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Opportunities at the Center for Nanoscale Materials



Eric D. Isaacs

Center for Nanoscale Materials
Argonne National Laboratory

APS Monthly Ops Meeting, February 28, 2007



Center for Nanoscale Materials: A DOE facility for nanoscience research



Full facility operations in October '07.



State-of-the-art scientific user facility at Argonne National Laboratory for the development and dissemination of the techniques for the synthesis, fabrication, characterization and theory of materials at the nanoscale.

Integrated Scientific Themes:

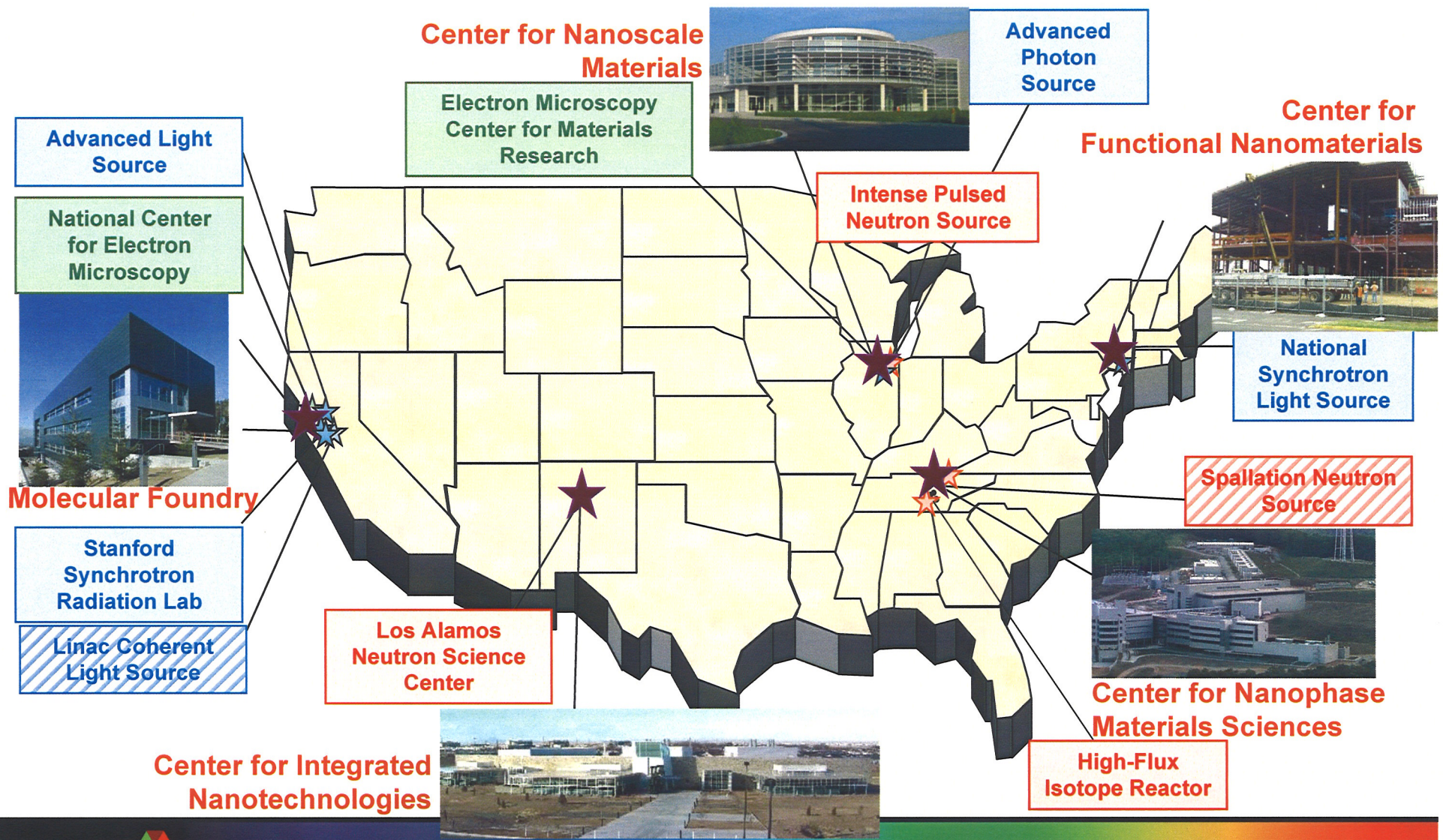
- Electronic and Magnetic Materials & Devices
- Nanobio interfaces
- Nanophotonics
- X-ray imaging

Enabling capabilities:

- Synthesis and assembly
- Nanofabrication
- Nanocharacterization
- Theory and simulation

[www.nano.anl.gov!](http://www.nano.anl.gov)

Five DOE Nanoscale Science Research Centers and Facilities Integration

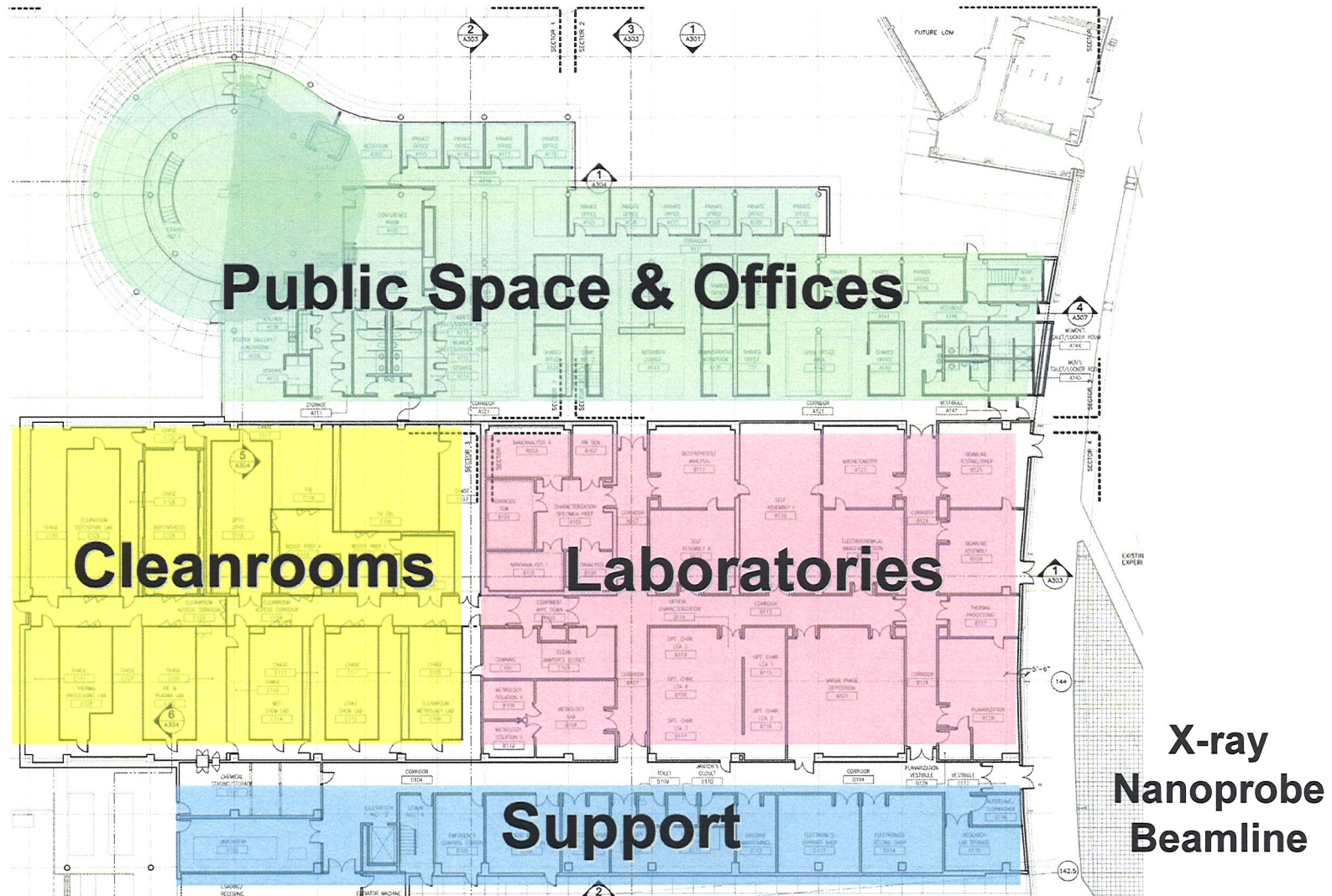


CNM Dedication Ceremony on September 18, 2006



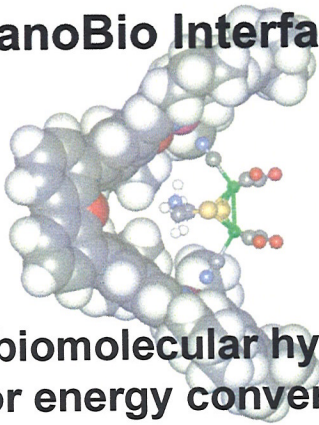
Early operations began May '06
Full operations begin fall '07

CNM Building Layout



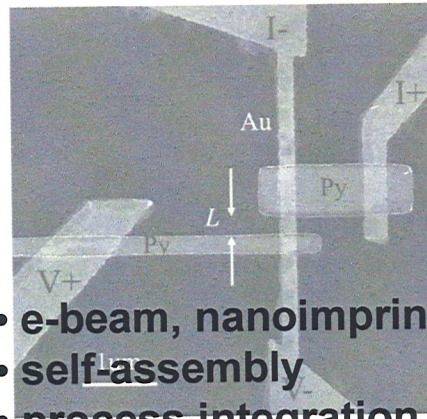
Six Integrated Scientific Themes

NanoBio Interfaces



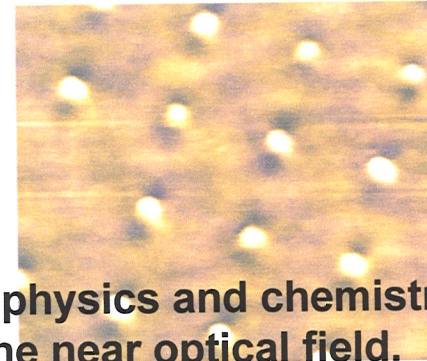
- biomolecular hybrids for energy conversion
- biomimetics
- dynamics

Nanofabrication



- e-beam, nanoimprint
- self-assembly
- process integration

Nanophotonics



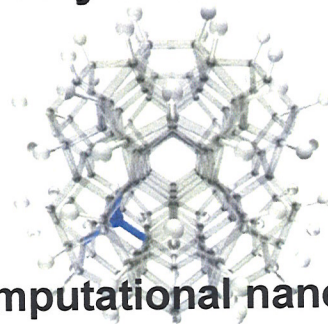
- physics and chemistry in the near optical field.
- plasmonics.

X-ray Imaging & Scattering



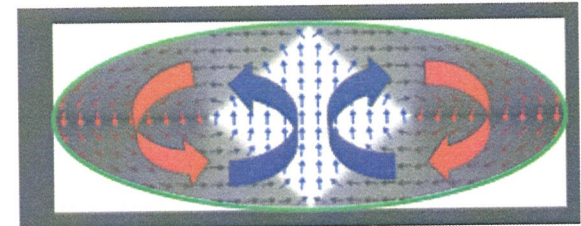
- Ultimate x-ray microscope
- chemical, structural, strain, domain mapping.
- in-situ processes.

Theory & Simulation



- computational nanoscience; 'virtual fab lab'
- advanced computing; user friendly code

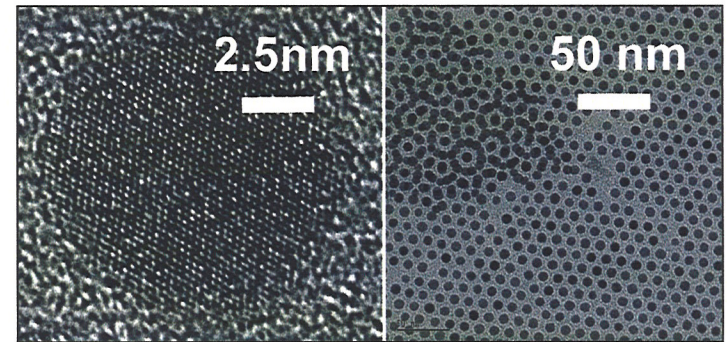
Electronic/Magnetic Materials & Devices



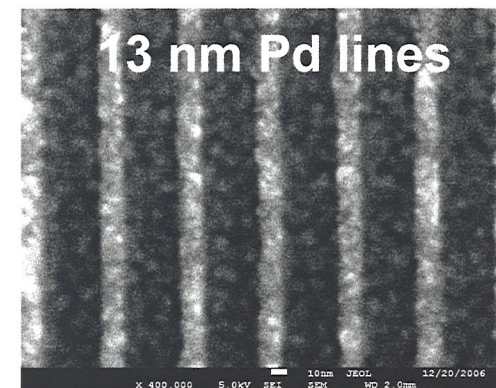
- nanomagnetism
- nanoferroelectricity
- oxide MBE, UNCD
- STM (e.g, spin-polarized)
- novel devices

Enabling Technical Capabilities

- Nanosynthesis - 'bottom-up'
 - bio/organic/inorganic synthesis, self-assembly, thin film deposition.
- Nanopatterning - 'top-down'
 - lithography (ebeam, FIB, optical), imprint, pattern transfer (eg, RIE).
- Nanocharacterization
 - structural, magnetic, electronic, optical, chemical and dynamical properties.
 - AFM, MFM, SEM, confocal optical
 - hard x-ray nanoprobe
- Theory and Simulation
 - computational materials science
 - leverage ANL leadership computing.



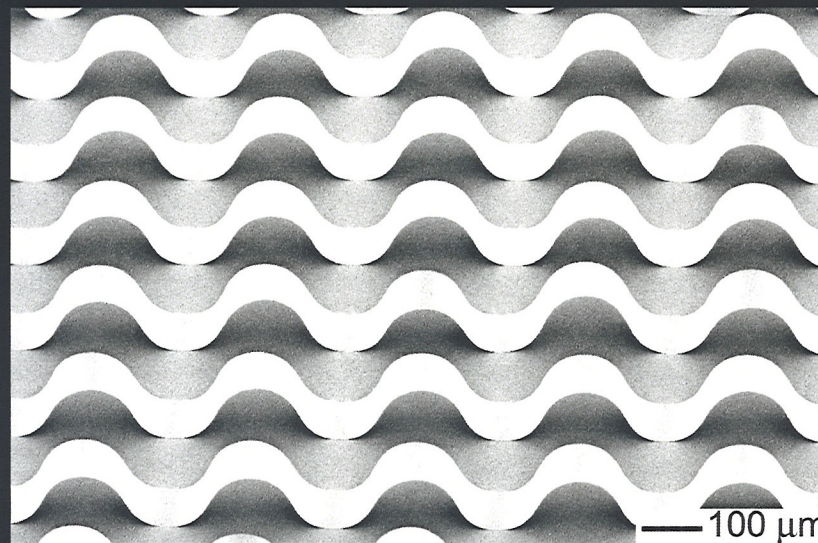
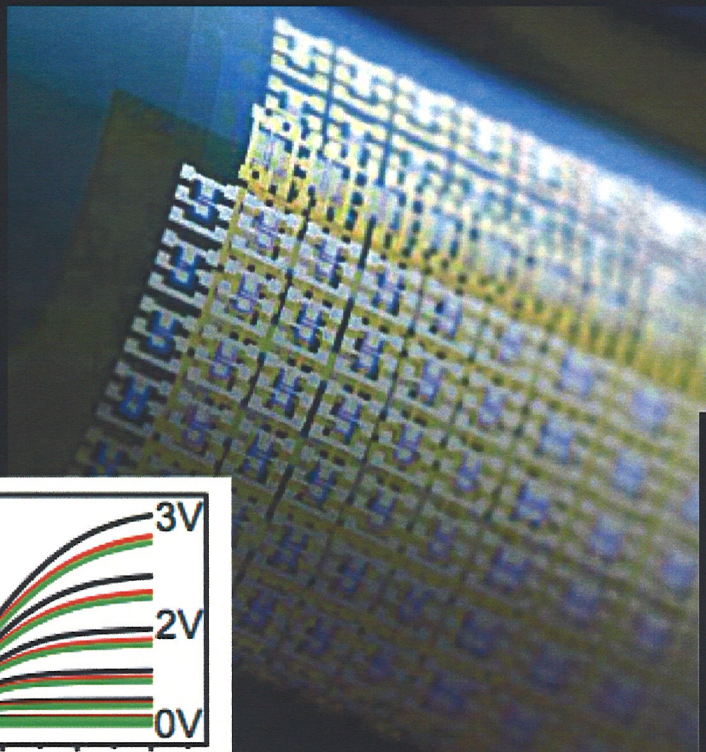
'bottom-up' synthesis and assembly of colloidal nanoparticles



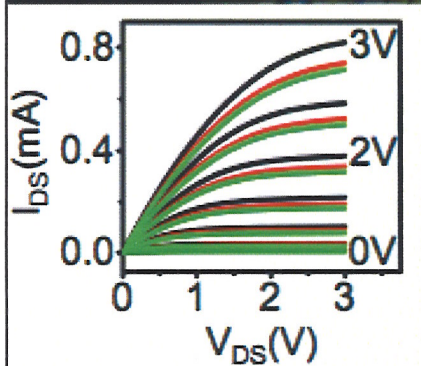
'top-down' patterning of Pd wires; new cold develop process.

Novel Synthesis: Flexible Electronics and Sensors

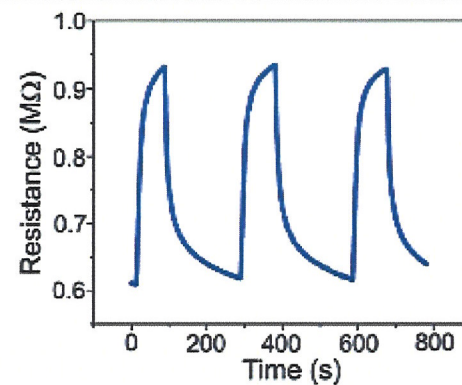
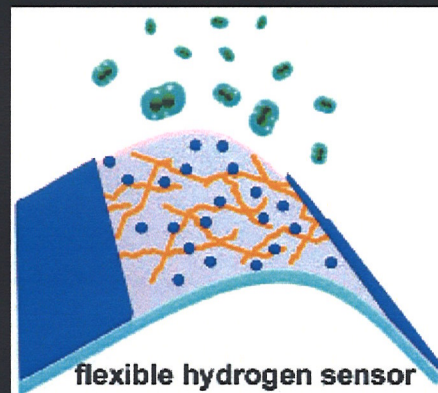
Yugang Sun (CNM), John Rogers (UIUC), et. al.



Flexible Si nanoribbons
Nature, Dec. '06



Rogers, Nuzzo

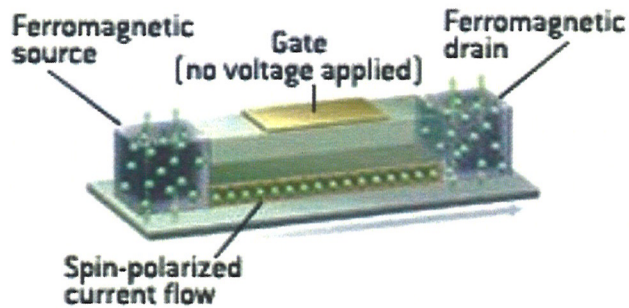


Flexible H-sensor - Pd decorated SWNT film
on flexible substrate.

Novel devices: Materials and Nanopatterning

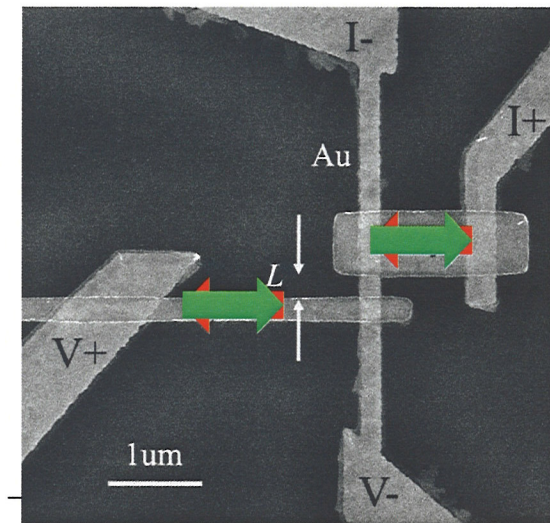
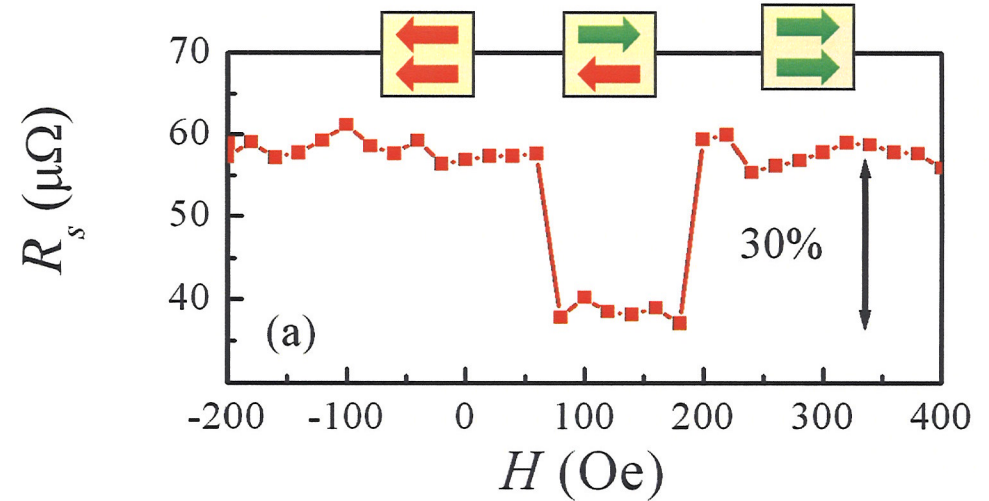
Goal: Spin transistor with gain.

Challenge: Coherent spin transport, materials with 100% spin polarization.



The 'Johnson' (spin) Transistor

Y. Ji, A. Hoffman, S. Bader



Advanced Characterization: spin-polarized STM

Goal: understand and control the relationship between structure and properties of magnetic and (bio)molecular materials at the nanoscale.

Strategy: Develop world-leading programs with novel scanning-probes: STM, polarized-STM; NSOM; AFM/MFM; STM/SEM.

Synergistic with x-ray nanoprobe.



Matthias Bode

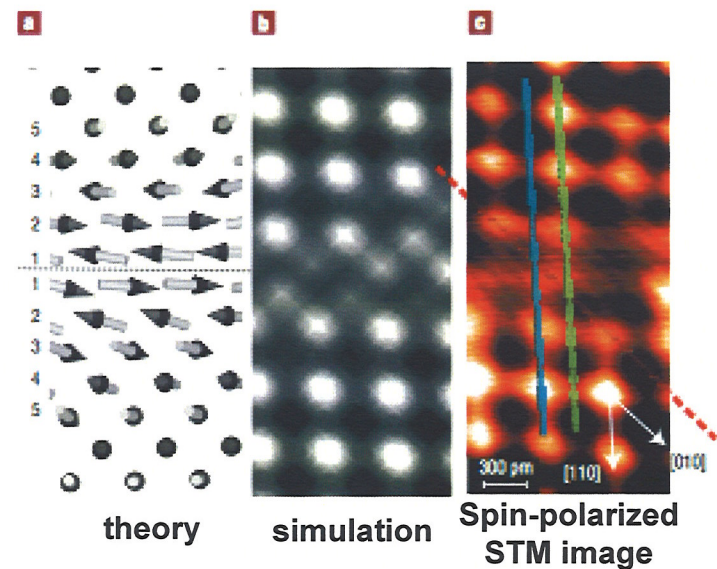
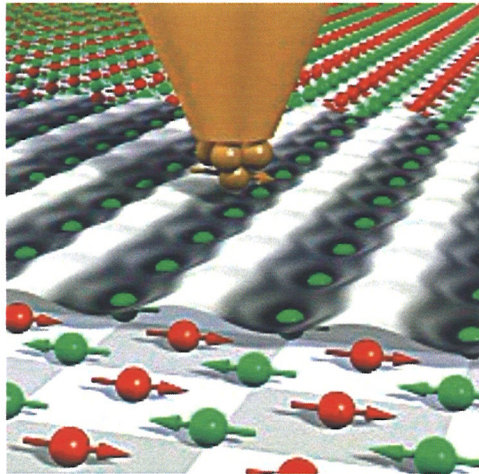
Ph.D.: U. Hamburg, 1996

Senior Scientist, Wiesendanger Group, U. Hamburg, 1996 - present.

Awards: Phillip-Morris Award, '03
Distinguished Lecturer, IEEE, '07.

CNM start date: March 1, 2007.

Spin-polarized STM



Bode, et al, Nature Materials, May (2006)

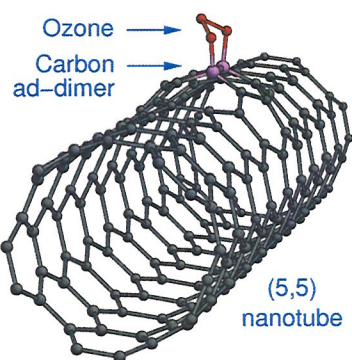
Materials by Design: The *Virtual* Fab Lab

Sternberg, Zapol, Curtiss

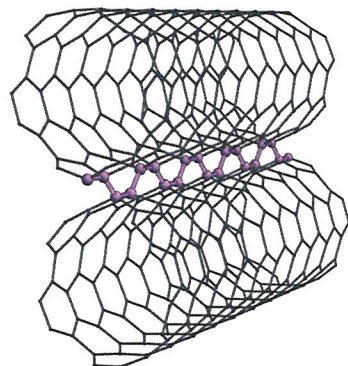
Goals: Create materials with user specified properties.

Computational nanoscience:
Multiscale modeling - tight binding, molecular dynamics, & ab-initio calculations

Example: New Nanomaterials from Functionalized Nanotubes

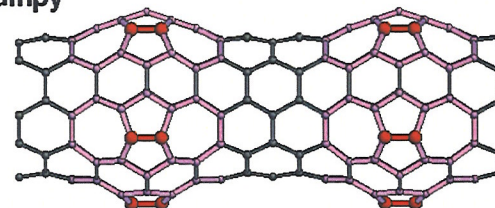


Sidewall Ozonization

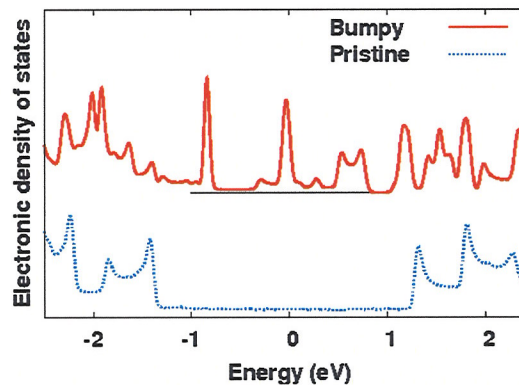
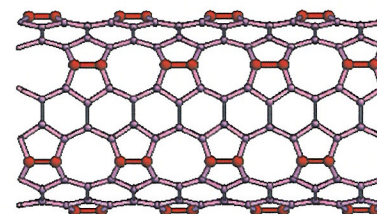


Fused CNTs

“Bumpy”



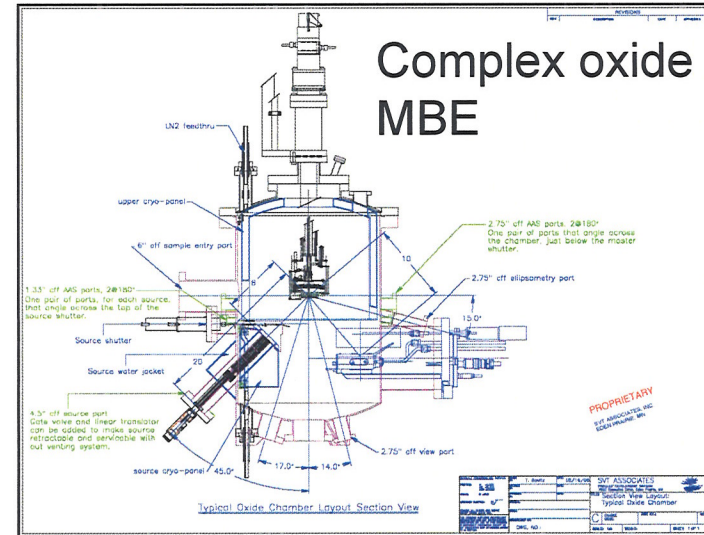
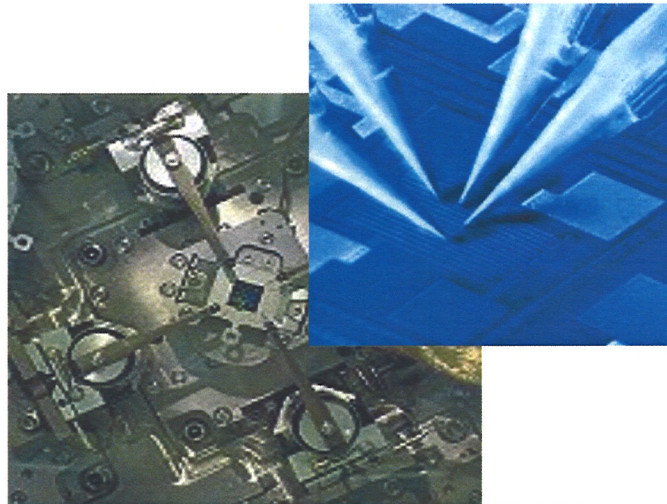
“Multi-zipper”



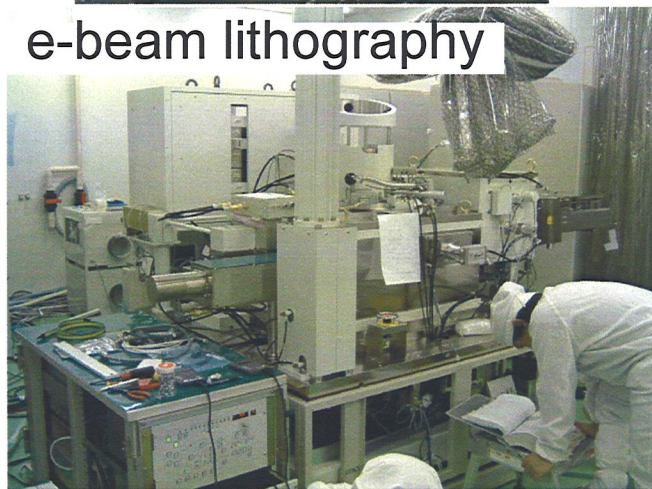
Sternberg *et al*, PRL **96** 075506 (2006)

Key Fabrication and Characterization Tools

Combined STM/SEM



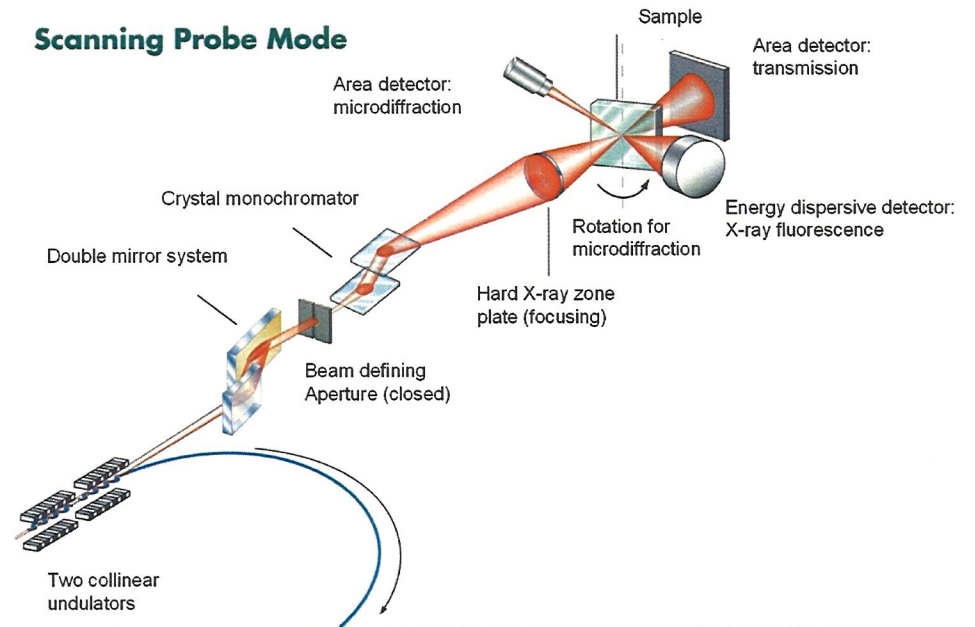
e-beam lithography



Near-field Scanning Optical Microscope

Hard X-ray Nanoprobe

- Mirror installation underway.
- Mono delivered mid-April.
- Nanoprobe instrument (Xradia) delivered in April, installation over the summer.
- Ramp-up to full operations during FY08.



Nanoprobe Science

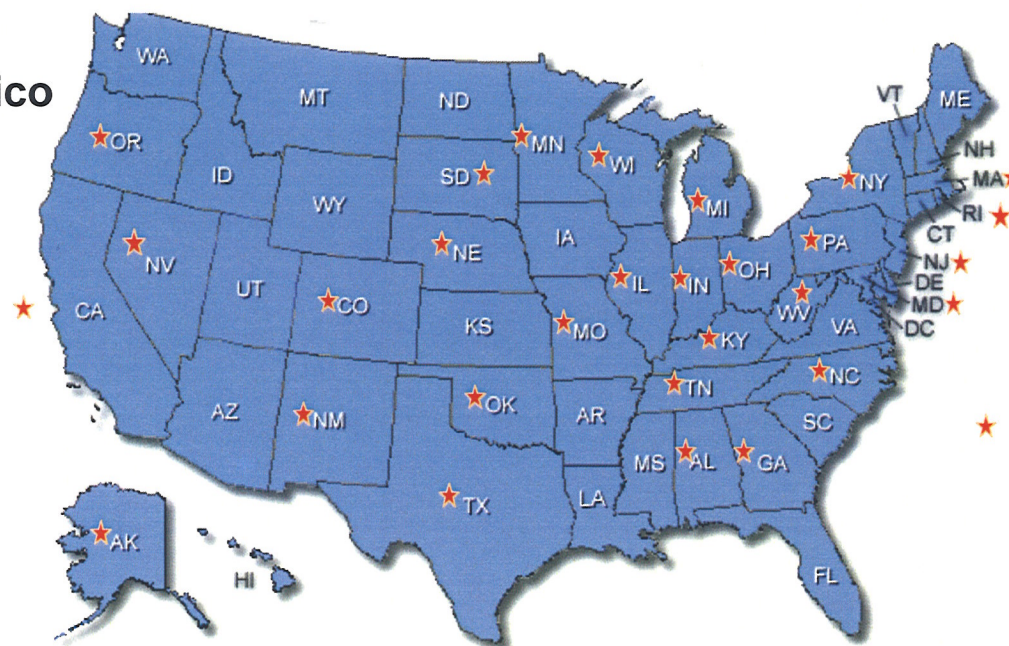
- Imaging - scanning probe, full-field (e.g., tomography), coherent diffraction.
 - Large NA optics (e.g., Multi-layer Laue Lens).
- Nanomagnetism, nanoferroelectricity.
- In-vivo characterization of biomolecular hybrid materials.
- In-situ processes - self-assembly, MBE, MOCVD, catalysis, ...
- Dynamics at the nanoscale.

CNM User Program

- Early ops, May '06; full ops, Fall '07
- 320 registered users
- 150 user proposals in three calls
- 115 publications (~ 50/50 staff/user)
 - Nature, PRL, Nanoletters, APL, JACS, JPCB, ...

www.nano.anl.gov

28 States and Puerto Rico
17 Countries



★ **Asia/Pacific**

- Beijing, PRC
- Daejeon, ROK
- Clayton, Australia

★ **Middle East & Africa**

- Holon, Israel
- Nsukka, Nigeria
- Cape Town, South Africa

★ Medellín, Colombia
Cali, Columbia

★ Mayaguez, Puerto Rico
San Juan, Puerto Rico

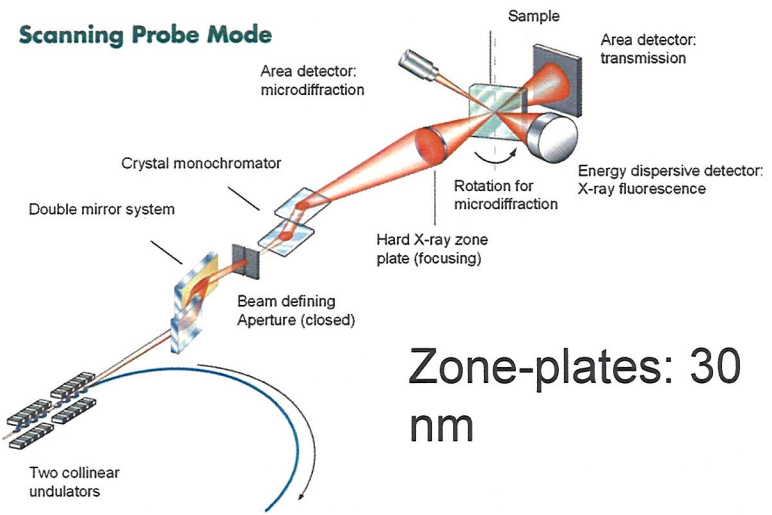
Opportunities for Nanoscience

- Synergies amongst four BES facilities at ANL: APS, IPNS, EMC, CNM - proximity matters.
 - CNM brings new capability to BES facility portfolio - synthesis, fabrication, characterization and theory of materials at the nanoscale.
- Nanoscience with x-rays
 - Sub-10 nm x-ray imaging, coherent diffraction, dynamics (sub-100 ps), in-situ processes (self-assembly, catalysis, ...).
- Nanoprobes at CNM
 - STM, spin-polarized STM, STM/SEM, AFM, MFM, electron microscopy (STEM, SEM), SPM/SEM.
- 'One-stop' user access to all four facilities.
 - www.nano.anl.gov

Center for Nanoscale Materials: A DOE facility for nanoscience research



Hard X-ray Nanoprobe



www.nano.anl.gov