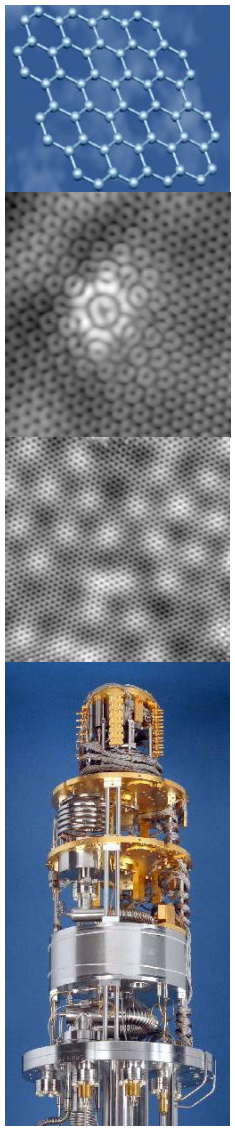
- The CNST consists of a Research Program and the CNST Nanofab
  - The Research Program
    - Enabling nanotechnology with measurement solutions
  - The Nanofab
    - A National User Facility with state-of-the-art ***measurement*** and ***fabrication*** capabilities

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

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

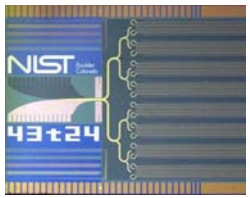


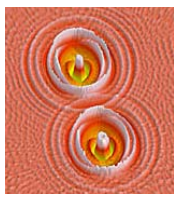
Present:

- 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



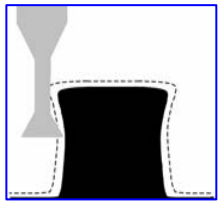


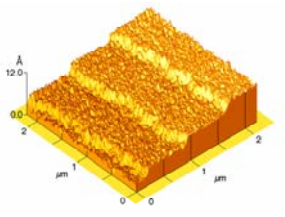
Present:

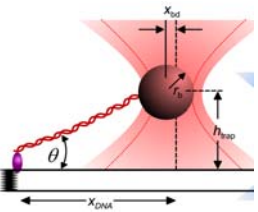
- Nanofabricated electrical standards
  - Quantum dots for single photon sources
  - State-of-the-art Josephson voltage standards.
- Nanoelectronics
  - Si-based nanoelectronics and molecular electronics
  - Measurements of molecular crossbar switching devices
- Nanomagnetic devices
  - Spin-torque nano-oscillators

Future:

- Hybrid compound semiconductor nanostructures
  - Nanophotonics





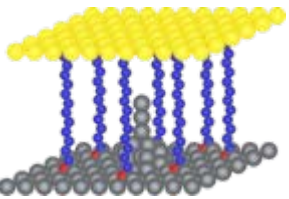


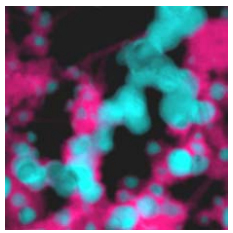
Present:

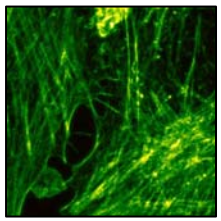
- Nanometer scale length metrology
  - Critical dimensions by AFM & SEM
  - Linewidth to 1 nm uncertainty
- Calibration standards
  - Atom-based step-heights
  - Physical and documentary standards
- Ultra-low force metrology
  - Traceable low force measurements
  - Calibration of AFM micro-cantilevers

Future:

- Intrinsic force standards
  - DNA stretching





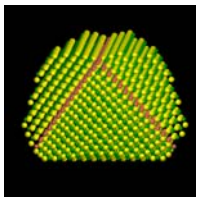


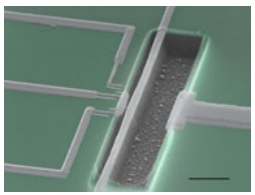
Present:

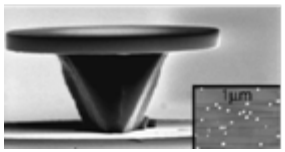
- Molecular level electronics
  - Insulating molecular monolayer with propagating Ag filament
- High resolution imaging with chemical contrast
  - Goal: In the analyzed volume, identify each atom and its location
- Super resolution optical imaging
  - Structured illumination microscopy based on a the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

Future:

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





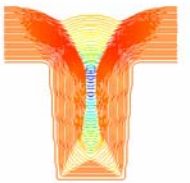


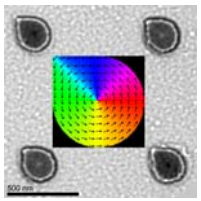
Present:

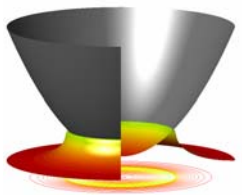
- Atomic scale simulations of nanosystems
- Nanomechanical systems
  - Precision metrology and quantum science with nanomechanical systems
- Nanotechnology enabled biosensing
  - Semiconductor quantum dots and metallic nanoparticles

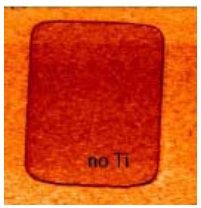
Future:

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







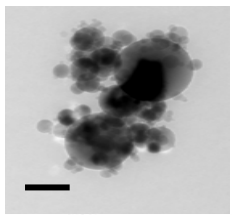


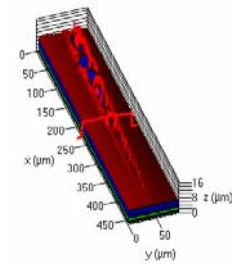
Present:

- 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



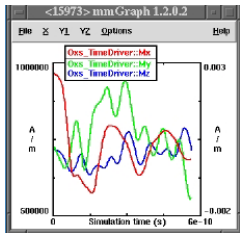


Present:

- 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

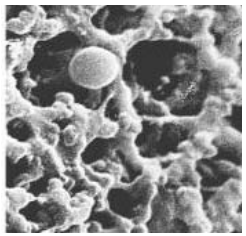
Future:

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



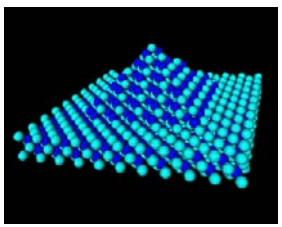
Present:

- Magnetic nanostructures
  - OOMMF system for nanoscale magnetic modeling



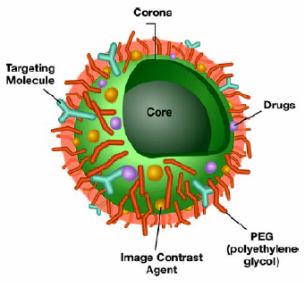
- Nanostructure imaging
  - Poisson singular integral method for real-time blind image deconvolution: deblurring of SEM microscopy

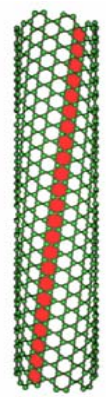
Future:

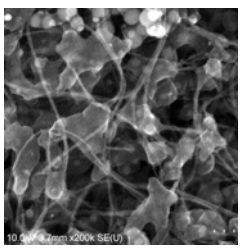


- Modeling and simulation
  - Improved algorithms and tools for multi-scale modeling and simulation of nanoscale phenomena

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!

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