BNL: Overview and Energy Initiatives

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Deputy Director for
Science & Technology
October 25, 2007

SIXTY YEARS
OF DISCOVERY
1947-2007

BROOKHAVEN
NATIONAL LABORATORY

Office of Science
U.S. DEPARTMENT OF ENERGY

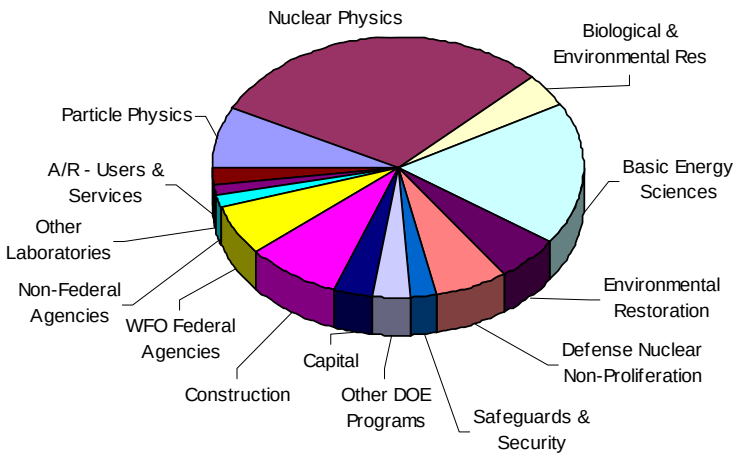
Aerial View of BNL

Snapshot

- BNL is celebrating its 60th anniversary
- Six Nobel Prizes garnered
  - Latest in 2002 and 2003
- ~2600 employees
- >4000 scientific facility users annually
- S&T Portfolio
  - Nuclear & Particle Physics
  - Basic Energy Sciences
  - Life Sciences
  - Environment
  - National Security
  - Computational Science

FY 2007 New Funds

$492 Million



2/3 from Office of Science

DOE Mission

Discover the Solutions that Power and Secure America's Future

BNL Approach

An Integrated, Coherent Approach Among Core Programs, Facilities, Collabs. and Users

RHIC I, II

CFN

NSLS I, II, JPSI

NY Blue

BES, BER, EENS, NPP

Core programs

Facilities

Interdisciplinary team-oriented research

Collaborators, Users

Science Challenges

- Energy Security/Climate Change
- Origins of the Universe
- The Standard Model
- Accelerator Science/Detectors
- Understanding/Curing Addiction
- National Security

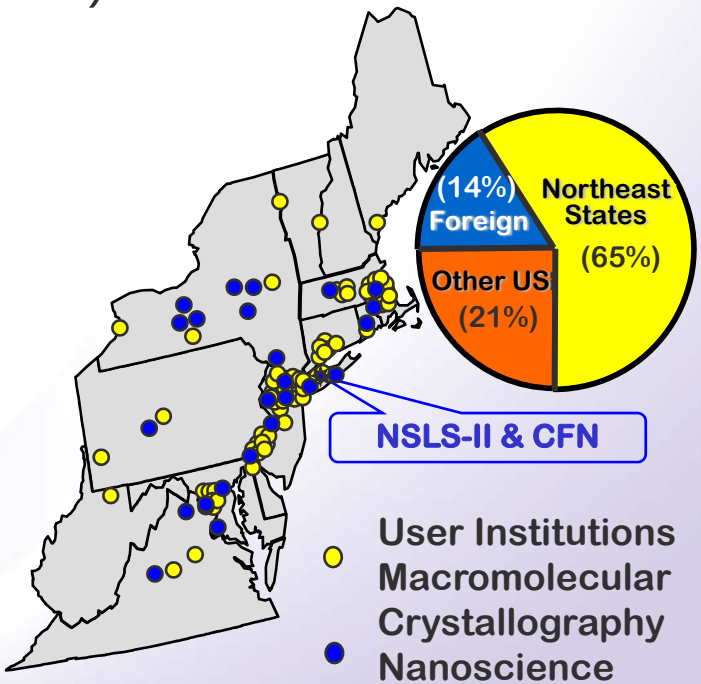
SBU, Columbia, Cornell

IBM, GE, Toyota, GM, LI Industry

National Synchrotron Light Source

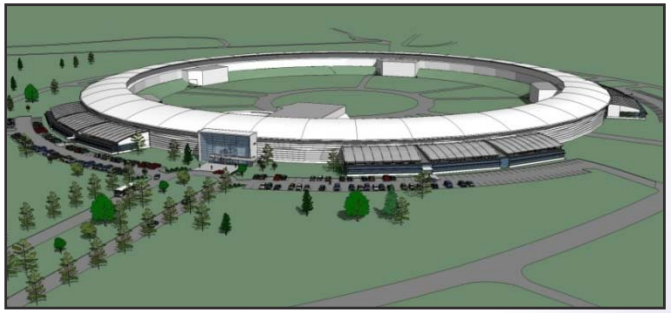
- Crucial resource for the Northeast
  - 2100 Users in FY 2006
  - 400 institutions
    - academic, industrial, government
  - > 900 publications in FY 2006 (a record)
  - ~ 25% in premier journals

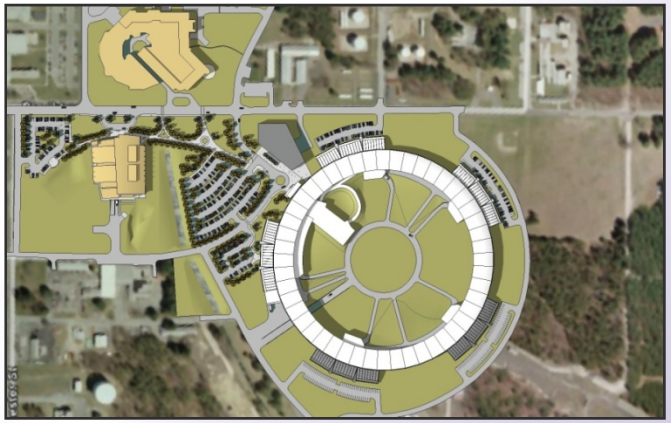
- Vital for BNL programs:
  - Energy, CFN, Catalysis Center, Structural Biology, Environment
- What's next: NSLS-II
  - NSLS ~25 years old



NSLS-II: Enable the Nanoscience Revolution

- World-leading performance
  - 10,000 brighter than NSLS
  - 1 nm spatial resolution
  - 0.1 meV energy resolution
  - Synergy with the CFN
    - Dynamical characterization of new materials, reactions, processes
- CD-1 announced on July 17
  - $750-925M TPC
  - Full operations in FY2015
    - Comparable in scope to RHIC operations





Center for Functional Nanomaterials

To develop and share materials and processes at the nano-scale to address the country's critical needs

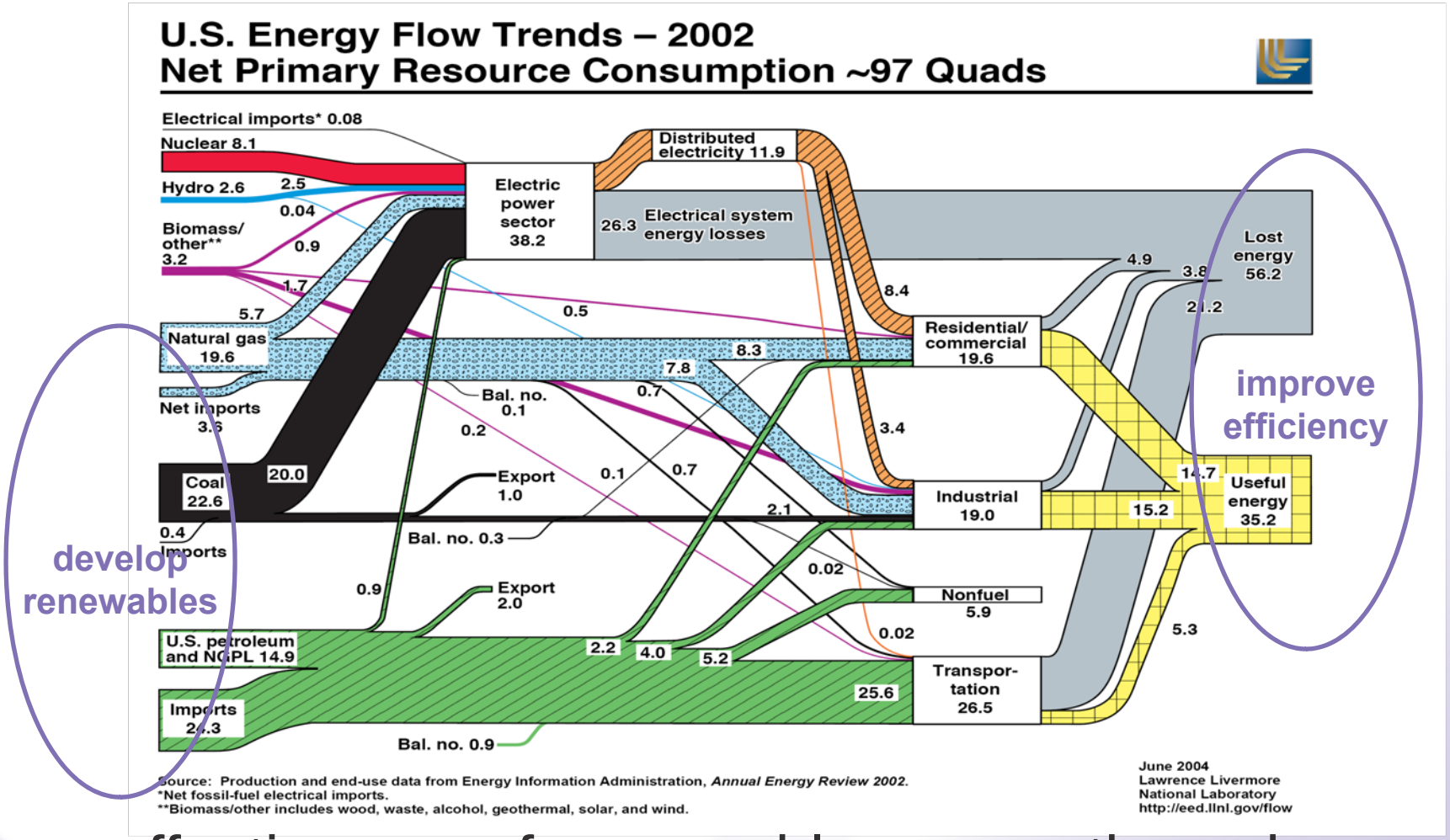
Themes

- **Electronic Nanomaterials**
- **Soft/Bio Nanomaterials**
- **Nanocatalysis/Interfaces**

- **Properties: User-oriented, Focused on energy**
- **Capabilities: Preparation, Characterization, Understanding, New Techniques**

- User facility, fully operational 5/08
- In FY 2006, 91 proposals received; 88 accepted; 31 new

U.S. Energy Flows and Consumption



…effective use of renewable energy through improved conversion, transmission, and storage

Brookhaven Strategic Plan

BNL Initiatives

NSLS-II

CFN/Nanoscience

New York Blue

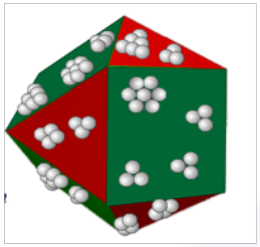
RHIC→ RHICII→ eRHIC

BNL Energy Vision
Basic/applied research underlying breakthroughs in effective use of renewable energy through improved conversion, transmission, and storage

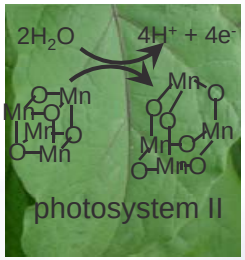
Energy Themes

- **Catalysis**
- **Solar**
- **Complex Materials**
- **Biofuels**

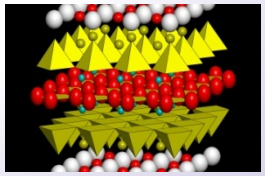
Focused Energy LDRD Investment



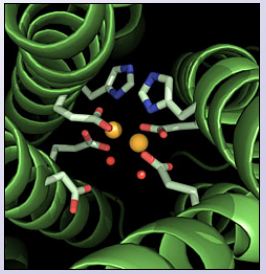
Nanocatalyst



Solar Fuel, PV



Superconductor



Engineered Enzyme, combustion

BROOKHAVEN **Partners: SBU/Universities/Industry**

BNL Energy Portfolio

Basic and applied research underlying breakthroughs in efficient use of renewable energy

Production/ Conversion

Biofuels
Solar Fuels
Solar PV
Catalysis

Transmission

Superconductivity

Materials

Storage

Catalysis/Electro chem.
- Fuel Cells
-Batteries
New Materials

End Use

Biofuels (Combustion)
Solid State Lighting
Catalysis

CFN, NSLS I, II, New York Blue

Spectrum of energy research

Discovery Research	Use-inspired Basic Research	Applied Research	Technology Maturation & Deployment
▪ Basic research for fundamental new understanding ▪ Development of new tools, techniques, and facilities	▪ Basic research for new understanding specifically to overcome showstoppers on real-world materials.	▪ Research with the goal of meeting technical targets, with emphasis on the development, performance, cost reduction, and durability of materials and components or on efficient processes ▪ Proof of technology concept	▪ Cost reduction ▪ Scale-up research ▪ Prototyping ▪ Manufacturing R&D ▪ Deployment support
Office of Science		Technology Offices	

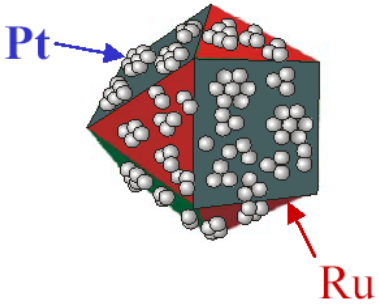
Brookhaven: "Complete spectrum" of energy research

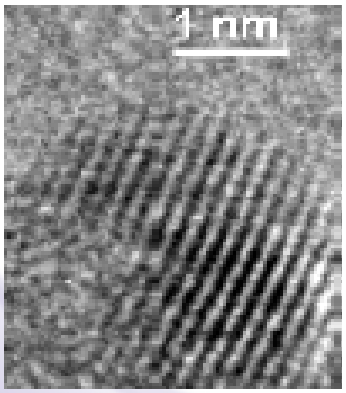
Discovery Research | Use-inspired Basic Research | Applied Research | Technology Maturation & Deployment

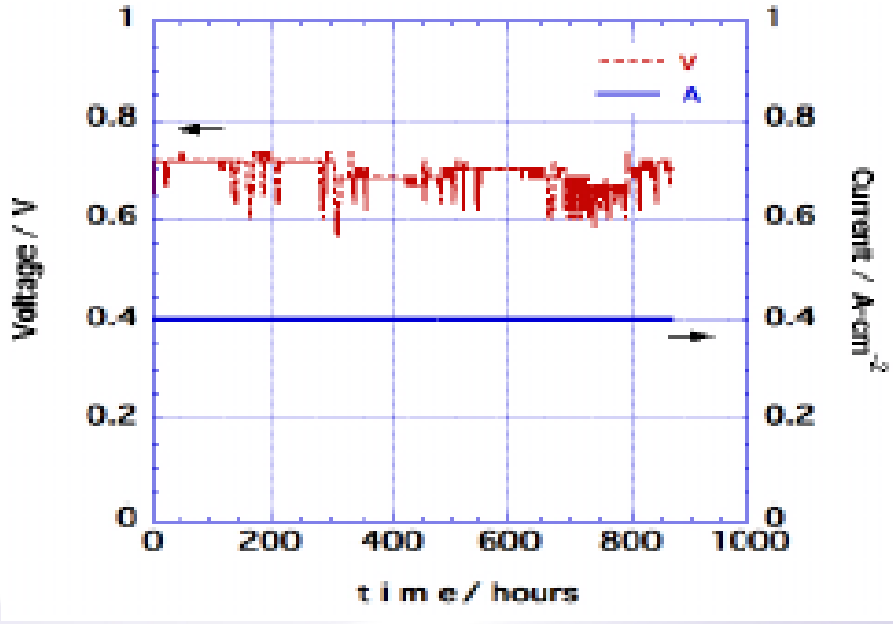
Fuel Cell Nanocatalysis

Challenge: Pt loading, activity, stability

–Solution: Pt submonolayer on nanoparticles







CRADAs with Industry

- GM: Scale up of nanocatalyst synthesis
- Toyota: Oxygen reduction new nanocatalysts
- Battelle: Integration with fuel cell membranes
- Dupont: Methanol oxidation nanocatalysts

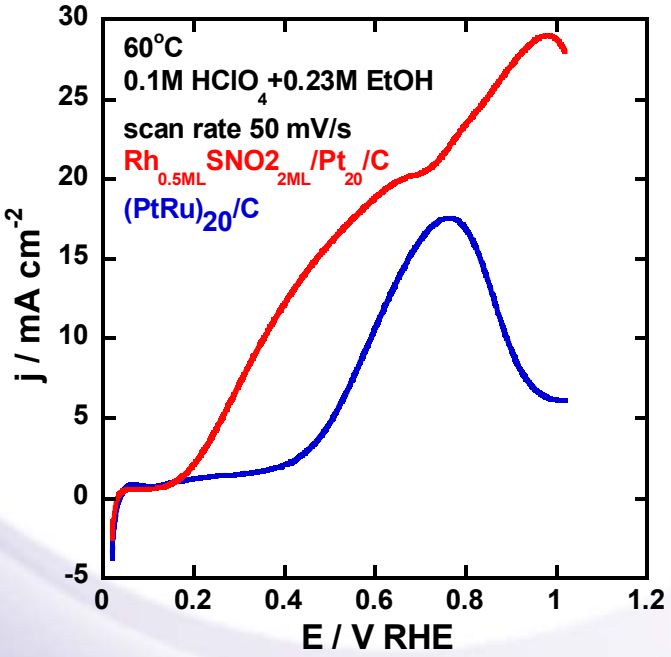
Energy Storage: Catalysis/Electrochemistry

Direct Ethanol Fuel Cell

$C_2H_5OH + 3\ H_2O \rightarrow 2\ CO_2 + 12\ H^+ + 12\ e^-$

Challenge: C-C bond is broken only at extreme potentials

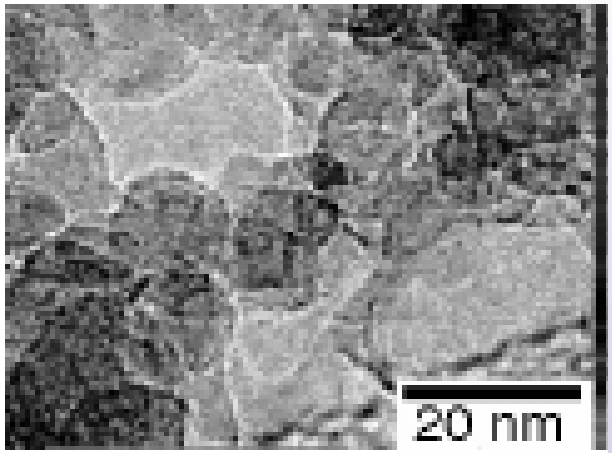
Solution: Pt/SnO2/Rh Catalyst



Lithium Batteries

Challenge: capacity, cycle life, charge time

Solution: Nanostructured electrode materials for larger area electrodes



Electron micrographs of nanostructured Li-Al-Sn prepared at BNL.

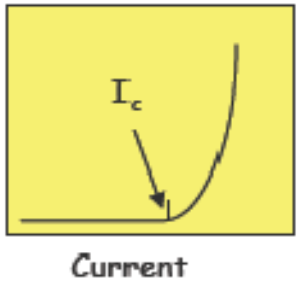
Capacity 10 x Industry Standard

Transmission: Superconductivity

Opportunity: Improving infrastructure of the electrical grid

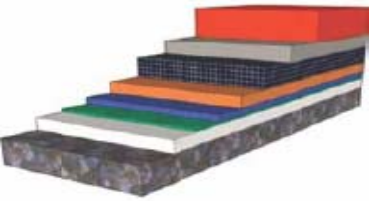
Capacity Reliability Efficiency

Lower Manhattan underground infrastructure. Courtesy Con Edison



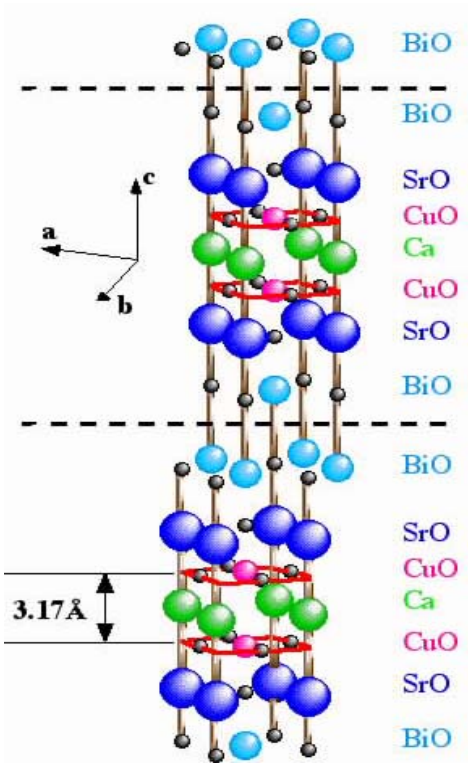
SC Wire IS the controller
Self-healing

SC Wire: less transmission loss



SC Cable
5x capacity of Cu

Challenge: chemically and structurally complex



The unit cell of $Bi_2Sr_2Ca_4Cu_5O_{14}$ contains 54 atoms!

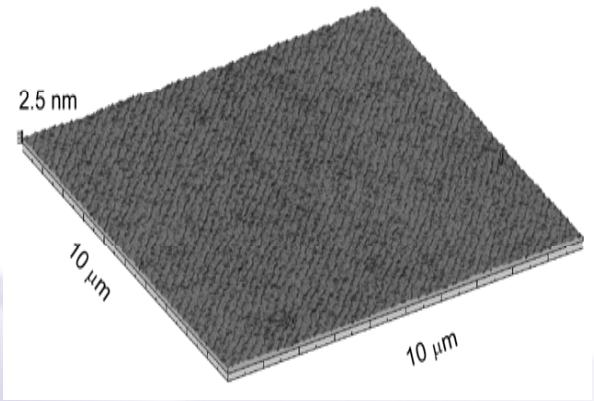
High quality synthesis essential for progress

3rd generation MBE: Discovery of interface superconductivity

Solution: Atomic *layer-by-layer* molecular beam epitaxy (MBE) machine

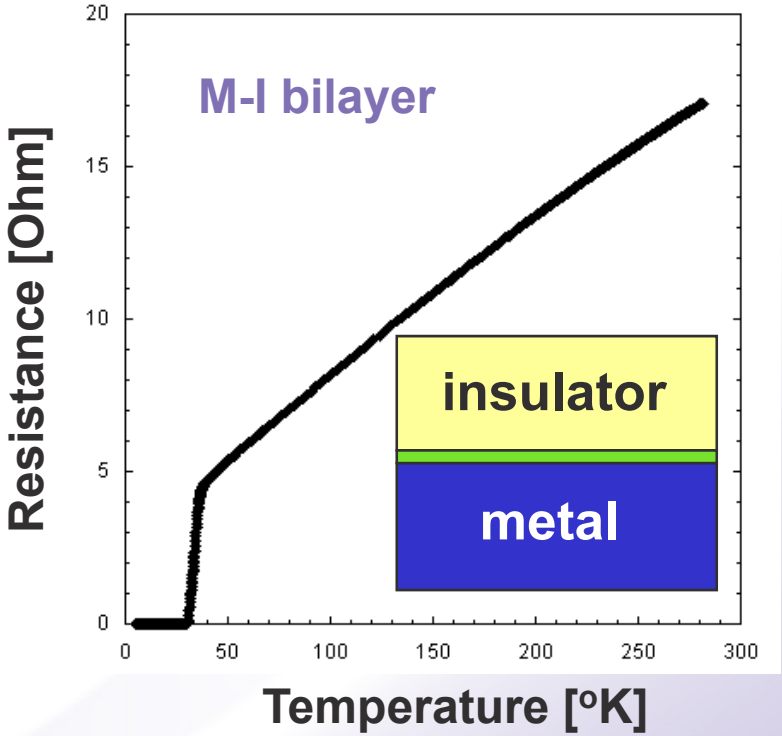
Grow 1 layer at a time

AFM



Interface Superconductivity

- ***Superconductivity at an interface between two materials that are NOT superconducting***



EERE: Superconducting wires
CRADA: American superconductor

Production: Biofuels

- **Understand at the molecular level the fundamental mechanisms that catalyze biological conversions of materials**
- **Develop tools and methods for engineering plant and microbial enzyme systems**

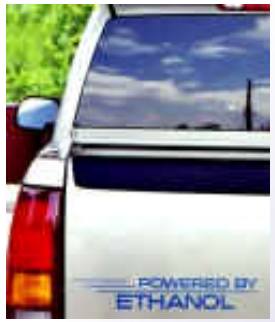
Poplar plantation

BNL/NREL: Poplar biomass

- alternative to corn (marginal land use)

Poplar biomass

Bioethanol production



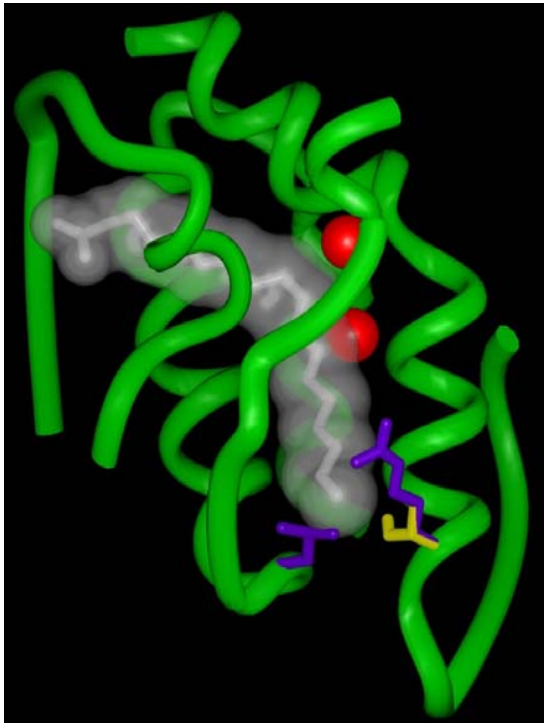
Fuel

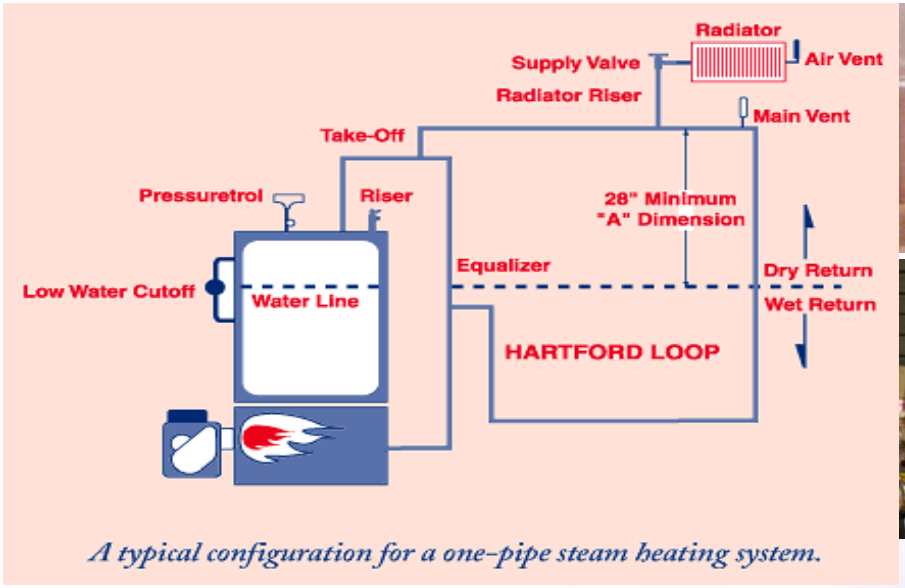
Exploit endophyte mechanisms: improve plant growth over 40%

End Use: Biofuels

- **Genetically engineered microbes to produce desired fuels**
- **Combustion research**

Specifically designed biofuel: Reduced storage degradation, better cold-flow properties, cleaner combustion





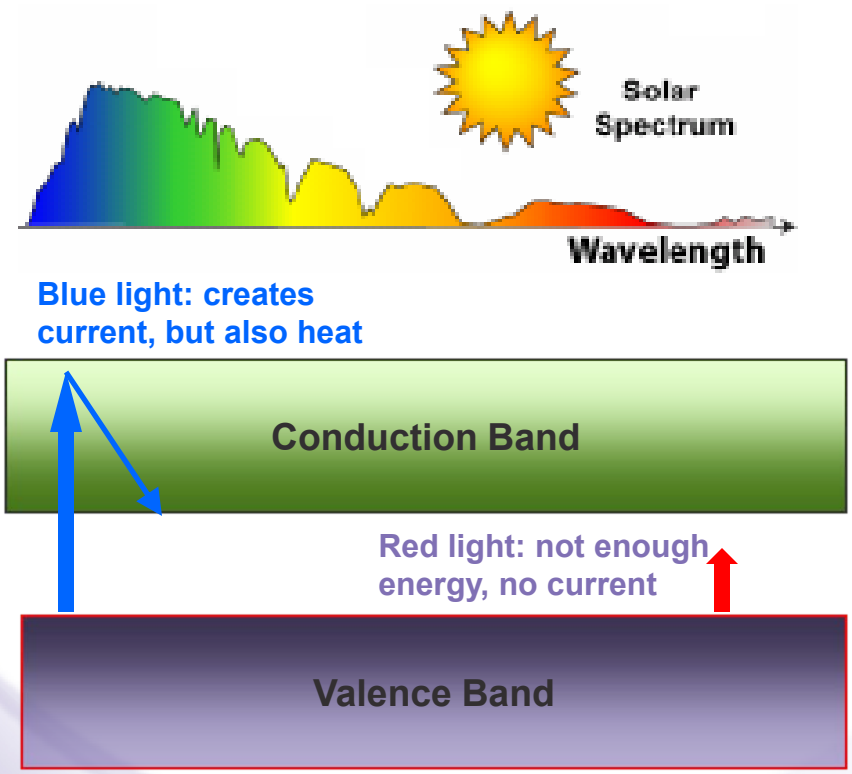
A typical configuration for a one-pipe steam heating system.

Engineering to form oils with desired properties: high energy content/clean burning

NYSERDA
Keyspan
Renewable Energy Long Island
Changing World Technologies – Long Island
Heat Wise, Inc. – Long Island
Fulton Boiler Co. – Fulton, N.Y.
Oilheat Institute of Long Island

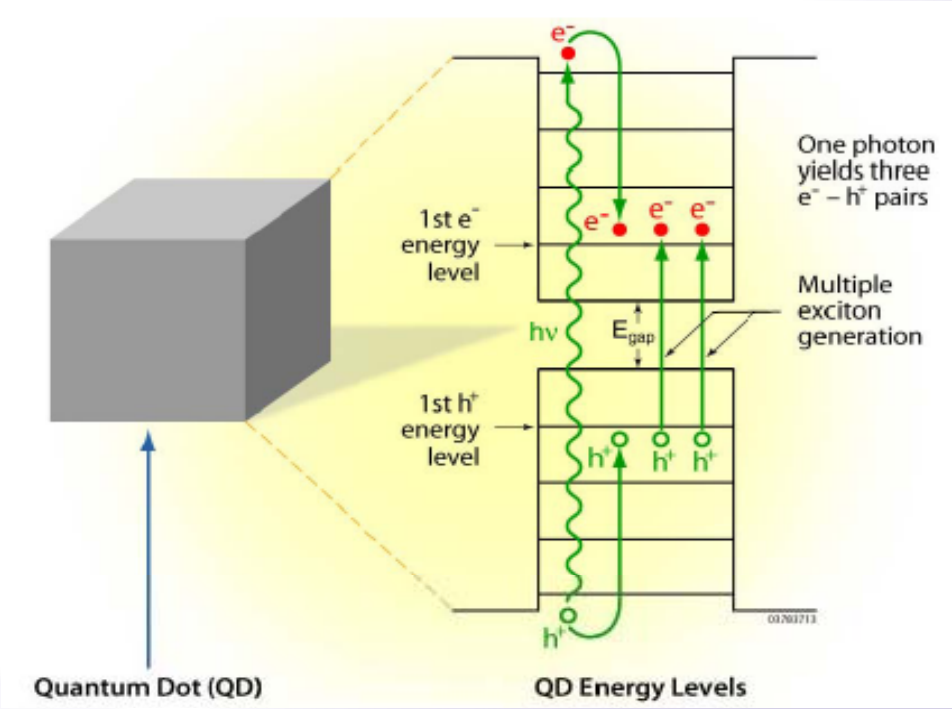
The Role of Science and Basic Research

Challenge: Efficiency Limit in Conventional Photovoltaics (32%)



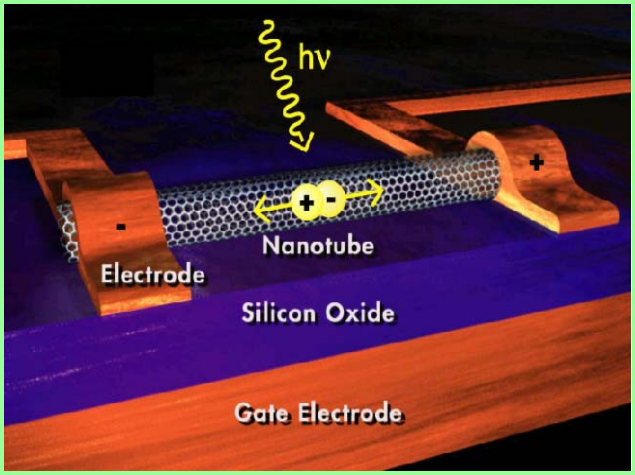
Opportunity: Unusual physics of nanoparticles

- Recovering Heat Normally Lost

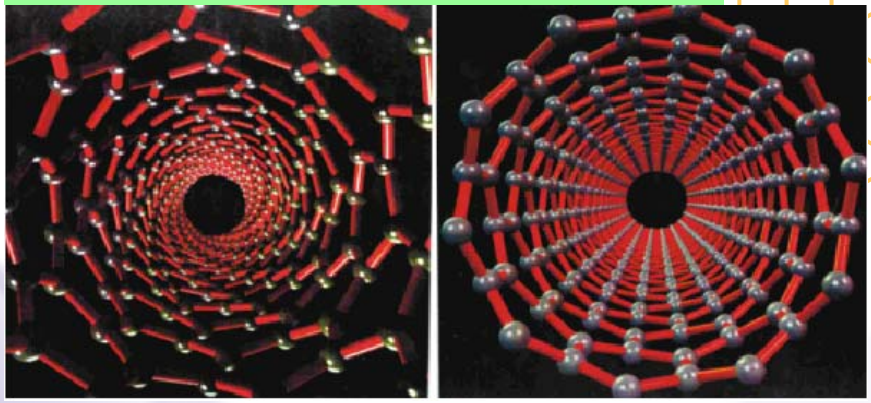


Best compromise: 32% efficiency

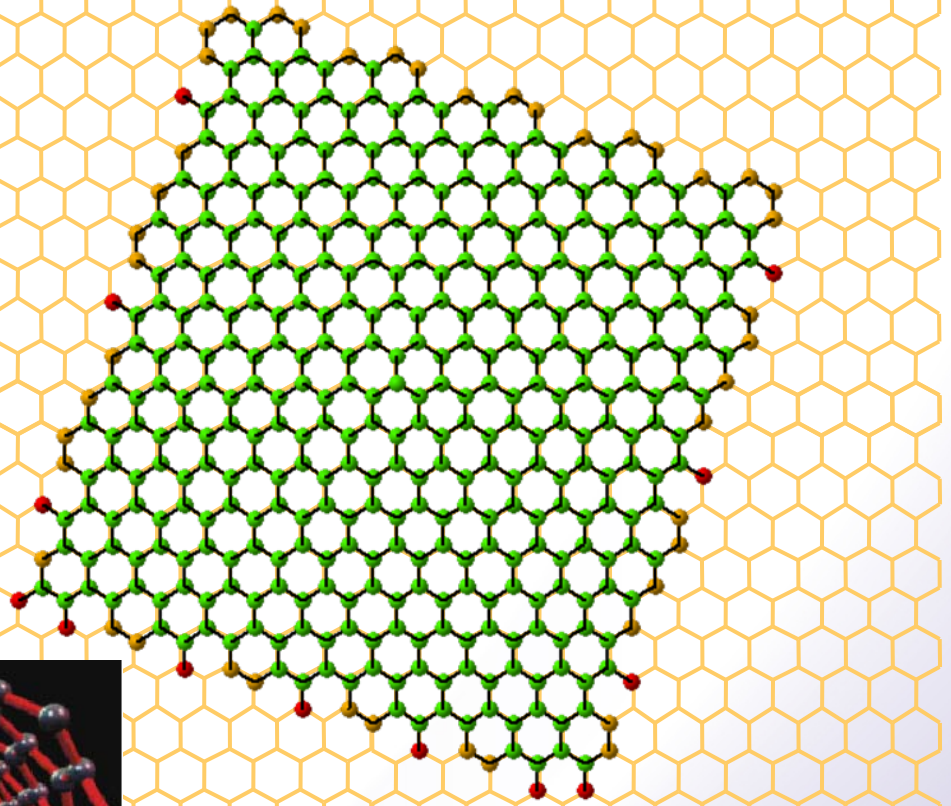
Conversion: Carbon Nanotube Photovoltaic Device



World's smallest Photovoltaic



Freitag, Misewich et al., Nano Letters 3, 1067 (2003)

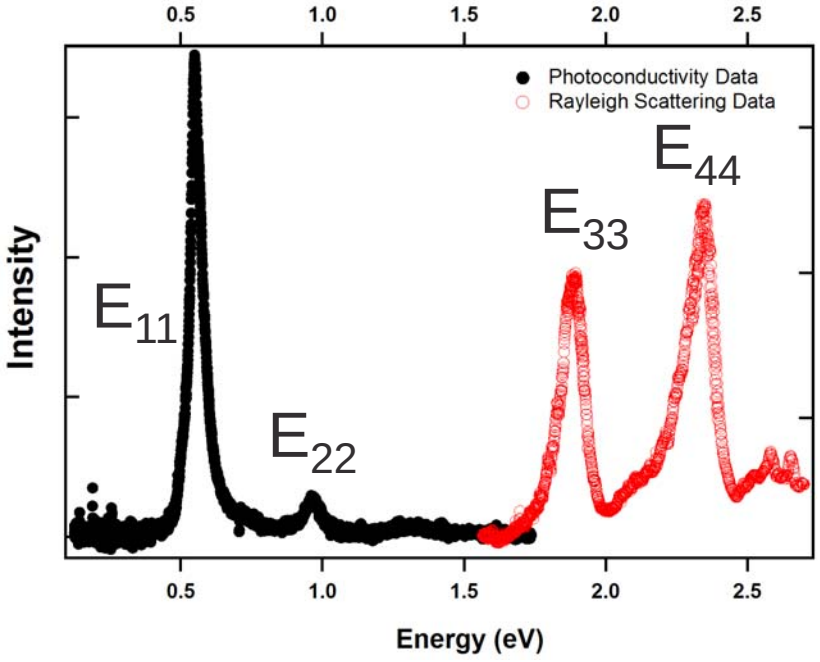


Nanomaterial diversity is a challenge for nanoscience—there are many different structures.

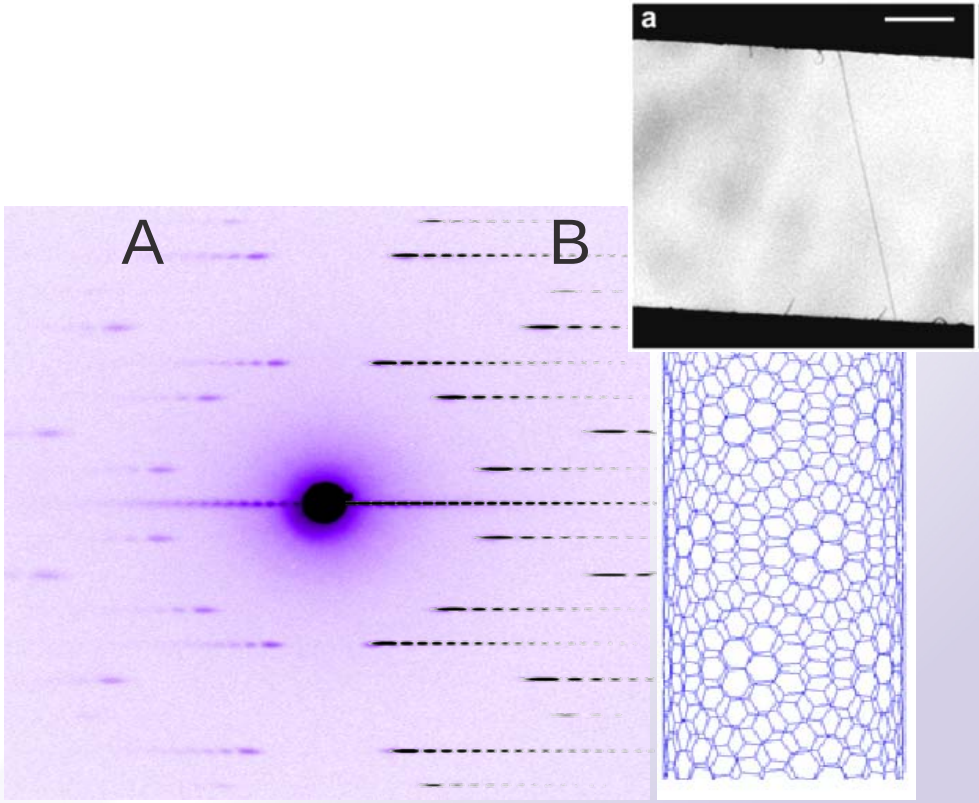
How do we pick out the ones with the best properties?—BNL FACILITIES

Facility Solutions: High sensitivity for nanomaterials

NSLS: IR Beamline
Determining the photoconductivity of a single nanotube



CFN: TEM Facility
Determining the physical structure of the same single nanotube



Working in concert to provide new insight into nanoscience

Sfeir, Zhu, Misewich et al.Science 312, 554 (2006)

BNL Impacts: Future Vehicle Fleet

Largest user of petroleum is transportation (drives fuel switching)

Energy lost is greater than energy used (drives efficiency, recovery and storage)

Biodiesel
Efficient plant/produce engineering

Superconductors
Reliable grid to bring power to charge batteries for plug in hybrids

Lithium Ion Battery Pack
improved electrodes and electrolytes

Hydrogen Hybrid Electric…

Direct ethanol fuel cells
nanocatalysts for C-C bond breaking

Fuel cell catalysts
stable nanocatalysts with high activity, low loading

Hydrogen Storage
understanding of alanate storage mechanisms/catalysis

Thermoelectric heat recovery
nanostructured high thermopower materials