The Center for Functional Nanomaterials: A User-oriented Research Center

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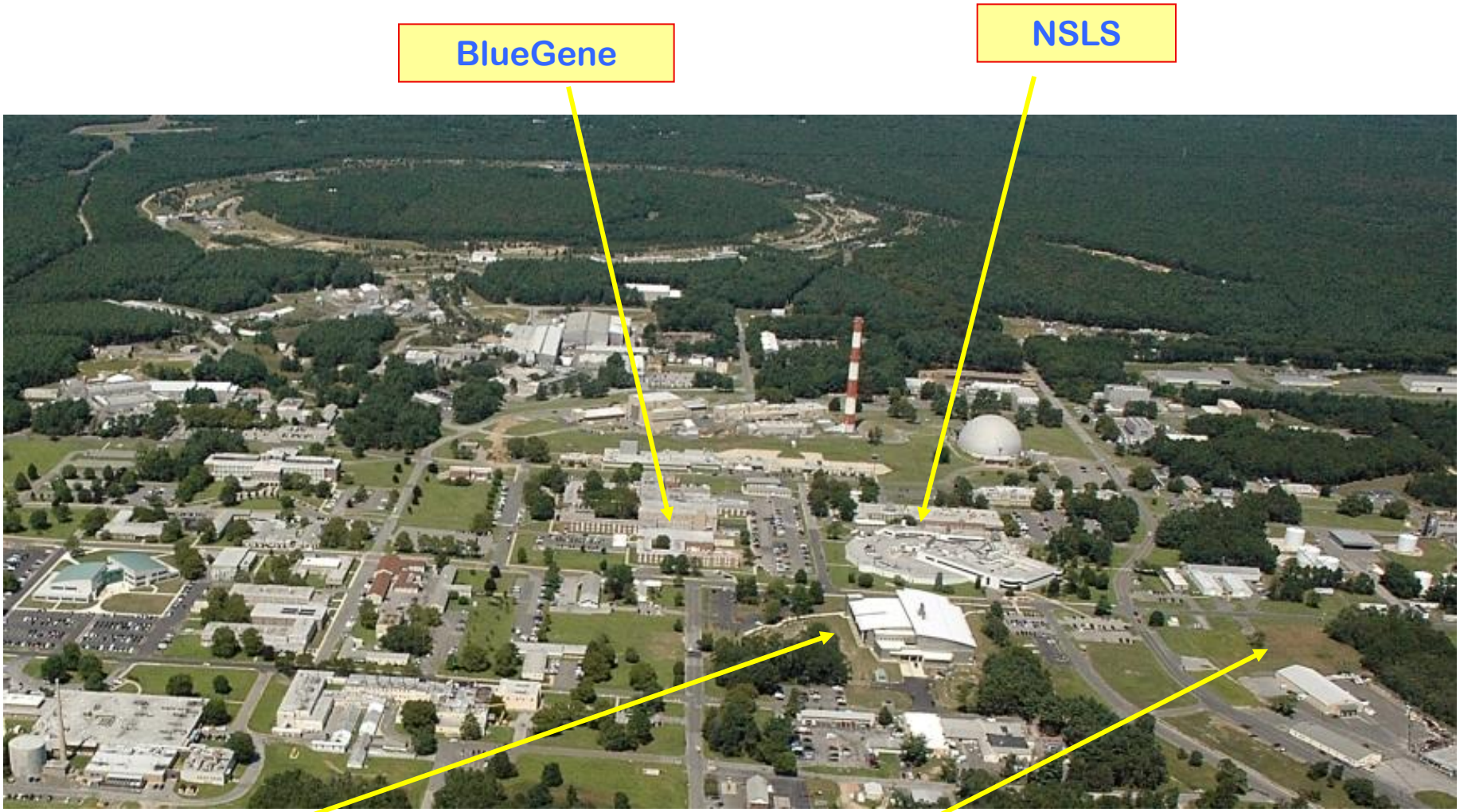
EPSCoR Meeting
July 21, 2009

Center for Functional Nanomaterials
Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

Major Facilities for Nanoscience at BNL



A User-oriented Nanoscience Research Center

Goal: To become a world-class hub of nanoscience research

Mission

To contribute to the solution of the country's critical challenges by

1) Discovering, understanding, and exploiting energy-related nanomaterials
2) Enabling the community of external users develop their top-quality nanoscience projects

(high concentration of state-of-the-art nanoscience tools) + (top scientists in nanoscience) + (energy mission)

Scientific Mission

Scientific Themes

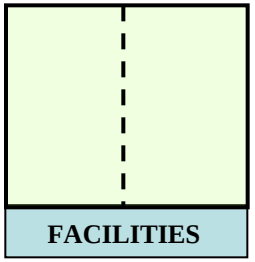
- electronic materials / photovoltaics
- interface science & catalysis
- soft & biomaterials

Cross-cutting Programs

- electron microscopy
- theory and computation

– are relevant to the energy challenge
– address important scientific questions
– are synergistic with BNL's core programs
– take advantage of BNL facilities

Facilities



TEM

Characteristics

- **State-of-the-art** nanoscience-research equipment
- **Comprehensive** suite of tools
- **Balance** between equipment requiring straightforward training with equipment demanding extensive training and expert knowledge

Materials Synthesis

Nanofabrication

Trans. Elect. Microscopy

Proximal Probes

Ultrafast Spectroscopy

NSLS Beamline(s)

Computer Cluster

Dual-beam FIB

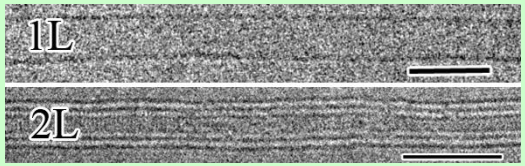
SEM

CVD Reactor

Low-T Nanoprobe

Synthesis of Nanostructures

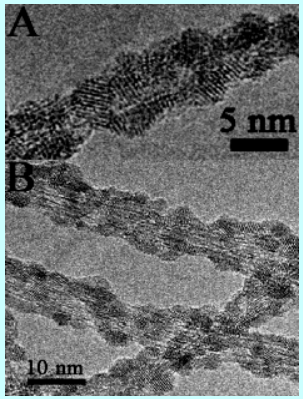
Single- & double-wall BN nanotubes



W. Q. Han APL 2006

- H_2 storage
- SPM tips

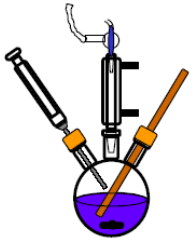
Single-wall C nanotubes functionalized with SnO_2



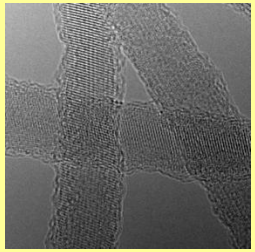
W. Q. Han, NanoLett, JACS

- Chemical (H_2) sensors
- Photocollectors

Wet Chemistry



Doped (Fe, C, N) TiO_2 nanorods



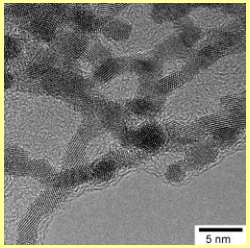


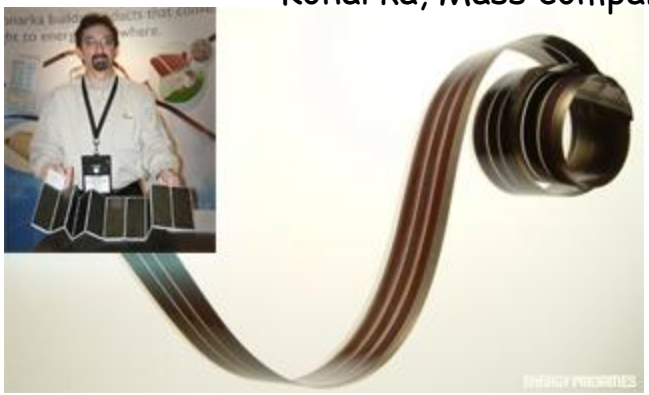
Photo-induced decomposition of water

Chemical Vapor Deposition

Organic Photovoltaic Cells

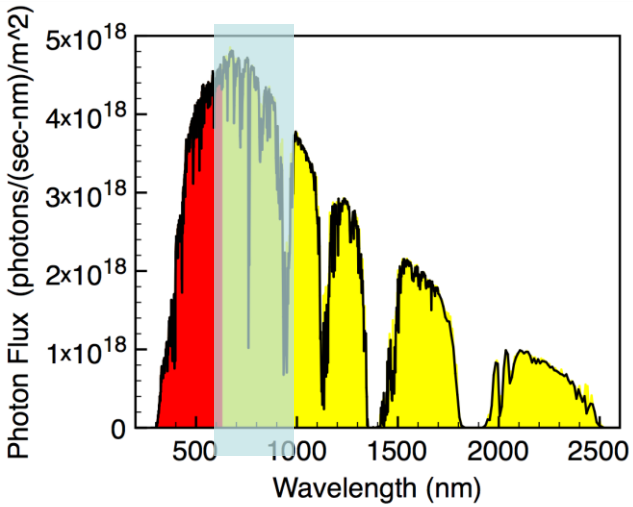
- Cheap fabrication
- Low efficiency
- Not very durable

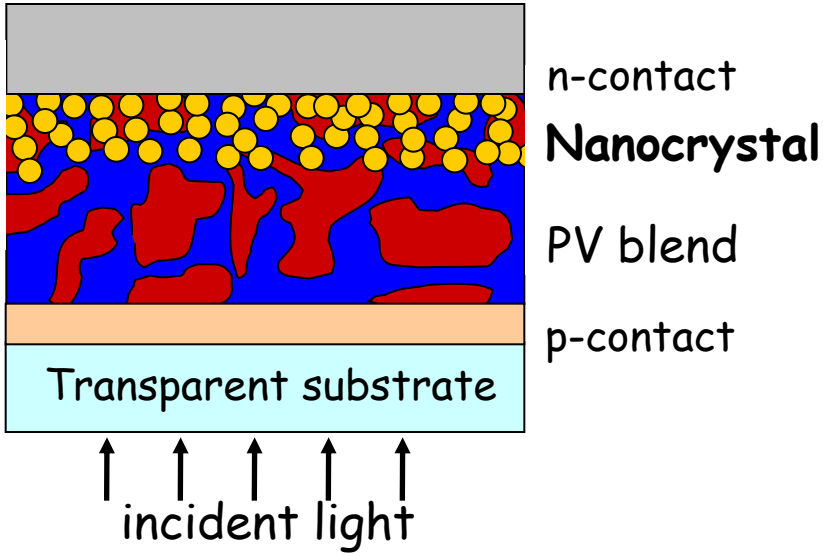
Konarka, Mass company



CFN Goals:

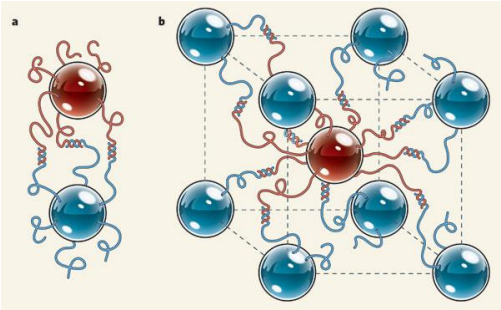
- Increase number of electrons collected with **nanostructured polymers**
- Increase number of photons absorbed with inorganic nanoparticles



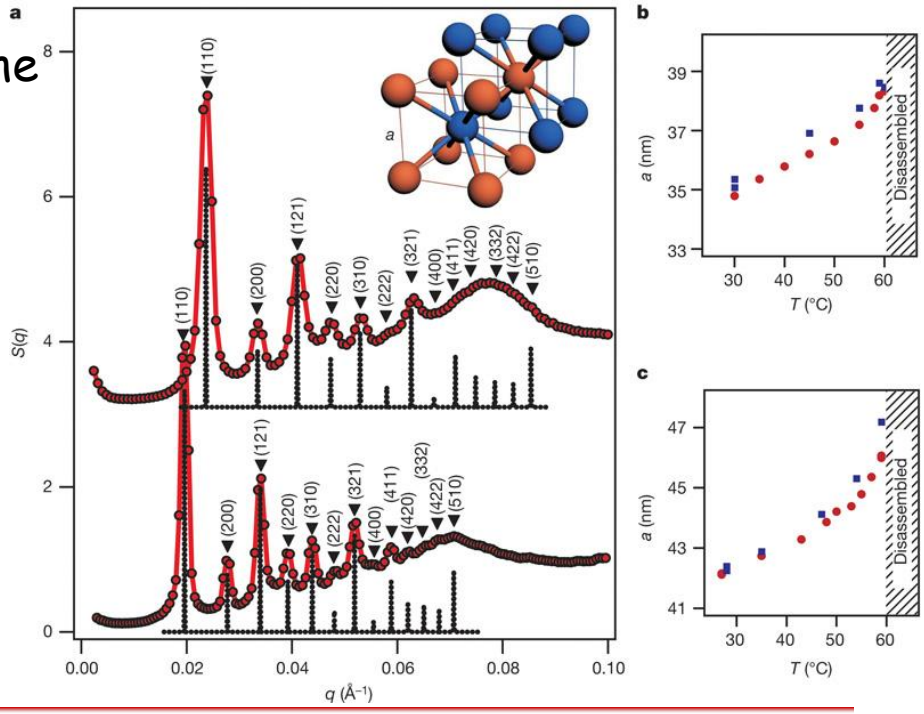


DNA-guided Crystallization of Nanoparticles

D. Nykypanchuk, M. Maye, D. Van der Lelie, O. Gang, *Nature* ***451***, *549 (2008)*



- Tuning the interparticle potential via **DNA tailoring** ⇒ 3D crystalline non-close packed phase.
- Nanoparticles occupy only few % of the lattice volume.
- **Unusual properties**:
  - Expansion coefficient is ~100x larger than in usual materials.
  - Wide range of phases expected.
- **Potential** for building novel optical, magnetic, catalytic materials

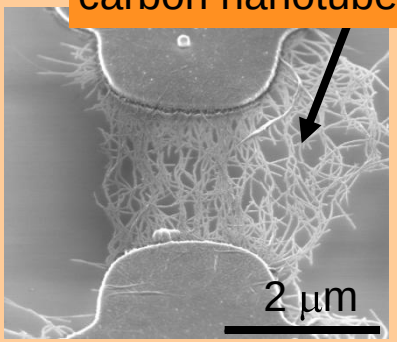


Nanofabrication

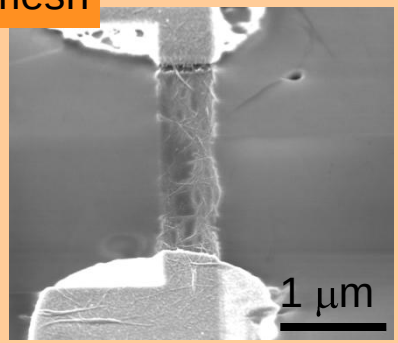
Focused Ion Beam / SEM

SEM-directed FIB-cleaning of nanodevices

carbon nanotube mesh

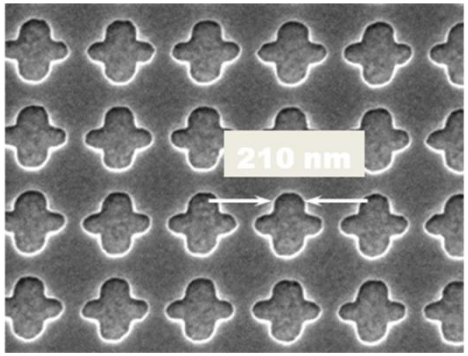


before

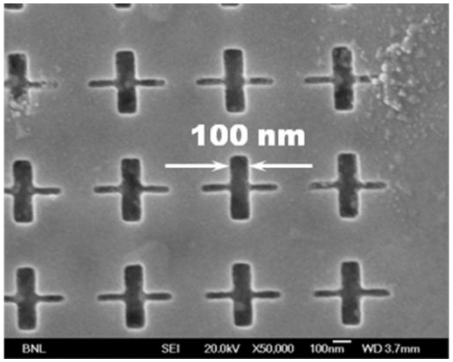


after cleaning

Electron-beam Lithography System



30 keV EBL

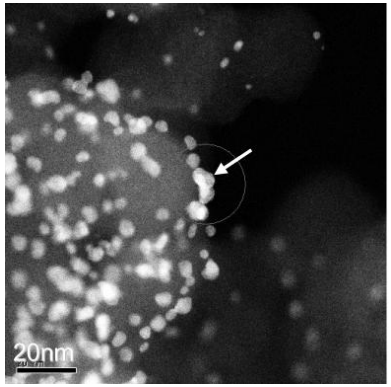


100 keV EBL

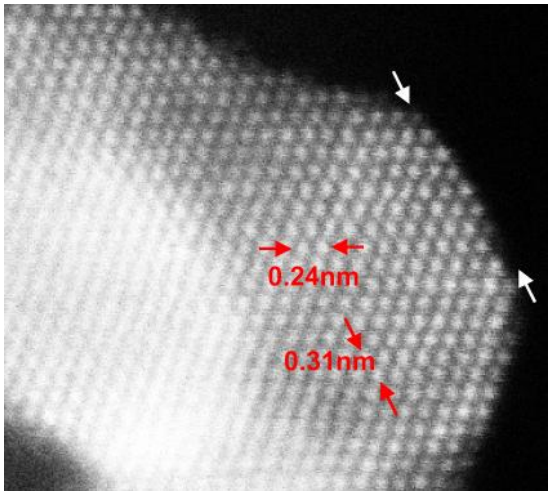
Transmission Electron Microscopy

Aberration-corrected e-TEM to study catalysis reactions

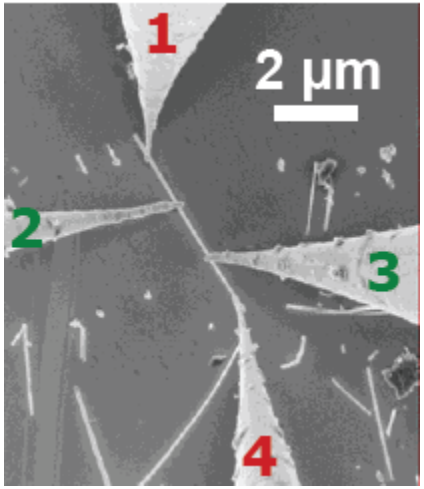
Aberration-corrected STEM to study catalysis nanomaterials

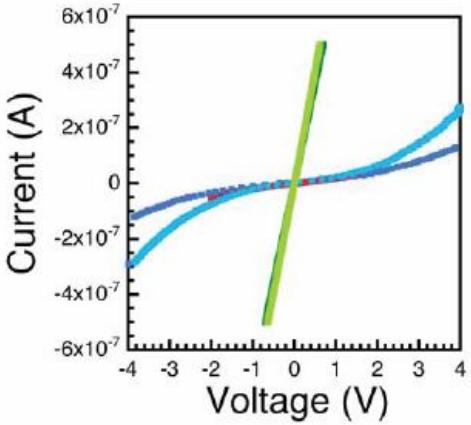


Pd/Pt nanoparticles used in fuel cells as active, durable, and low-cost catalysts

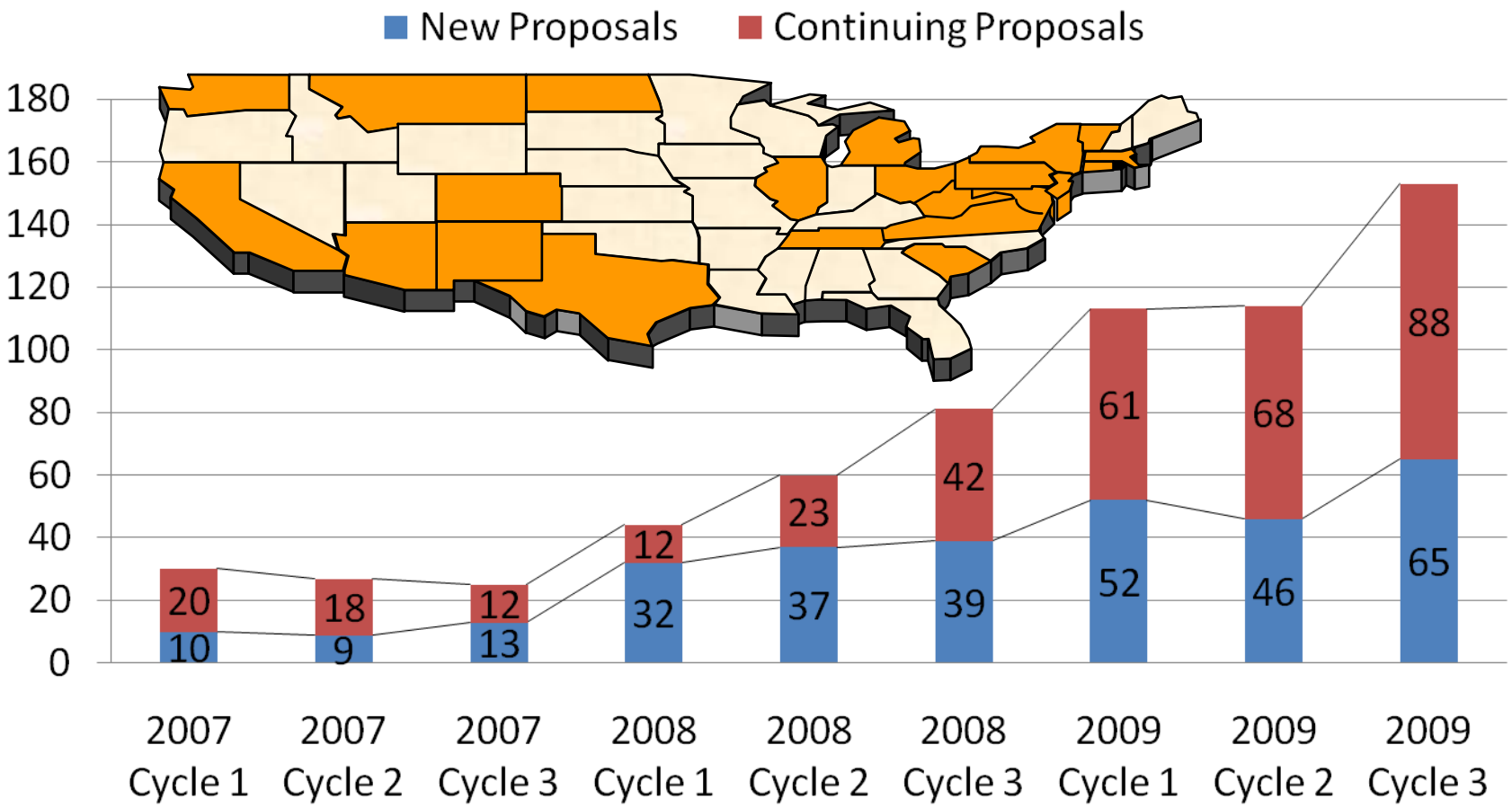


Four-point Nanoprobe

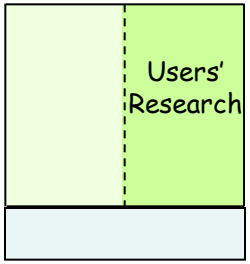




Evolution of Users' Proposals



User Program

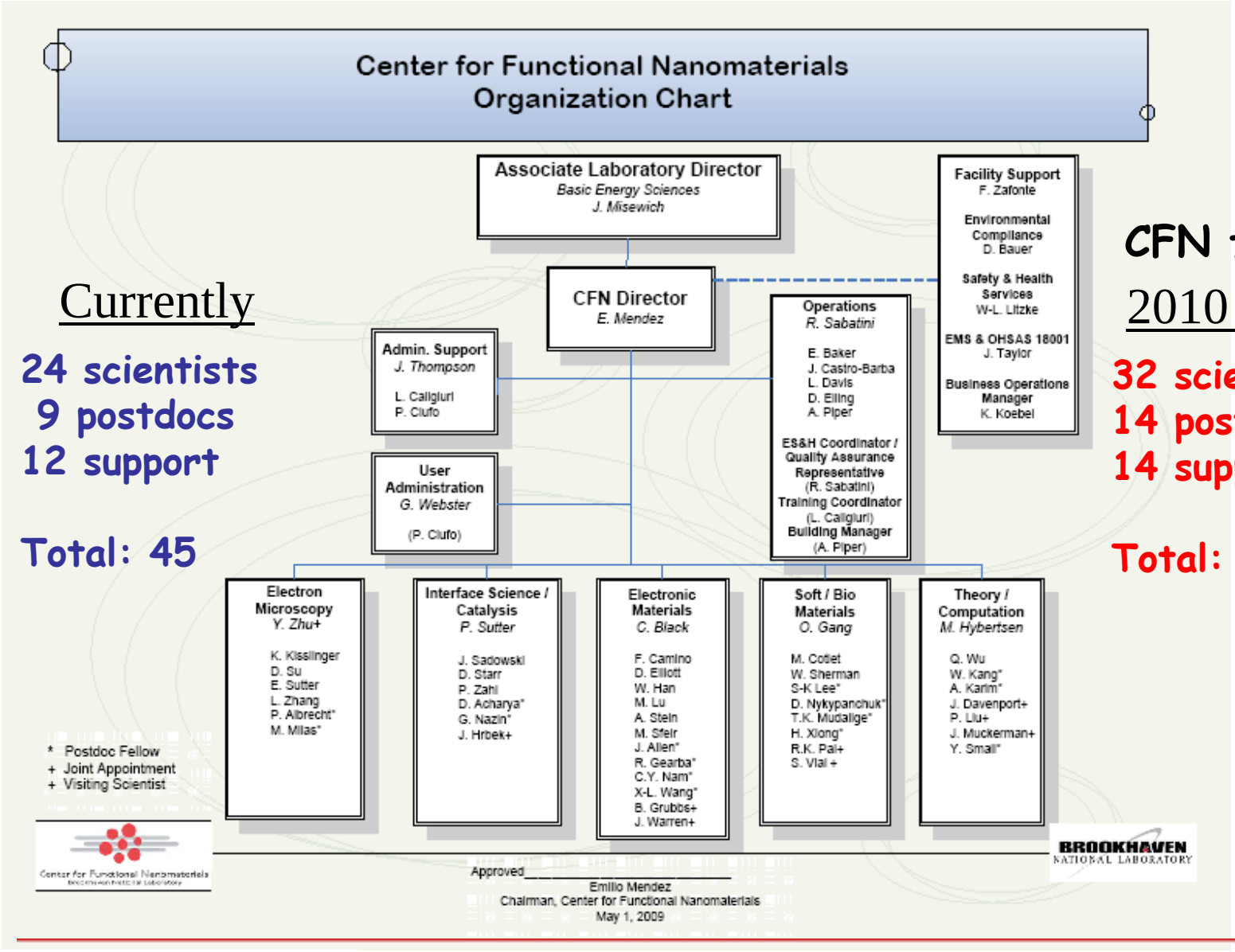


CFN Goal: To become a resource for the nanoscience community of the Northeastern US and beyond

Characteristics

- **Free access to facilities and expertise for non-proprietary research**
  academia, companies, national laboratories
- **Based on peer-reviewed proposals**
- **Three proposal cycles per year**
  regular access, rapid access
- **Full-cost recovery for proprietary work**
- **Suitable to a wide range of users' needs**
  from straightforward, one-time measurements
  to complex, extended experiments

Back-up Slides



Currently

24 scientists
9 postdocs
12 support

Total: 45

CFN funded

2010 Goal

32 scientific staff
14 postdocs
14 support

Total: 60

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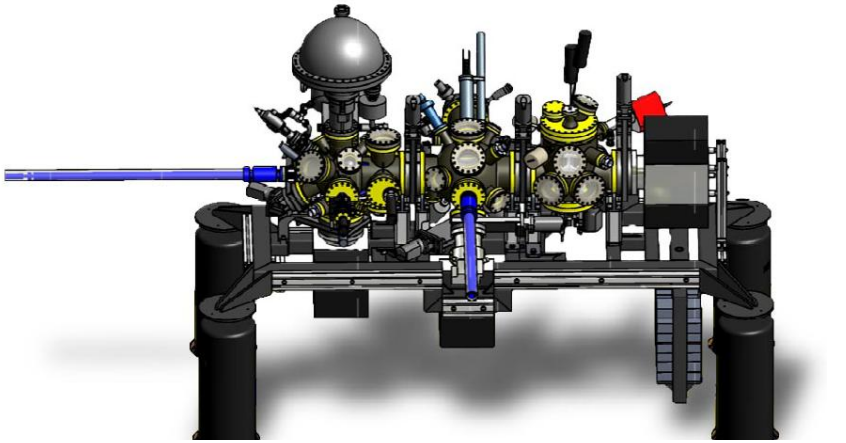
New Techniques

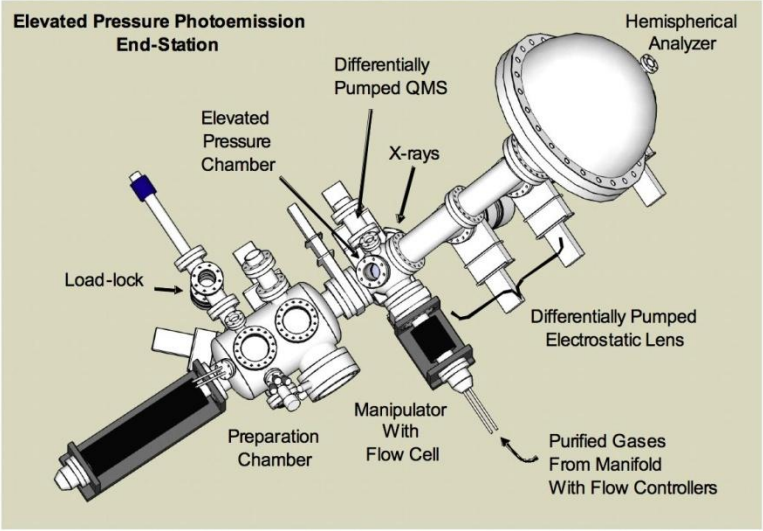
Reactor STM

- Small-volume catalytic flow reactor with integrated STM
- Samples prepared and and characterized in UHV
- Simultaneous STM imaging and mass spectroscopy of products



High Pressure Photoemission Spectroscopy

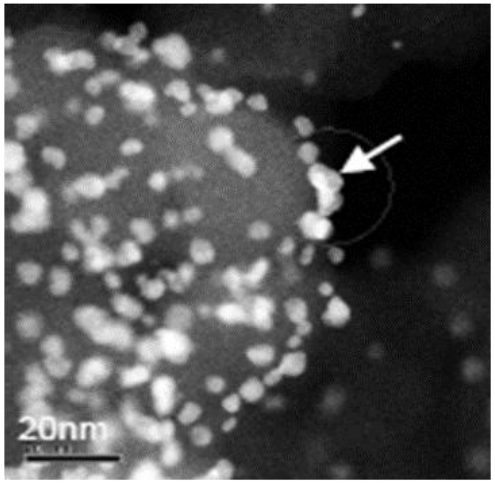
- High-resolution XPS & UPS
- Energy range: 100 - 1200 eV
- Sample preparation in UHV
- Small-volume high pressure cell (up to ~10 torr)

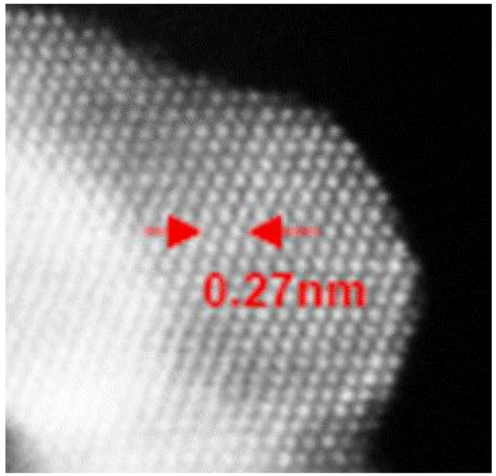


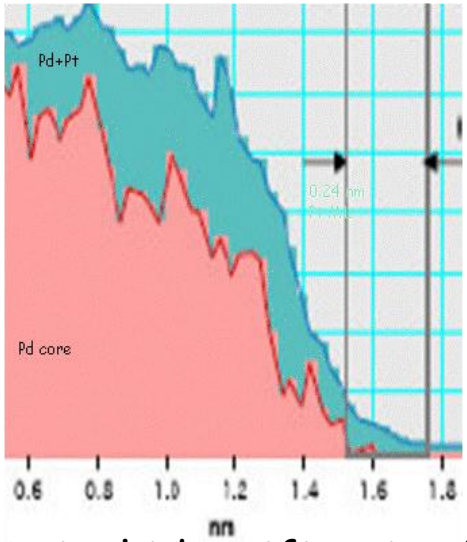
Probing Core-shell Nanostructure in Catalysts

with Adzic's group, Chemistry, BNL

- Catalysts with core-shell structure are economically attractive.
- Synthesis and structural characterization are difficult.
- Aberration-corrected STEM with EELS resolves Pd/Pt core/shell down to monolayer scale



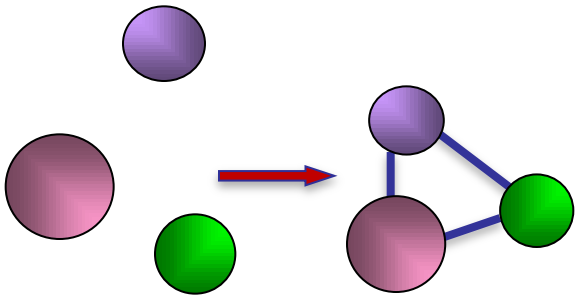




Cd/Pt (1ml) nanopartices on carbon support Chemical identification by EELS

Building Nanoclusters

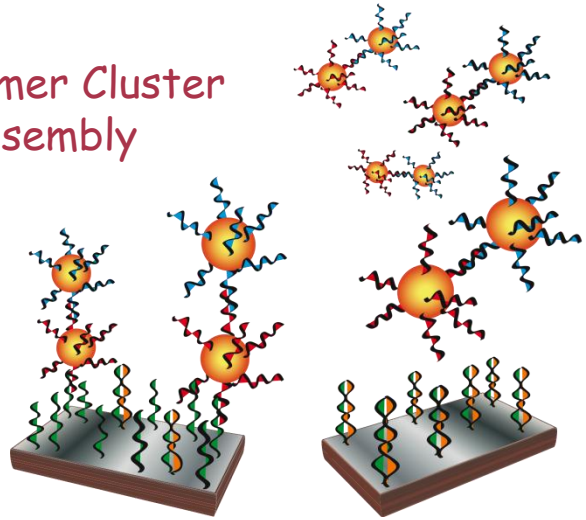
- Precisely assembled clusters (nano-"molecules") from nanoparticles allow to regulate functional properties of individual particles.
- Problem: How can we assemble clusters efficiently?
- Method: Cluster assembly via stepwise surface encoding

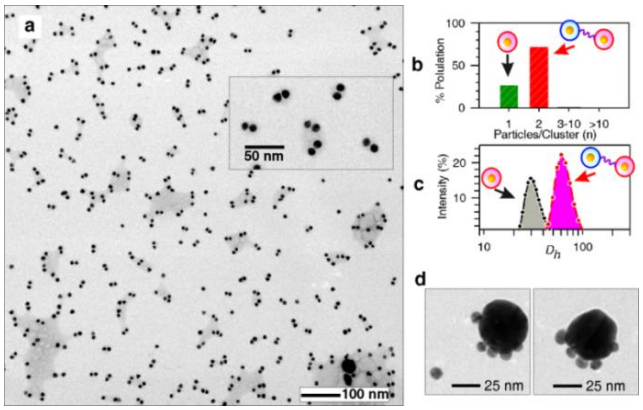


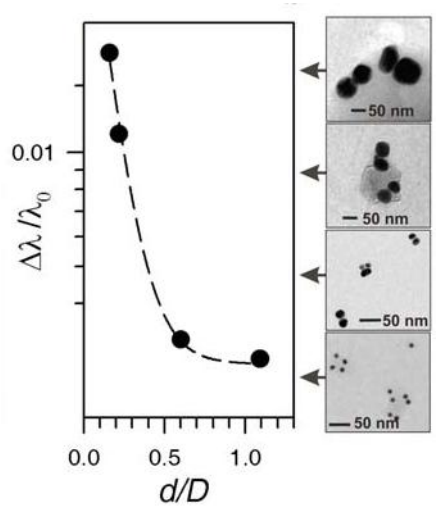
Single particles Artificial "molecules"

Nature Materials **8**, 365 (2009)

Dimer Cluster Assembly







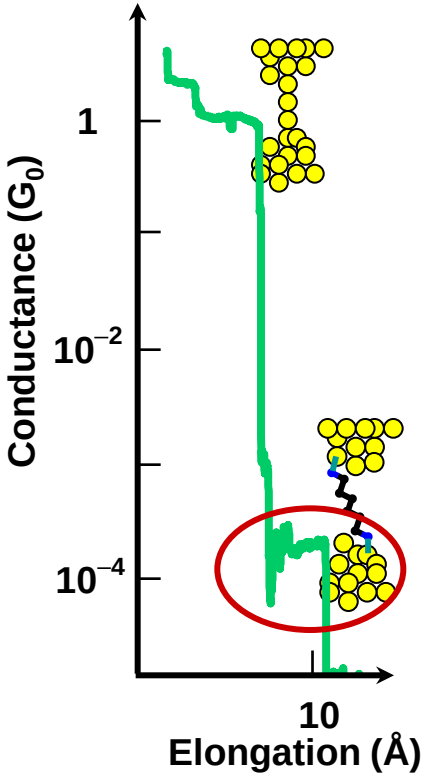
Single-molecule Junction: Evolution under Stress

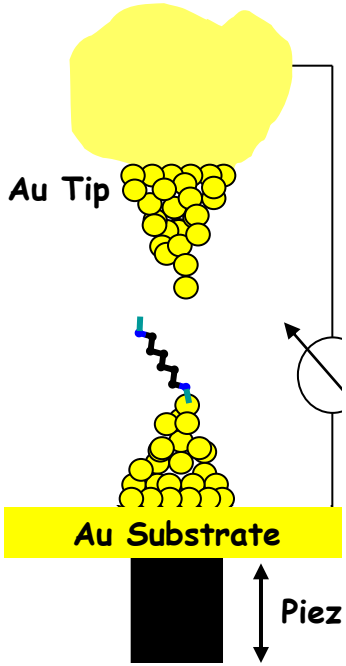
Phys. Rev. Lett. **102**, 126803 (2009)

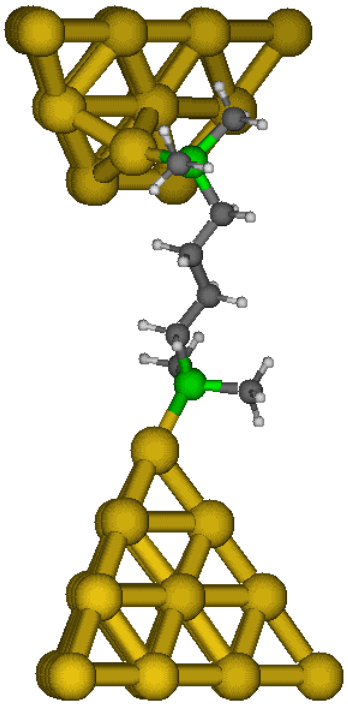
with Venkataraman's group, Columbia U.

Experimental Approach

MOLDEN







Major Instrumentation

Major facility acquisitions/upgrades coming

High-performance e-beam lithography system (JEOL JBX-6300FS)

- high resolution (10 nm dimensions)
- large-area patterning
- high placement and field stitching accuracy (~25 nm)
- operational in June 2009

TEM for soft materials

- for low contrast organic materials
- excellent (0.3 nm) resolution at 300K and cryotemp
- tomographic capabilities

Energy filter for 'workhorse' TEM

- to perform Electron Energy Loss Spectroscopy, for chemical identification

Reactive ion etching for metals