



Nanomanufacturing, Measurements & Materials

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NIST Nanotechnology Strategy

- Perform NIST's traditional roles
 - Discipline oriented laboratory research
 - Workshops to identify industry needs
 - Standards setting (physical & documentary)
 - Calibrations
- Form public-private partnerships
 - Nanoelectronics Research Initiative
 - College of Nanoscale Science and Engineering, University at Albany, NY
- Operate a multidisciplinary Center and shared-use nanofabrication facility
- Support nanotechnology through TIP, construction grants
- Coordinate and collaborate with industry stakeholders and other Agencies



Center for Nanoscale Science & Technology

- Established in 2007 as a national nanocenter to develop measurement and fabrication methods specifically to advance nanotechnology “from discovery to production”

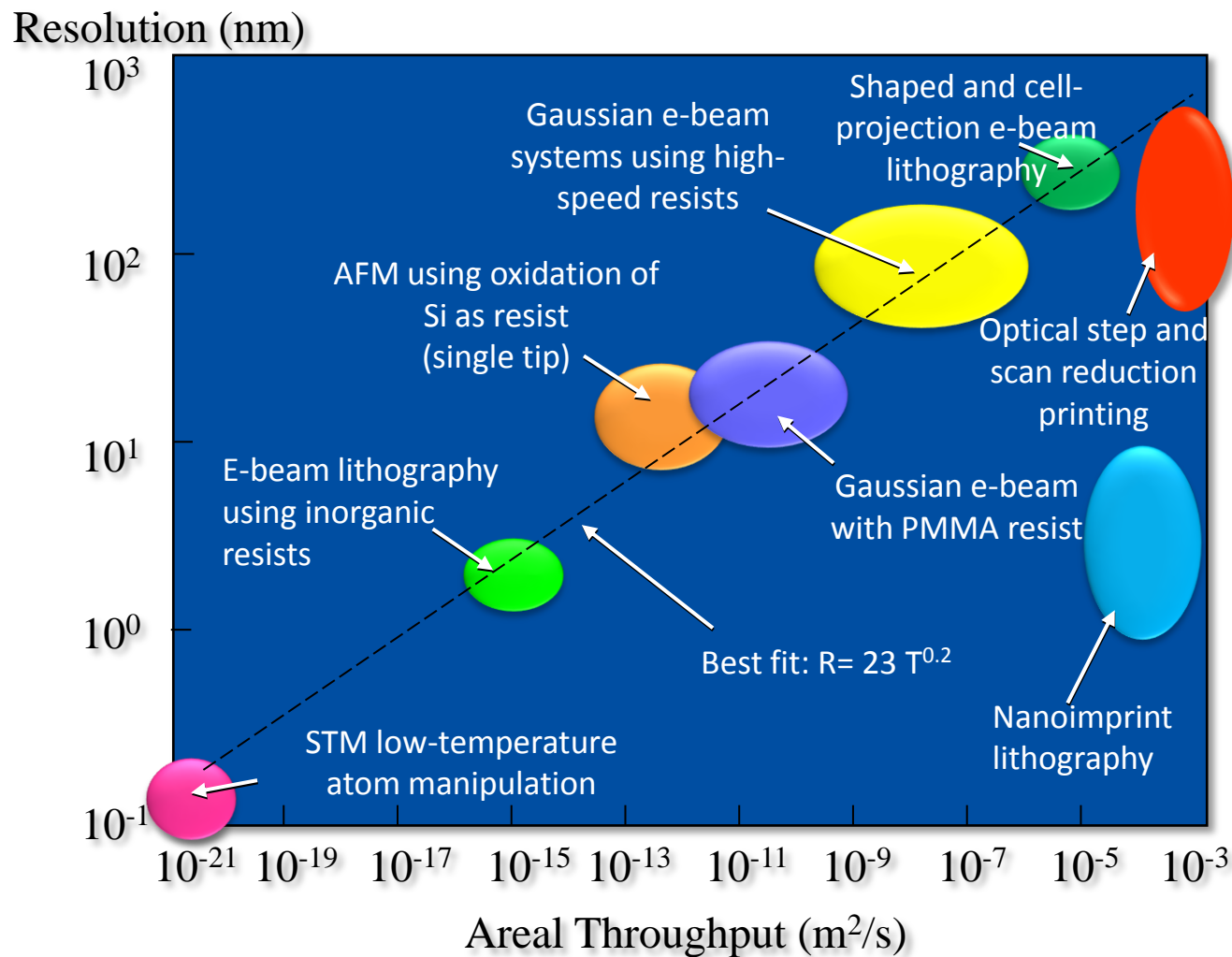


- Operates a national shared resource, the NanoFab, with world-class nanoscale fabrication and measurement capabilities accessible to all, including industry

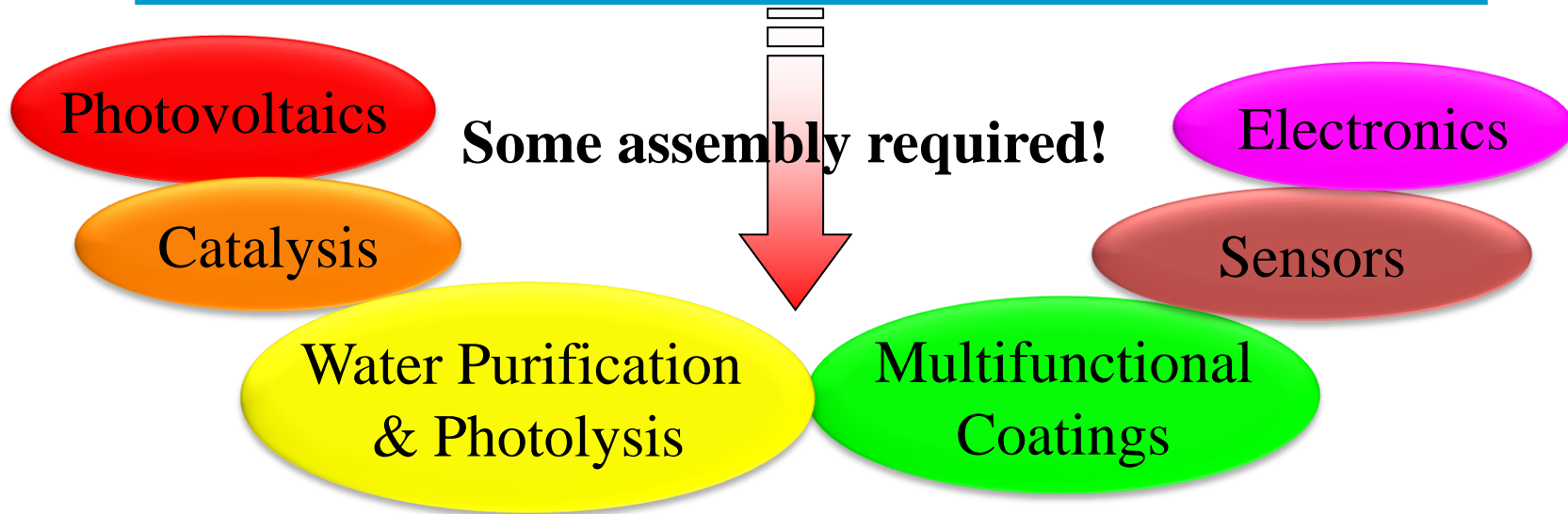
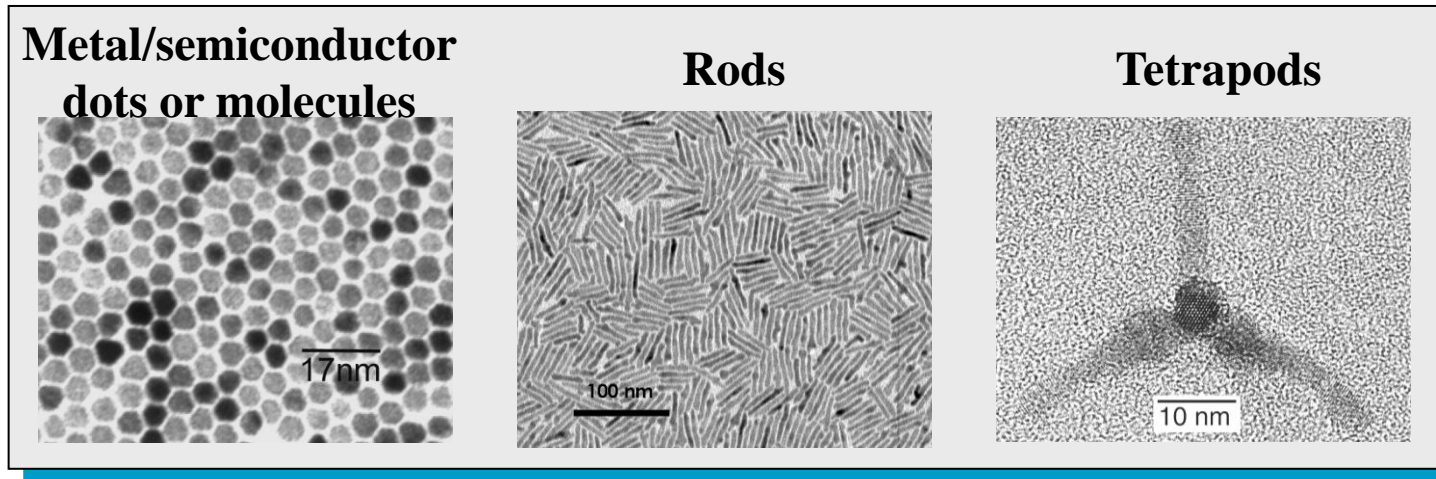


- Conducts multidisciplinary research to create the next generation of nanoscale measurement instruments, available through collaboration
- Serves as a hub to link the external nanotech. community to the vast measurement expertise that exists within the NIST Laboratories

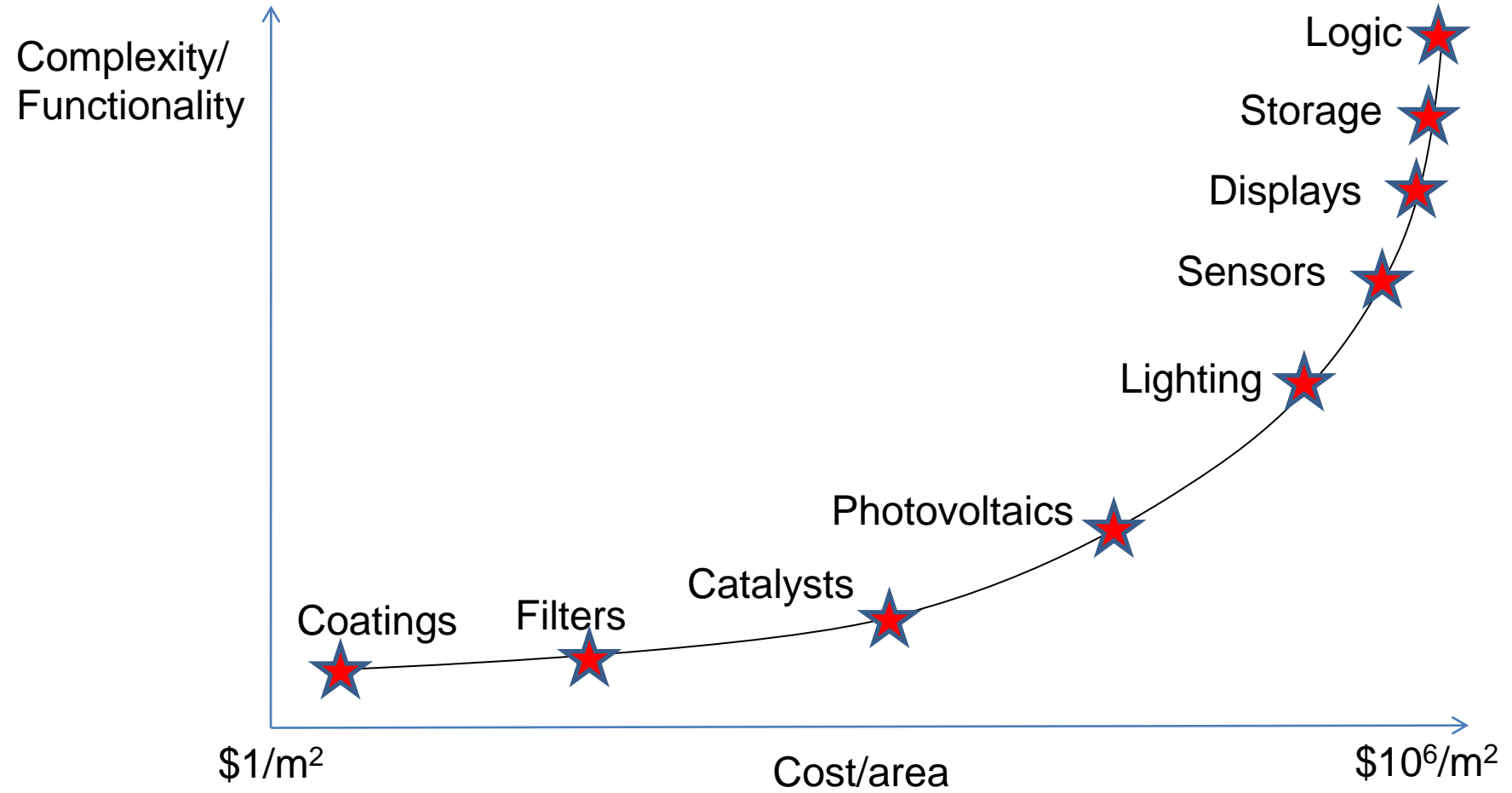
Nanomanufacturing Today



Nanomanufacturing Tomorrow

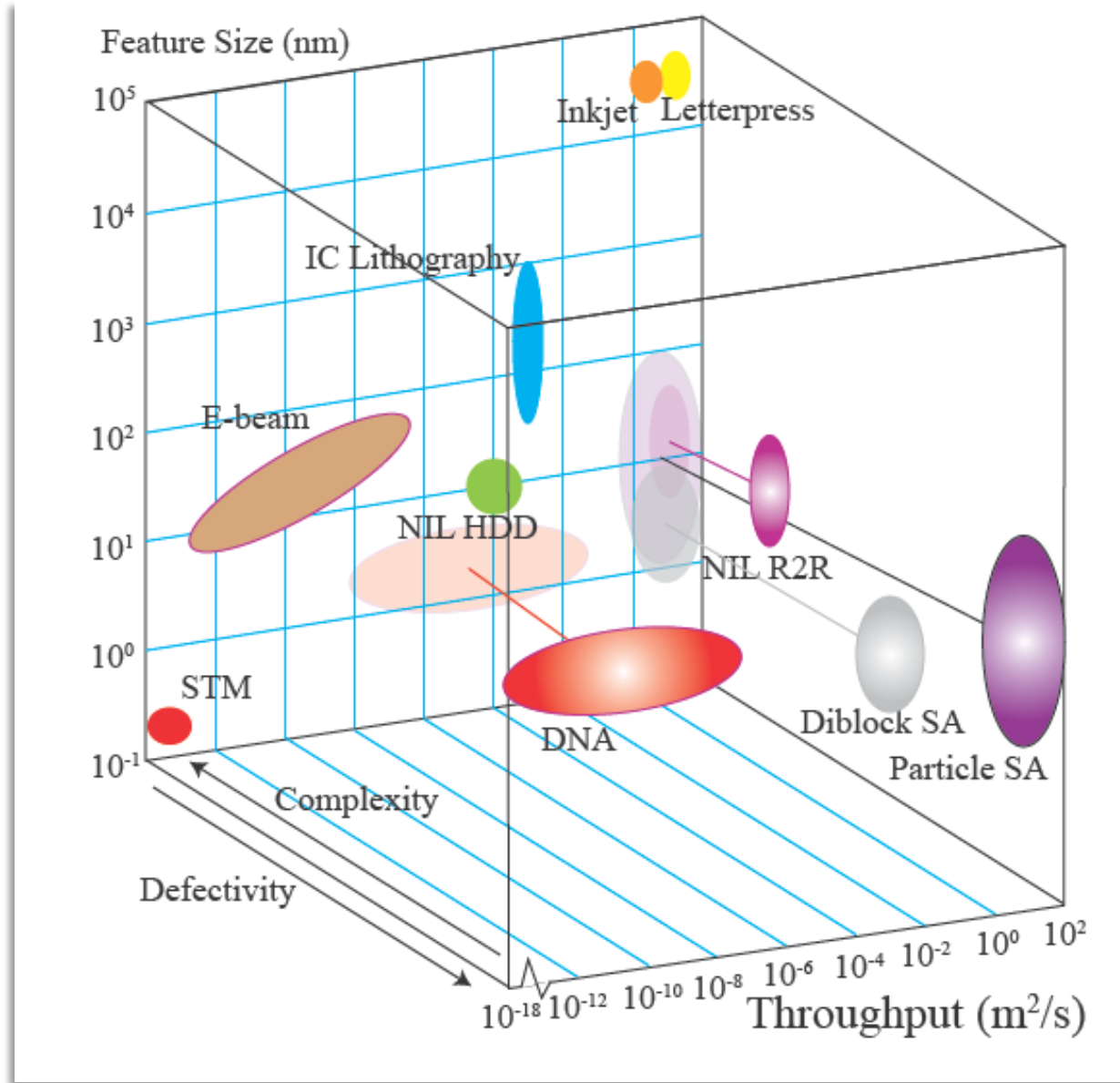


The Cost of Complexity



- Low-cost nanostructured materials:
 - Less complex
 - Higher defect levels

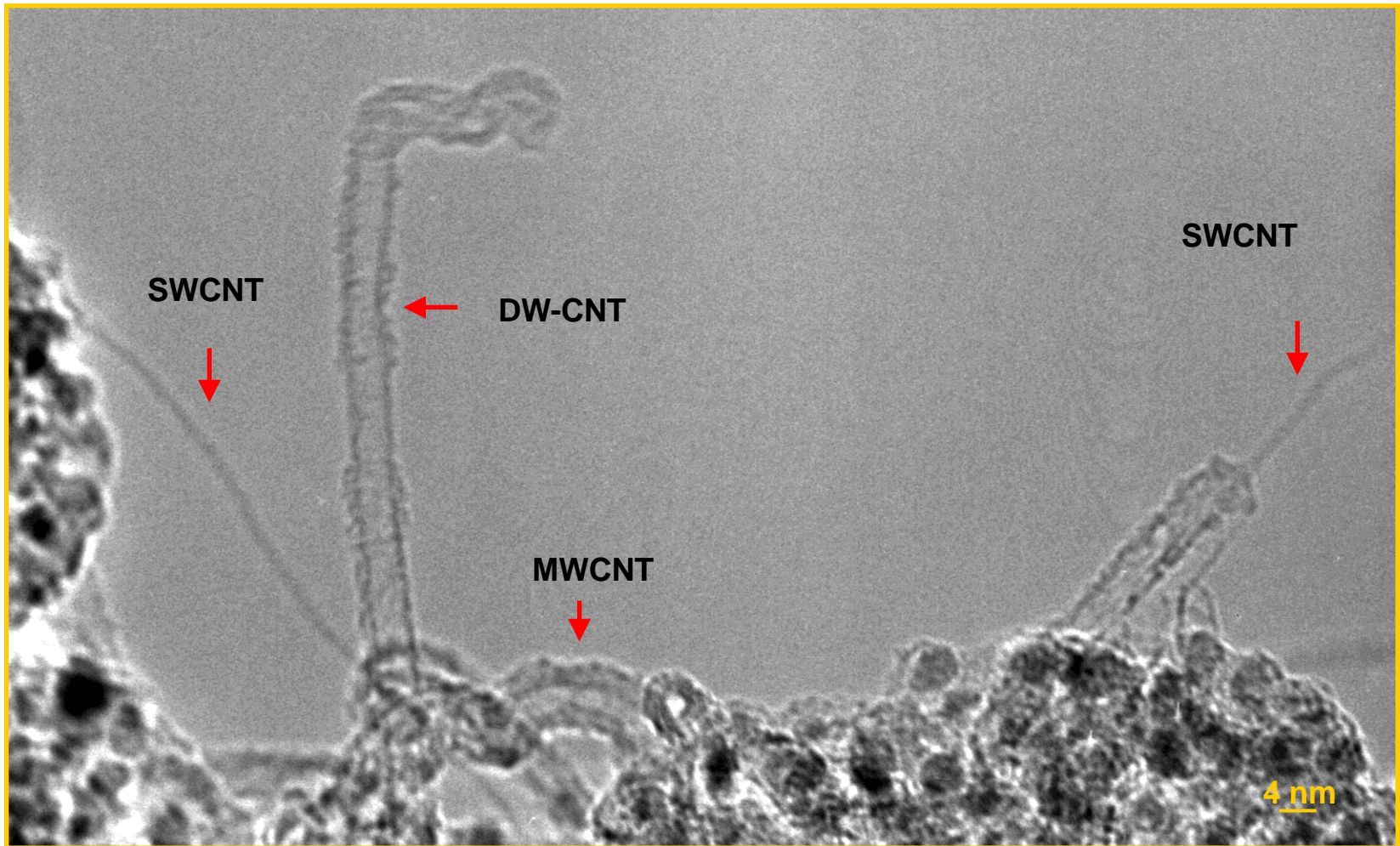
- Need:
 - Higher throughputs
 - Smaller features



What measurements are needed?

- Measurements for fundamental understanding
 - Slow, expensive, infrequent
 - New measurements needed for novel materials/devices fabrication processes
- Measurements for process/quality control
 - Fast, cheap, periodic or continuous
 - Off-line
 - Real-time

Morphological Diversity in CNTs

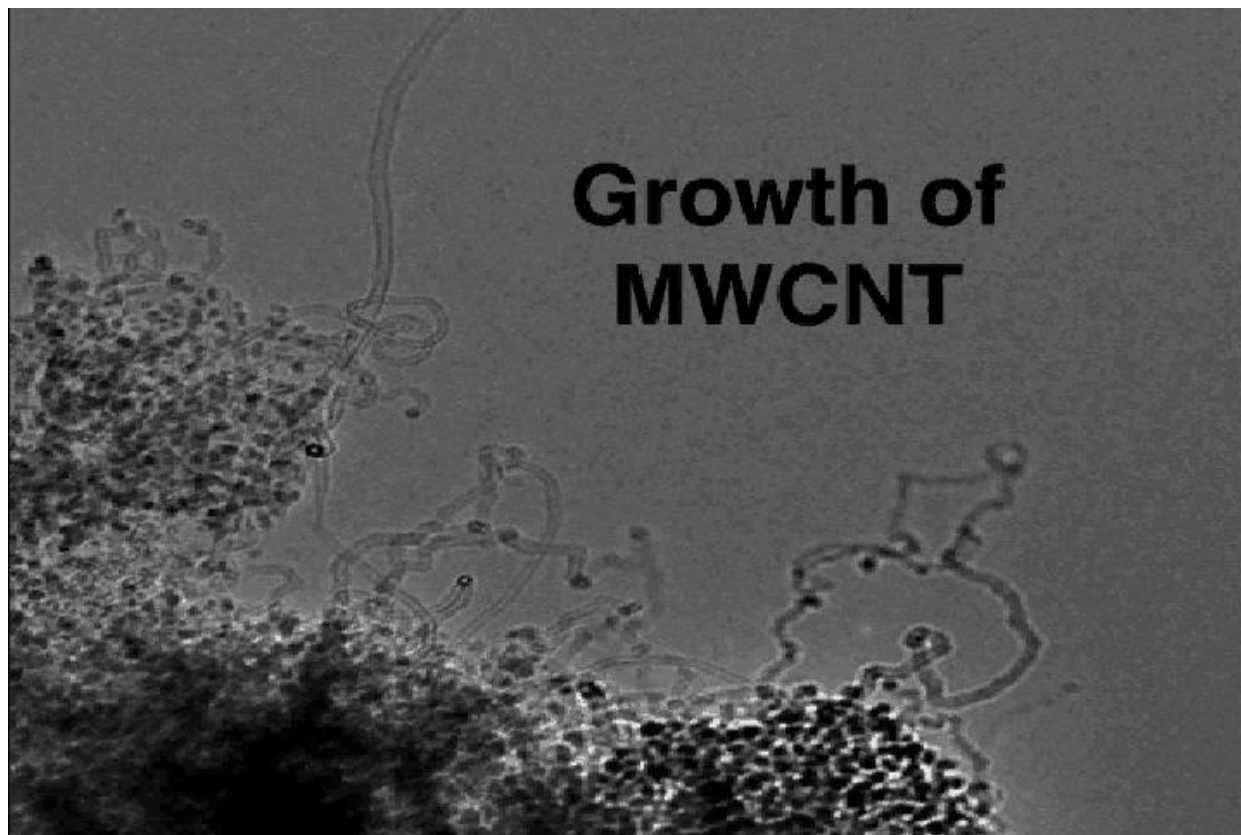


Growth at 500°C in 300 mTorr of C_2H_2

Factors Controlling the Catalytic CVD Synthesis of CNTs

- Catalyst: Ni, Cu, Co, Fe, Mo and bimetallic catalysts
- Support: SiO₂, MgO, TiO₂
- Temperature: 500°C – 1000°C (400 °C -700 °C)
- Precursor: Hydrocarbons (CO, CH₄, C₂H₄, C₂H₂ etc.)
- Pressure: 760 Torr (1 - 300 mTorr)

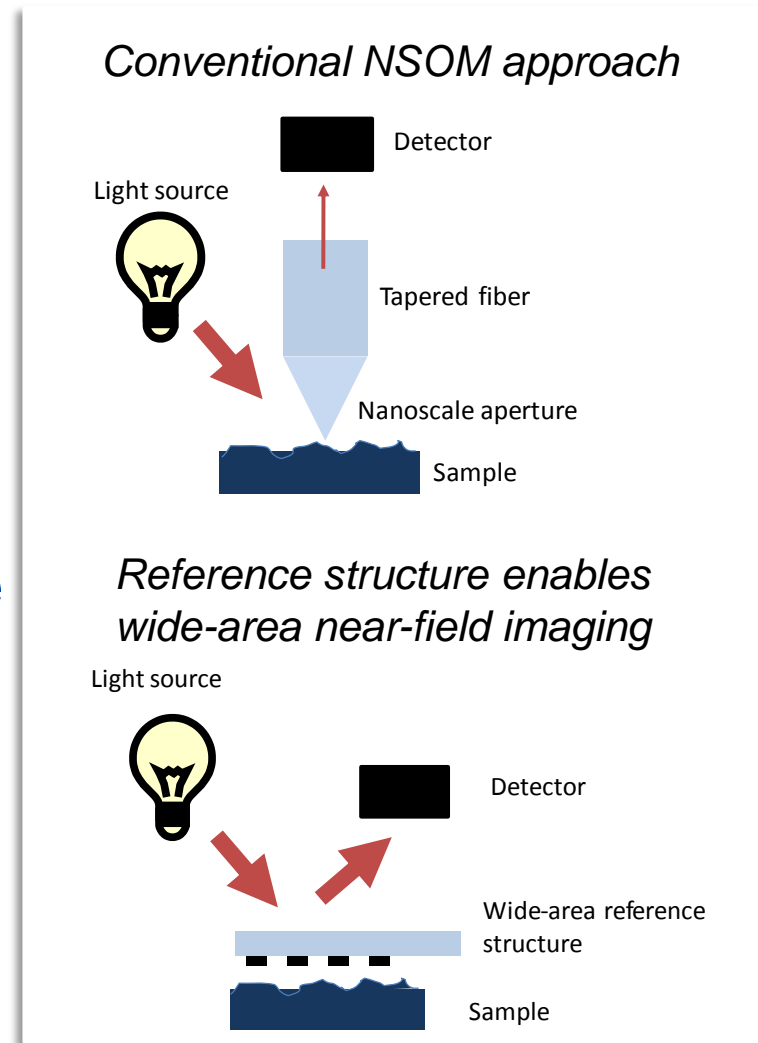
Environmental TEM



High-Throughput Optical Near-Field Imaging

- Far-field optical microscopy suffers from diffraction-limited resolution
 - Nearfield scanning optical microscopy (NSOM) greatly improves resolution but is too slow for practical applications

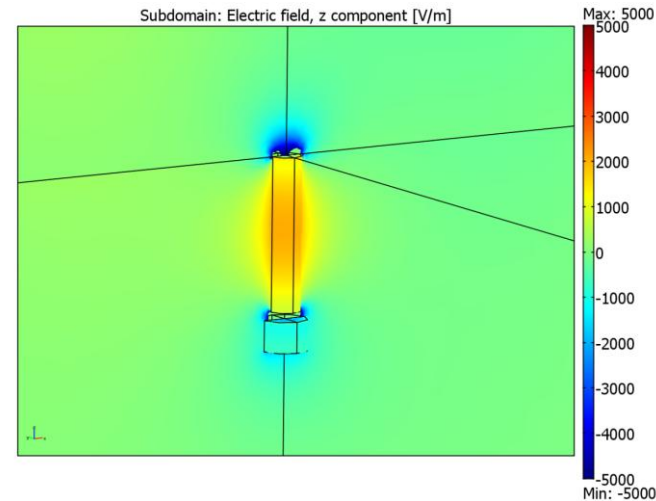
- Improve throughput of near-field microscopy with extended reference structure instead of single point probe
 - Reconstruct image from raw data using computational techniques
 - Initial targets: defect metrology needs of semiconductor and hard disk drive industries



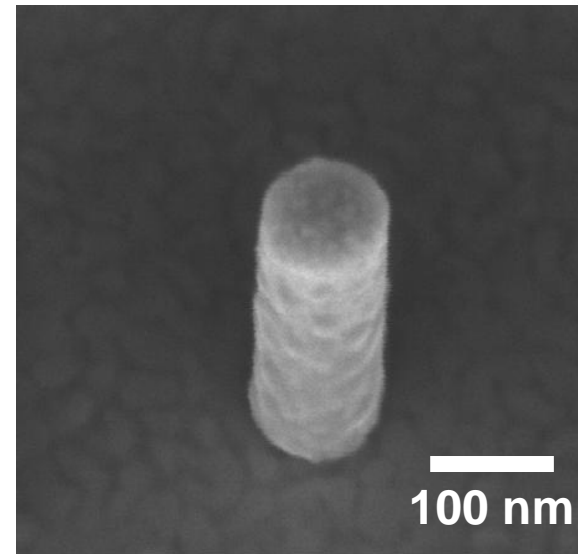
High-Throughput Optical Near-Field Imaging

- Reference structure design
 - Structure consists of arrays of nanoscale gold pillars
 - Light scattering from each pillar depends on local properties of the sample
 - Plasmonic resonance in the pillar enhances scattering

- Realization of reference structure
 - Gold nano-pillars fabricated by e-beam lithography and electroplating
 - Experimental setup places reference structure in nearfield of sample

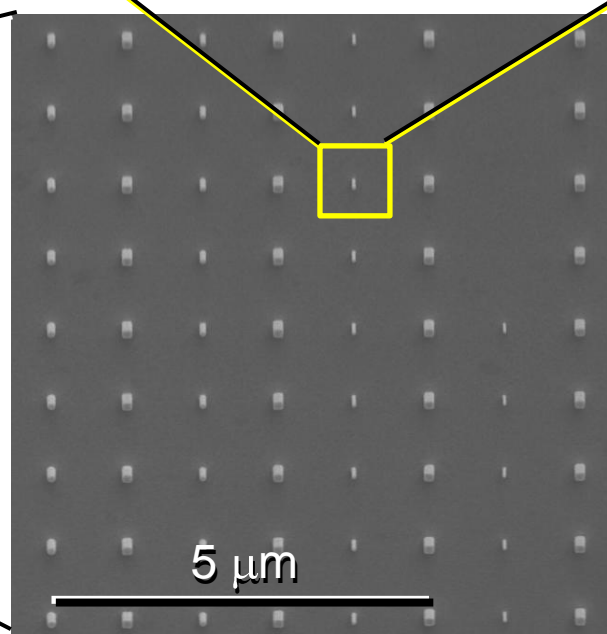
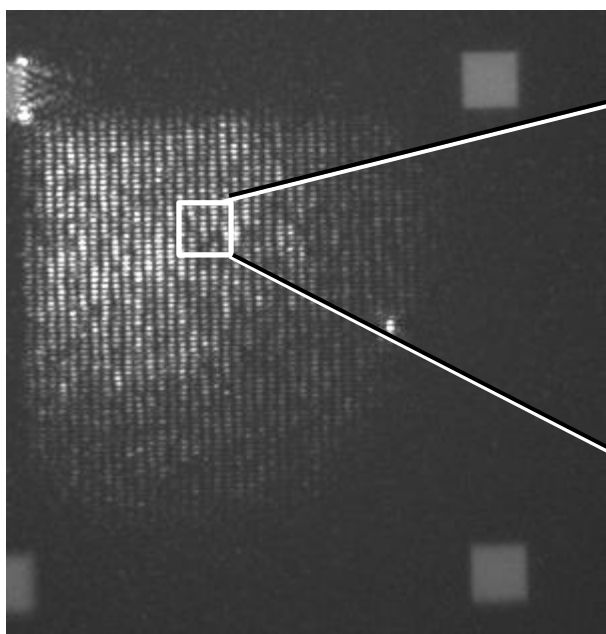
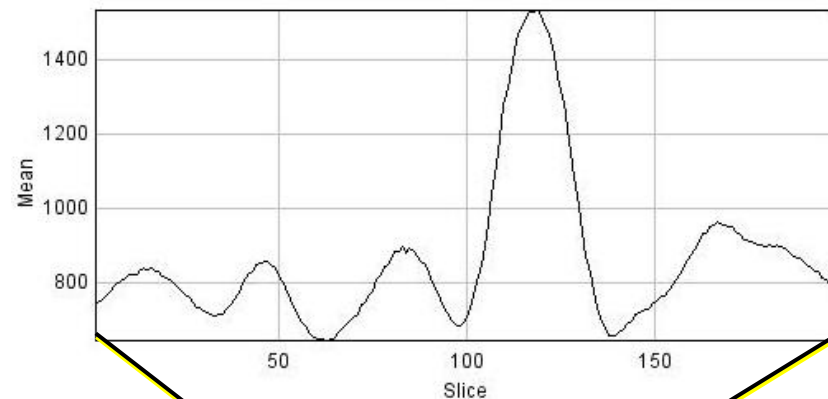
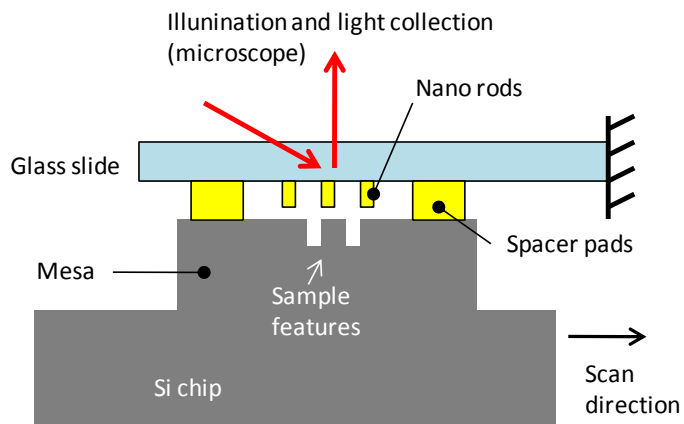


Model of gold nano-pillar showing field enhancement



SEM micrograph of 100nm diameter Au pillar

High-Throughput Optical Near-Field Imaging



Sustainable Nanomanufacturing

NNI Signature Initiative: Targeted Inter-Agency Collaboration with FY11 budget request

- Key requirements: scalable, controllable, sustainable & safe
- Thrust 1: Design of scalable & sustainable nanomaterials, components, devices & processes
 - Formation of consortia: carbon-based nanomaterials, metamaterials, cellulosic materials
 - Demonstration of materials and processes
 - Technology transfer
- Thrust 2: Nanomanufacturing measurement technologies
 - Consortium on metrology for roll-to-roll
 - Fast, robust process control measurement systems
 - Technology benchmarking and transfer with industry

NIST Nanomanufacturing Activities

- FY11 Budget request (\approx \$5M) aligned with NSI
- Collaboration with Center for Hierarchical Manufacturing at U.Mass (NSF NSEC)
 - Coupled to FlexTech Alliance
- CRADA under development with major company on carbon-based nanomaterials
- Workshop planned on carbon-based nanomaterials
- Quantitative measurements of nanoparticle release during forming operations, service and combustion

NIST Nanomanufacturing Activities

- Collaboration with U.MD and Johns Hopkins on process control for stochastic assembly
- Block copolymers
- DNA origami
- High-throughput near- and far-field optical metrology
- Dynamic measurements of single-molecule/nanoparticle interactions

THANK YOU

QUESTIONS?