

50nm

50nm

# Nanotechnology Educational Resources for High Schools

Chang Y. Ryu

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Assistant Professor of Chemistry and Chemical Biology  
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Troy, NY 12180

Rensselaer

why not chat



May 23, 2006

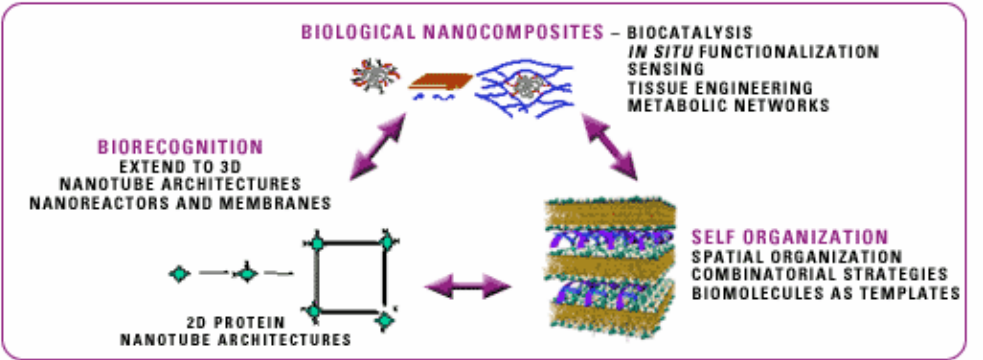
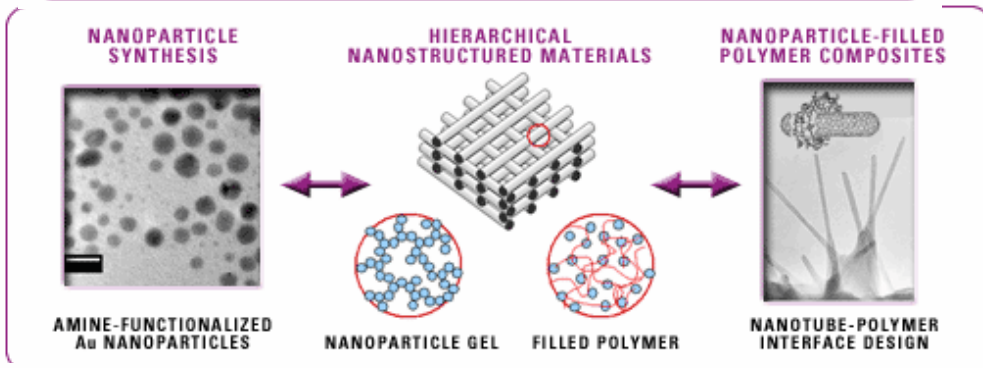
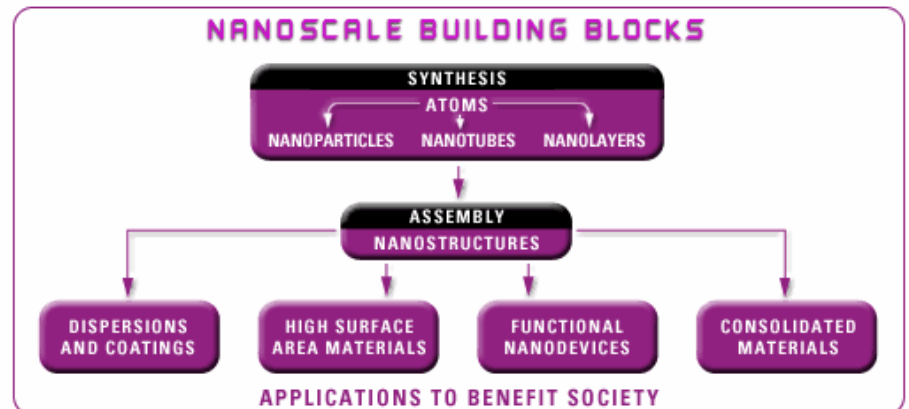
Albany Academy for Girls (<http://www.albanyacademyforgirls.org/>)

Albany, NY (Host: Dr. Terrell Neuge)

RPI (est. 1824)



[www.nano.rpi.edu](http://www.nano.rpi.edu)



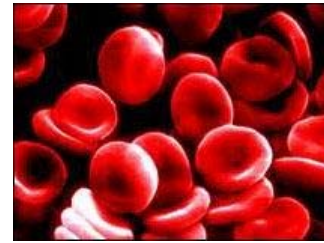
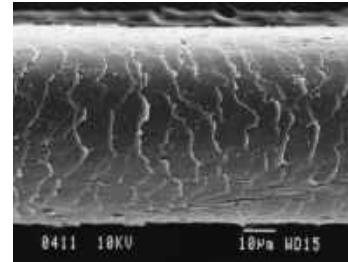
# Outline

- Brief Introduction on Nanotechnology
- Educational Resources on nanotechnology
  - [www.nano.gov](http://www.nano.gov)
- RPI Nanoscale Science and Engineering Center: High school outreach program
  - Bringing nanotechnology to the classroom (Program coordinator: Chang Y. Ryu ([ryuc@rpi.edu](mailto:ryuc@rpi.edu)))
    - Hands on module: Carbon nanotube synthesizer
    - Multimedia module: Virtual Scanning Electron Microscopy (SEM)
    - Lecture module: Atomic Force Microscopy (AFM)
    - Class supplementary information using nanoscale microscopy tools

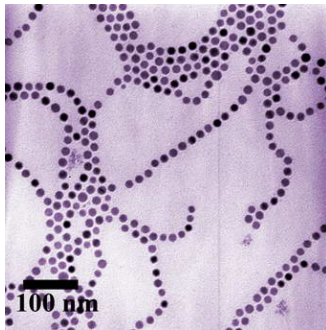


# nano-meter

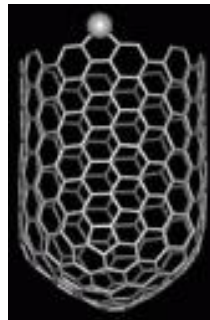
- 1 mm = 1,000  $\mu\text{m}$  = 1,000,000 nm
- nm =  $10^{-9}$  m
  - Thickness of human hair = 100  $\mu\text{m}$
  - Typical size of cells = 30 – 1  $\mu\text{m}$
  - Wave length of visible lights ~ 0.5  $\mu\text{m}$
  - Nanoparticles, nanotubes, nanowires, ...
  - Length of C-C bond: 0.15 nm (1.5 Å)



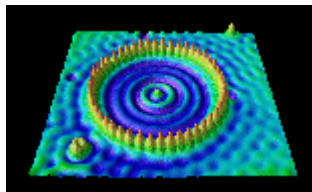
E. coli Bacterium



NIST magnetic nanoparticles



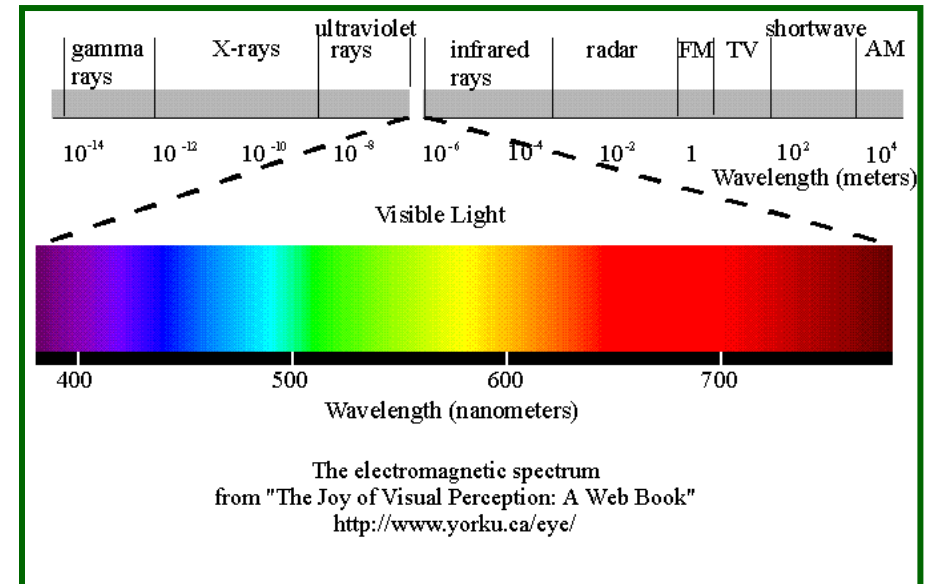
Carbon nanotubes



Iron on Copper



Xe on Nickel



# Technological advances

- In 1900,
  - Most people did **not** have cars, electricity, or indoor plumbing
- By 1950
  - Most people have cars, electricity, or indoor plumbing
  - Development of antibiotics, radio, TV, plastics, nuclear weapons and power, and the computer
- By 2000
  - Jet airliners are common
  - TV, computers, cell phones, global communications network, internet, biotechnology
- Future?
  - Nanotechnology, biotechnology, information technology, energy technology, ???

# Transistor & Information Technology

<http://nobelprize.org/physics/educational/transistor/history/index.html>

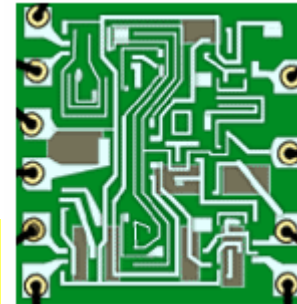
time →



**Vacuum tube**  
("Triodes", Thomson  
– Nobel, 1906)



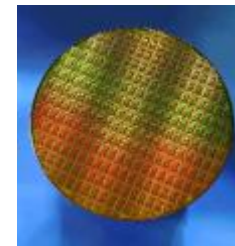
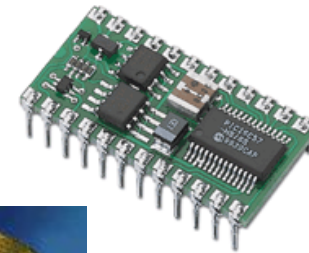
**Solid state**  
(Bardeen and Brattain  
-Nobel, 1956)



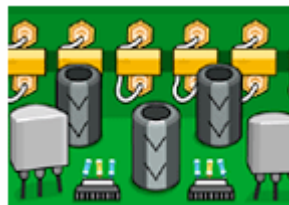
**Integrated Circuit**  
(Jack Kilby  
- Nobel, 2000)



Portable radio from  
Motorola (1959)



Computer  
(late 1940's)



# Nanotechnology: Definition

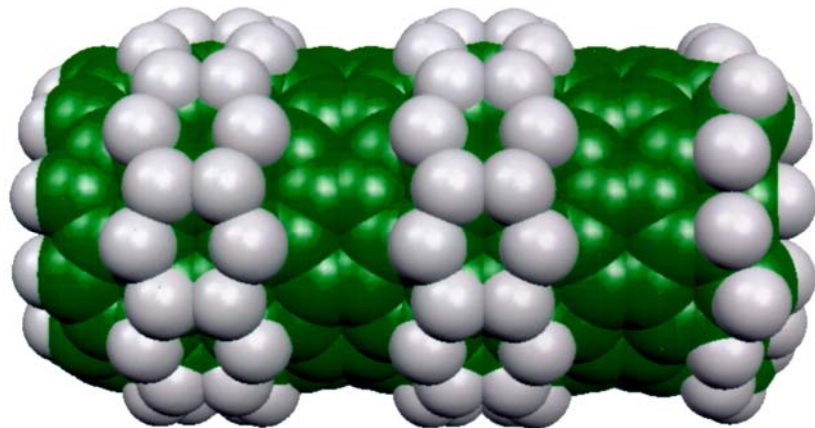
## (National Science Foundation )

[http://www.nsf.gov/crssprgm/nano/reports/omb\\_nifty50.jsp](http://www.nsf.gov/crssprgm/nano/reports/omb_nifty50.jsp)

- Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of **approximately 1 - 100 nanometer range**, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size. The novel and differentiating properties and functions are developed at a critical length scale of matter typically under 100 nm.
- Nanotechnology research and development includes **manipulation under control of the nanoscale structures and their integration into larger material components, systems and architectures**. Within these larger scale assemblies, the control and construction of their structures and components remains at the nanometer scale. In some particular cases, the critical length scale for novel properties and phenomena may be under 1 nm (e.g., manipulation of atoms at ~0.1 nm) or be larger than 100 nm (e.g., nanoparticle reinforced polymers have the unique feature at ~ 200-300 nm as a function of the local bridges or bonds between the nano particles and the polymer).

# What is Nanotechnology?

Nanotechnology is the creation of **USEFUL/FUNCTIONAL materials**, devices and systems through control of matter on the nanometer length scale and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale



Charles Bauschlicher

*“If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering.”*

-Neal Lane  
Former Assistant to the President for Science  
And Technology

Source: <http://www.ipt.arc.nasa.gov/>



# Current Nanotechnology examples

- Size matters! -

- Nanoparticles & “quantum dots”
- Carbon nanotubes
- Micro- and nano-lithography
- Nano- and molecular-electronics
- Nano-materials
- Nano-batteries

# Quantum dot – Biological tags

([www.qdots.com](http://www.qdots.com))

The image shows a screenshot of the Quantum Dot website and a diagram of quantum dot bio-labeling products. The website header includes the Quantum Dot logo, a search bar, and navigation links. The main content area features the text "Molecular Probes™ and Quantum Dot™ invitrogen detection technologies" and a grid of images. The diagram below illustrates the bio-labeling process and the resulting products.

**Quantum Dot**  
invitrogen nanocrystal technologies

Important News: Invitrogen acquires Quantum Dot as of October 5, 2005. Quantum Dot will join the Molecular Probes family of labeling and detection technologies.

Contact Us | Home

Search  GO

COMPANY TECHNOLOGY PRODUCTS NEWS & EVENTS ORDERING SITE MAP

**Molecular Probes™** and **Quantum Dot™**  
invitrogen detection technologies

**QDOT® BIO-LABELING PRODUCTS**

NOW AVAILABLE  
**QDOT® ITC™ QUANTUM DOTS**  
FOR FLEXIBLE CHEMISTRIES

**QDOT ITC™ CARBOXYL QUANTUM DOT**

**Qdot™ Nanocrystal**

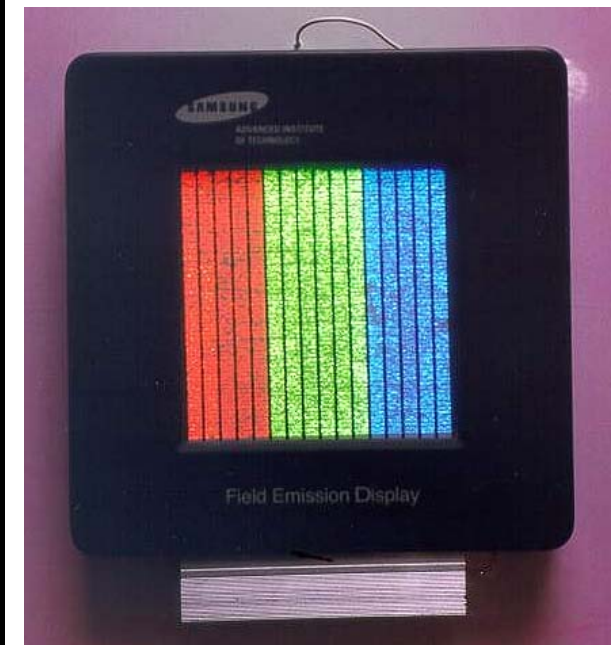
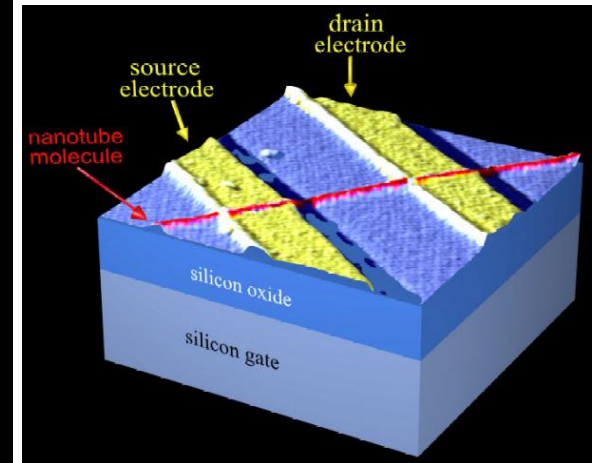
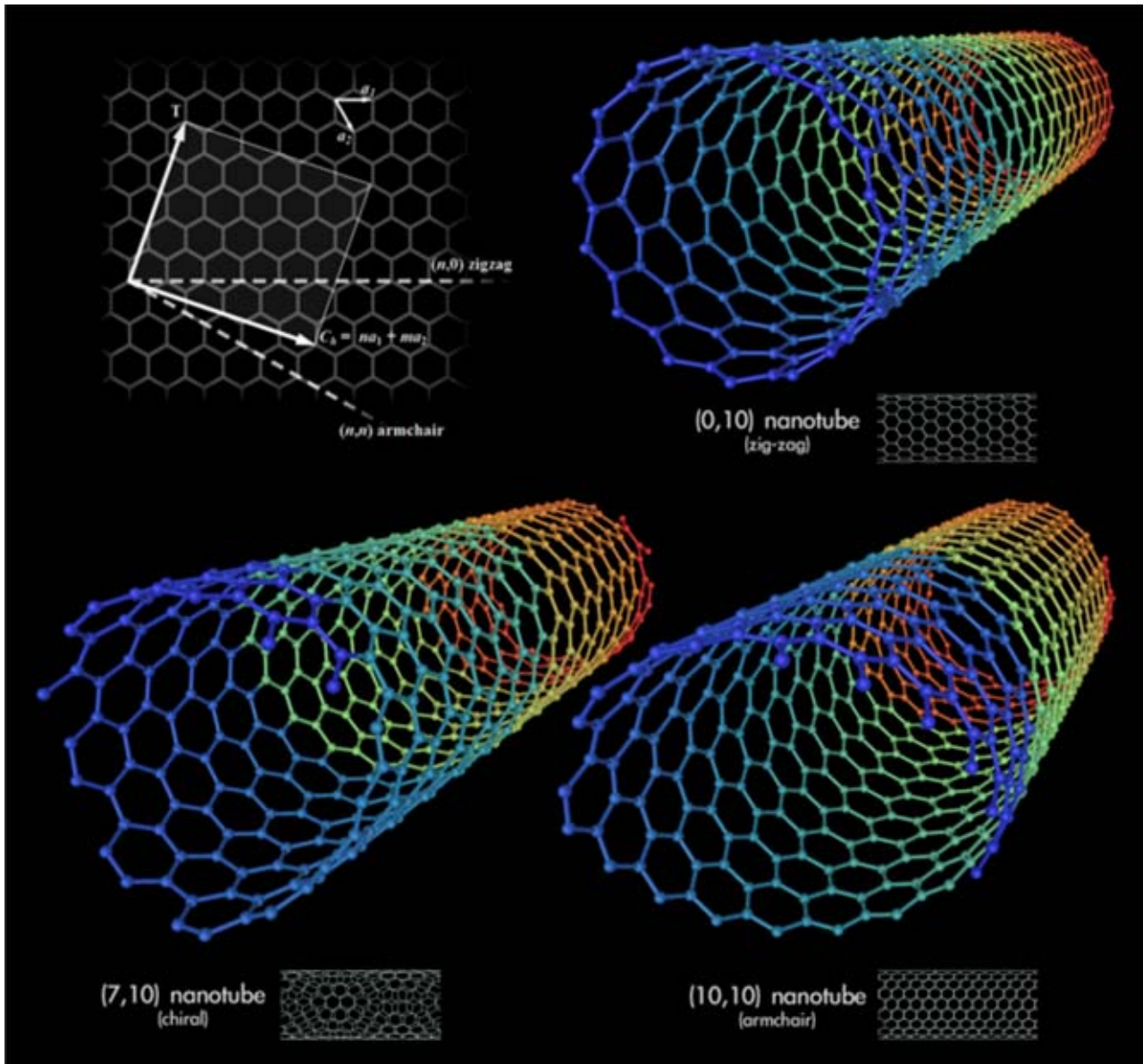
1 Å 1 nm 10 nm 100 nm 1 μm 10 μm 100 μm

**FITC** **GFP** **PE**

**Atom** **Small Dye Molecules** **Fluorescent Proteins** **Colloidal Gold** **Bacterium** **Animal Cell**

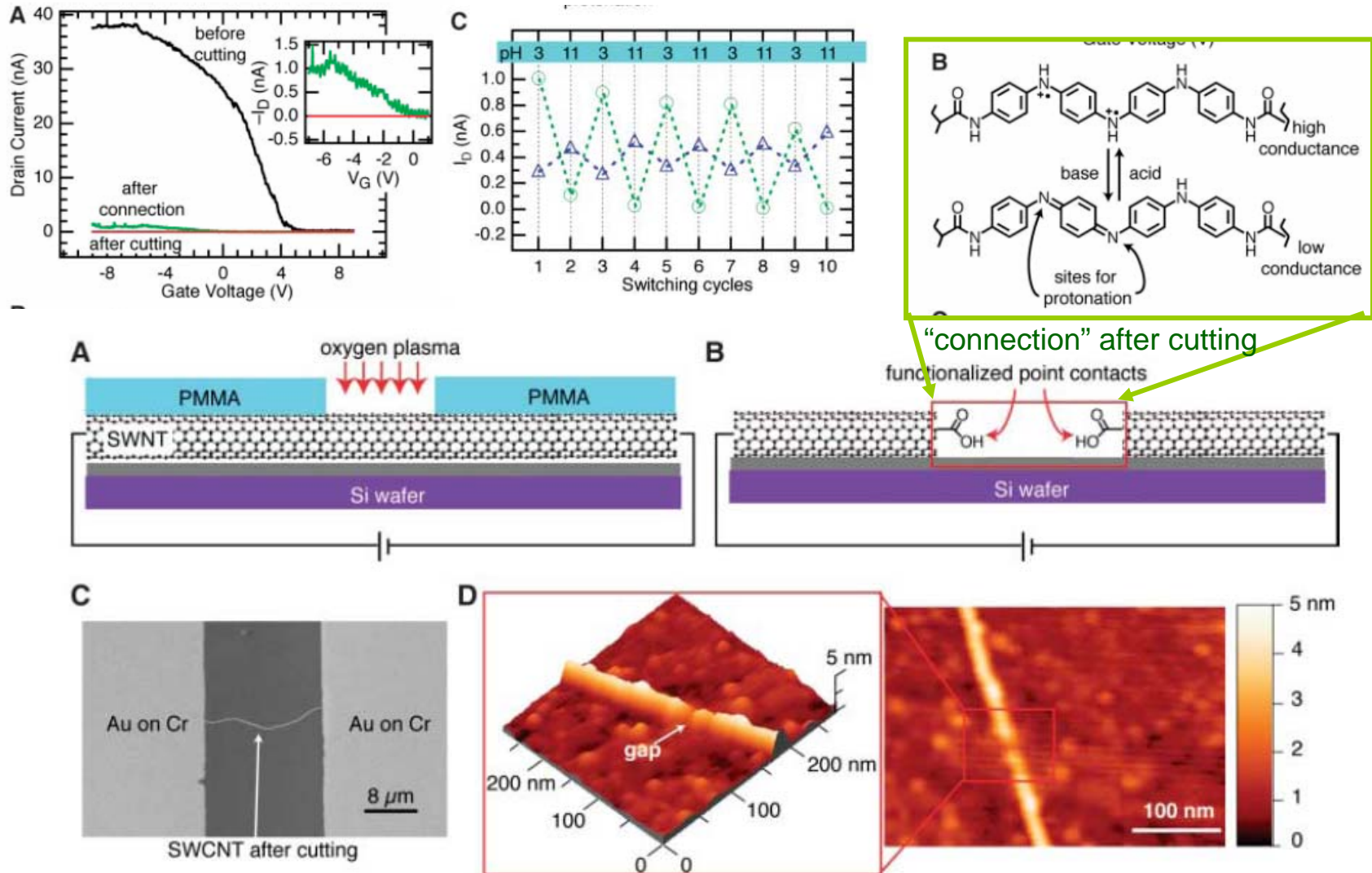
The diagram illustrates the bio-labeling process and the resulting products. It shows a quantum dot nanocrystal with a core and shell structure. The nanocrystal is shown with a scale bar ranging from 1 Å to 100 μm. The nanocrystal is shown with various labels: FITC, GFP, and PE. The nanocrystal is shown with various labels: Atom, Small Dye Molecules, Fluorescent Proteins, Colloidal Gold, Bacterium, and Animal Cell. The diagram also shows the resulting products: a series of colored dots (red, orange, yellow, green, blue) and a series of vials containing colored liquids (red, orange, yellow, green, blue).

# Carbon nanotubes

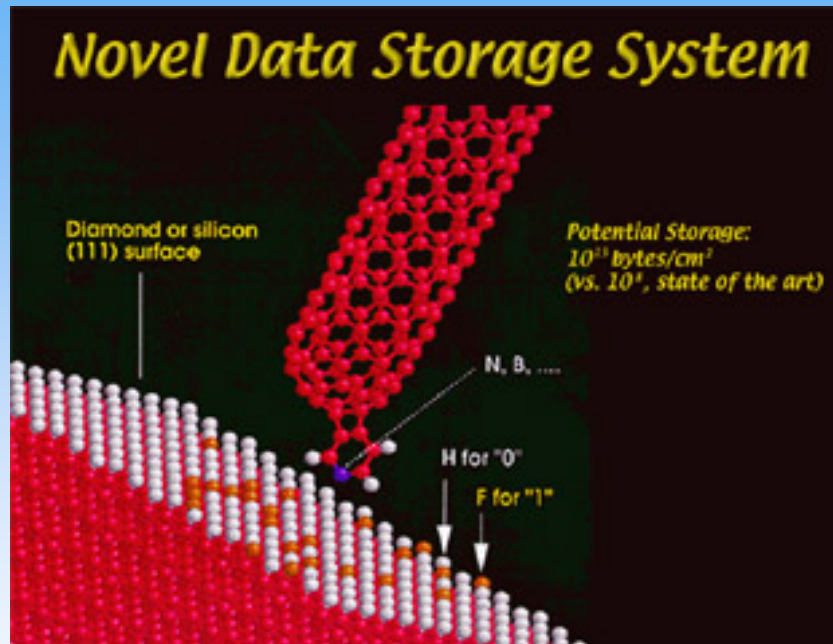
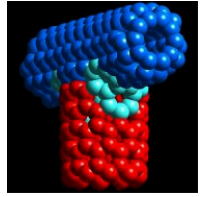


# e.g. Nanotube chemical sensors

Kim and Nuckolls *et al.* (Columbia Univ.), *Science* (Jan, 2006) 311, 356







**Nanotechnology is an enabling technology**

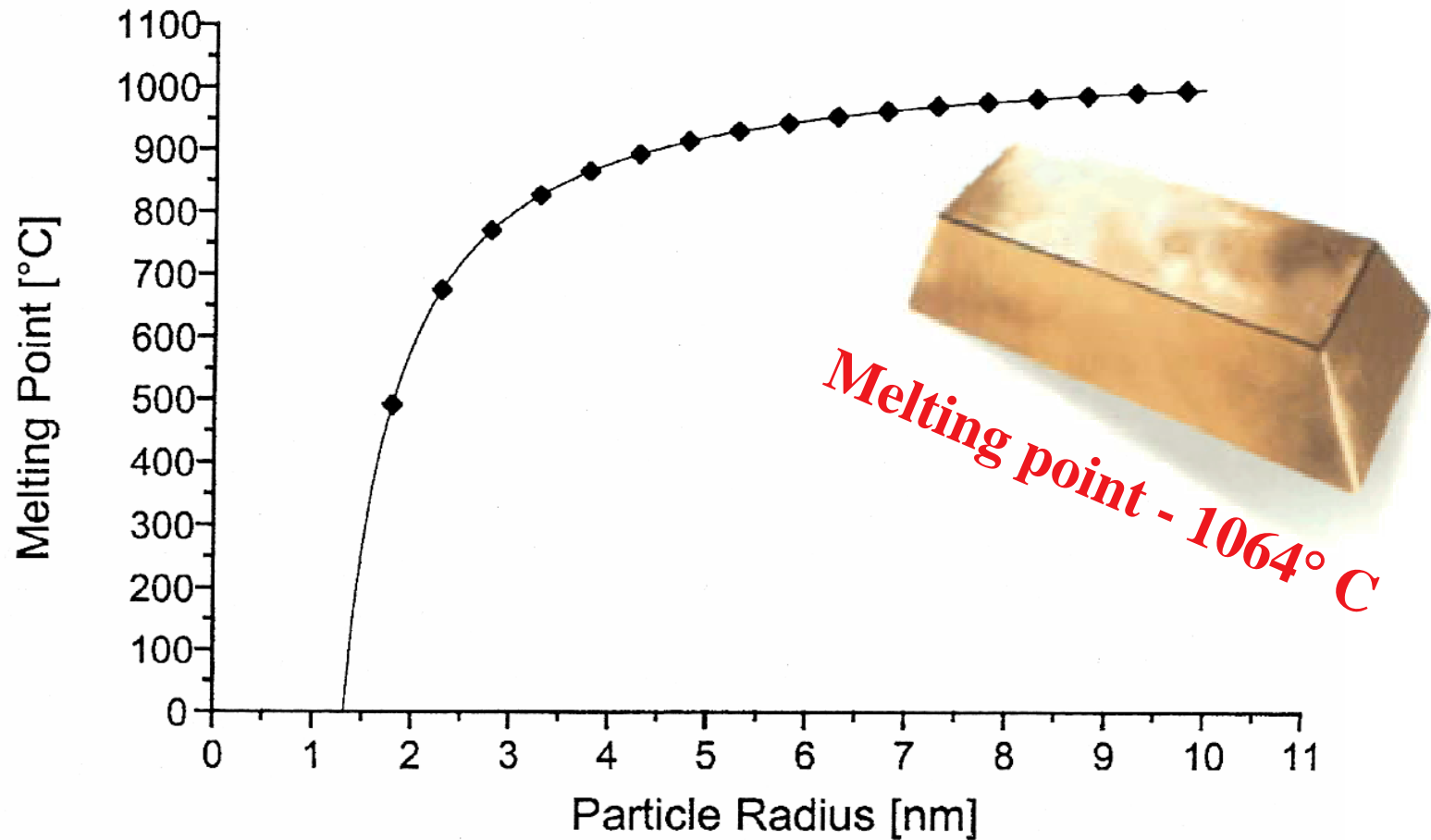
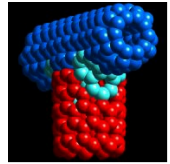
- Computing and Data Storage
- Materials and Manufacturing
- Health and Medicine
- Energy and Environment
- Transportation
- National Security
- Space exploration
- 

Source: <http://www.ipt.arc.nasa.gov/>

# Outline

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    - Multimedia module: Virtual Scanning Electron Microscopy (SEM)
    - Lecture module: Atomic Force Microscopy (AFM)
    - Class supplementary information using nanoscale microscopy tools

# Melting Point of Gold



Source: <http://www.ipt.arc.nasa.gov/>

Source: K.J. Klabunde, 2001

# www.nano.gov

**NATIONAL NANOTECHNOLOGY INITIATIVE**

The National Nanotechnology Initiative (NNI) provides a multi-agency framework to ensure U.S. leadership in nanotechnology that will be essential to improved human health, economic well being and national security. The NNI invests in fundamental research to further understanding of nanoscale phenomena and facilitates technology transfer.

Home Site Map Search Contact Us

Leading to a Revolution in Technology and Industry

**Nanotechnology White Paper Released by EPA for Comment**

An intra-agency Nanotechnology Workgroup, created by EPA's Science Policy Council in December 2004, has released a draft white paper on nanotechnology for public comment. The paper identifies key questions for EPA to address as nanotechnology is developed and its potential environmental and economic benefits are realized. EPA will use the white paper to address research needs and risk assessment issues concerning nanotechnology. Public comments will be submitted to an external review panel for consideration. EPA expects to issue a final white paper in early 2006. [Read more.](#)

**US to Lead ISO Group on Health, Safety and Environmental Standards**

The inaugural meeting of the International Organization for Standardization (ISO) Technical Committee 229, Nanotechnologies, was held in London, November 9-11, 2005. During the meeting it was decided that ISO/TC 229 will approach the development of International Standards for nanotechnology within

**Nano Currents**

- [Workpla Exchange](#)
- [NCI Allia](#)
- [Study: M](#)
- [Comm](#)

[Brookha](#)

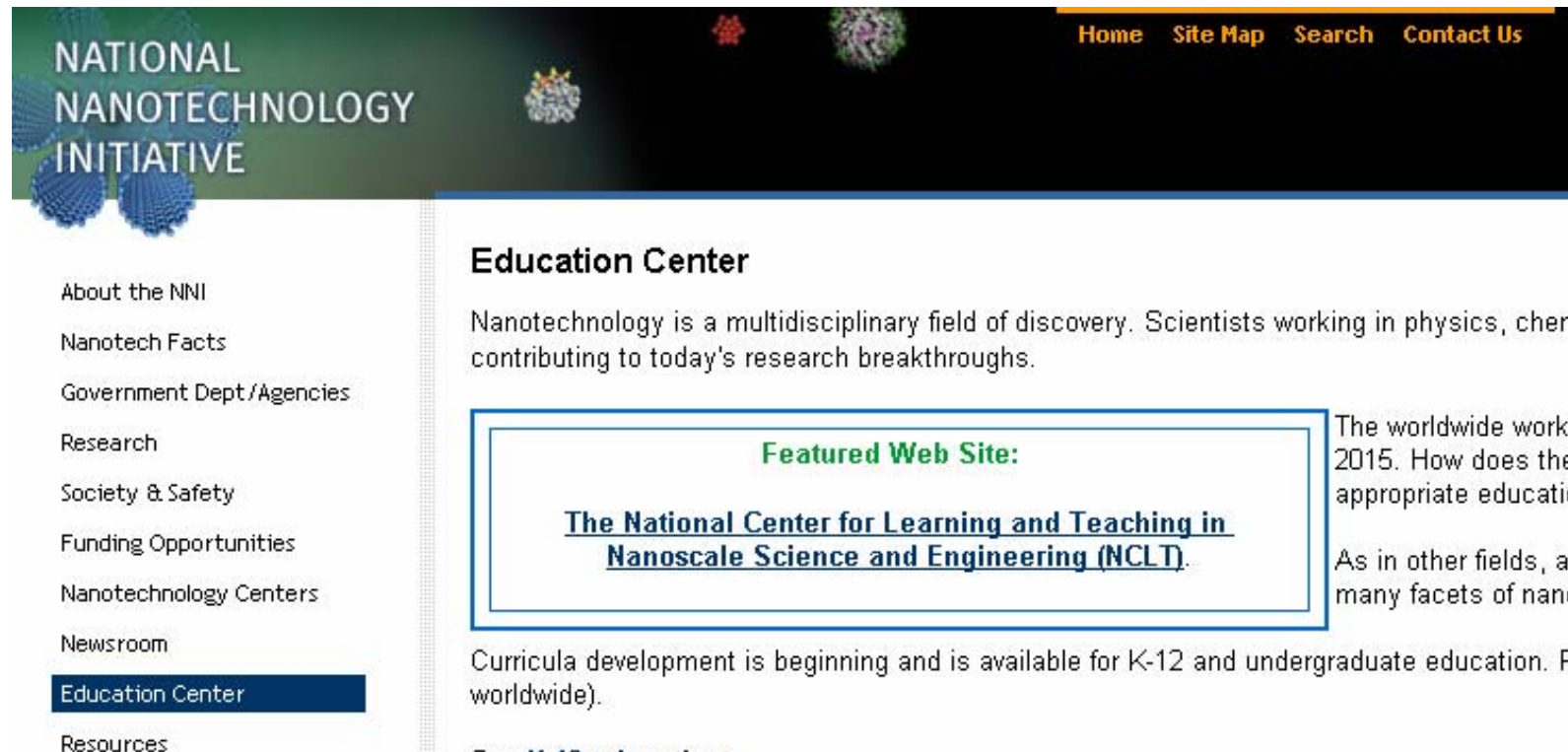
About the NNI  
Nanotech Facts  
Government Dept./Agencies  
Research  
Society & Safety  
Funding Opportunities  
Nanotechnology Centers  
Newsroom  
Education Center  
Resources



# NNI

- The **National Nanotechnology Initiative (NNI)** is a federal R&D program established to coordinate the multiagency efforts in nanoscale science, engineering, and technology.
- The goals of the NNI are to:
  - Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology;
  - Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit;
  - **Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology;** and,
  - Support responsible development of nanotechnology

# NNI – Educational Resources



The image is a screenshot of the National Nanotechnology Initiative (NNI) website. At the top, there is a dark header with the NNI logo on the left and navigation links for Home, Site Map, Search, and Contact Us on the right. Below the header is a left sidebar with a list of menu items: About the NNI, Nanotech Facts, Government Dept./Agencies, Research, Society & Safety, Funding Opportunities, Nanotechnology Centers, Newsroom, Education Center (highlighted in a dark blue box), and Resources. The main content area features a section titled "Education Center" with a paragraph describing nanotechnology as a multidisciplinary field. A blue-bordered box highlights a "Featured Web Site" link to "The National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT)". To the right of this box is a text block discussing worldwide work in 2015 and the facets of nanotechnology. Below the box, there is a paragraph about curriculum development and a list of links for K-12 education, University Education, Teacher Resources, and Careers.

**NATIONAL NANOTECHNOLOGY INITIATIVE**

[Home](#) [Site Map](#) [Search](#) [Contact Us](#)

About the NNI  
Nanotech Facts  
Government Dept./Agencies  
Research  
Society & Safety  
Funding Opportunities  
Nanotechnology Centers  
Newsroom  
**Education Center**  
Resources

## Education Center

Nanotechnology is a multidisciplinary field of discovery. Scientists working in physics, chem, contributing to today's research breakthroughs.

**Featured Web Site:**

[The National Center for Learning and Teaching in Nanoscale Science and Engineering \(NCLT\)](#)

The worldwide workf 2015. How does the appropriate educatio

As in other fields, a many facets of nano

Curricula development is beginning and is available for K-12 and undergraduate education. R worldwide).

See [K-12 education](#).  
See [University Education](#).  
See [Teacher Resources](#).  
See [Careers](#).

# http://www.nclt.us/

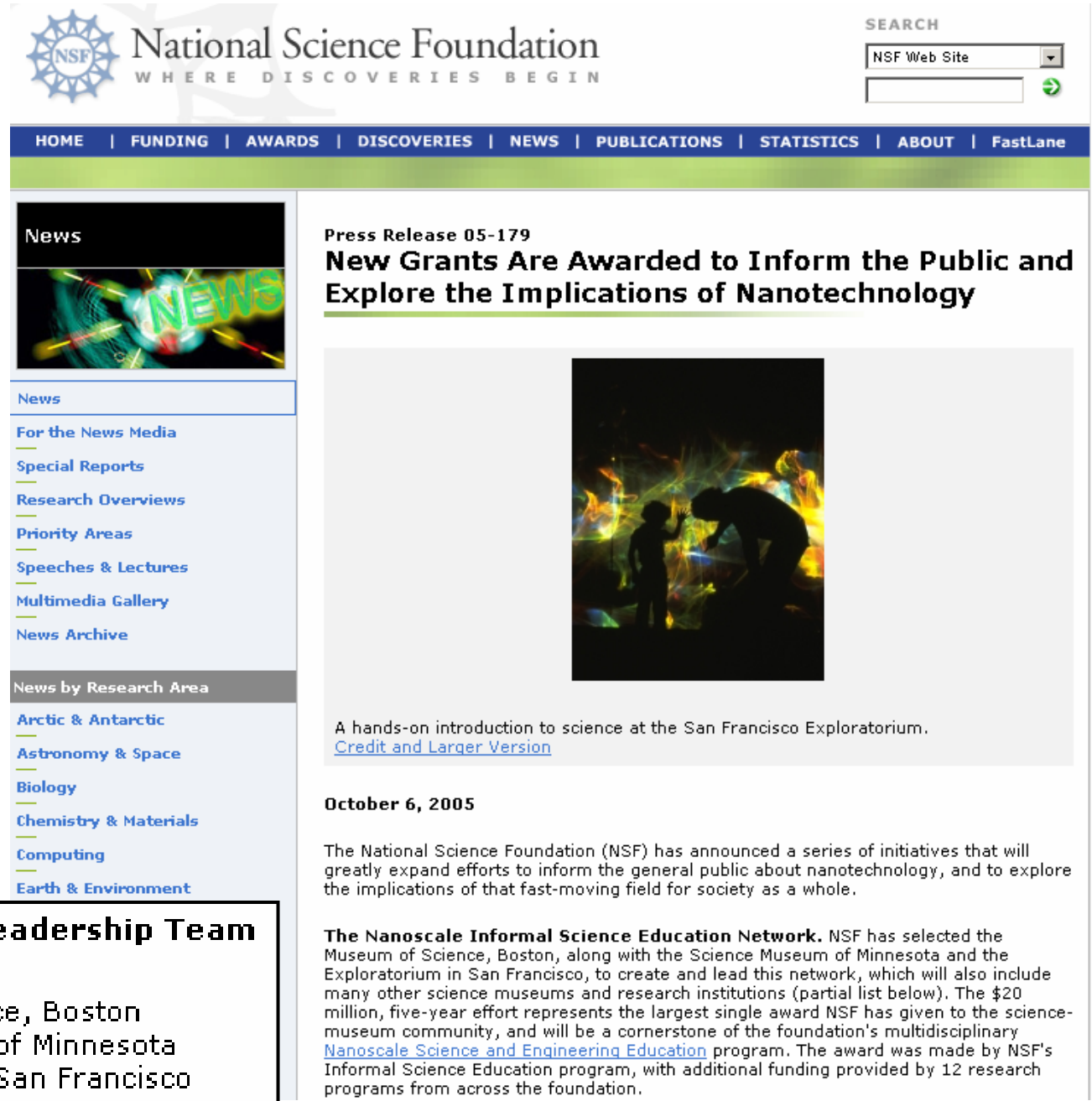
 <b>NCLT</b> National Center for Learning and Teaching in Nanoscale Science and Engineering		<i>International Virtual Institute</i>	
<a href="#">About NCLT</a> → <a href="#">Members</a> → <a href="#">Press Releases</a> → <a href="#">Centers</a> → <a href="#">Contact Us</a> → <a href="#">NCLT Logos</a> → <a href="#">FAQ</a>			
<b>Floor Directory</b>		<b>Welcome to the NCLT!</b>	
<a href="#">Professional Development</a>		<b>What's New</b>	
<a href="#">Nano Instructional Materials R &amp; D</a>		<b>Apply Today!</b>	
<a href="#">Information Resource Library</a>		<p>NCLT is accepting applications for graduate and post doctoral positions. Applicants should have a strong interest in the research of Nanoscale Science &amp; Engineering Education with backgrounds in the following:</p>	
<a href="#">Conferencing Facilities</a>		<ul style="list-style-type: none"><li>• <a href="#">Science Education</a> (Send application to <a href="#">Joseph Krajcik</a>, University of Michigan)</li><li>• <a href="#">Learning Science</a> (Send application to <a href="#">Tom Moher</a>, University of Illinois at Chicago)</li></ul>	
<a href="#">Degree Programs &amp; Courses</a>		<b>NCLT Activities at a Glance</b>	
<a href="#">Evaluation &amp; Assessment</a>			
<a href="#">Center Operations</a>		<b>Highlights</b>	
		<a href="#">Professional Development Activities</a> <a href="#">Information Resource Visual Library</a> <a href="#">NCLT Seminar Archive 2005</a> <a href="#">NCLT Seminar Archive 2006</a> <a href="#">Nano Courses and Modules</a> <a href="#">Operations Archive</a> <a href="#">Press Releases</a> <a href="#">NCLT Gallery</a>	
		<b>Announcements</b>	
		 <b>New!</b> <a href="#">Centerwide Meeting 5/11/06</a> <a href="#">Advisory Board Meetings 5/11-12/06</a>	
		<b>News</b>	
		 <b>New!</b> <a href="#">Nano Day at Northwestern</a> <a href="#">NSF Site Visit Gallery</a>	
		 <a href="#">Federal Program Backs Study of Key Disciplines</a> January 6, 2006	
		<b>Events</b>	
		<a href="#">NCLT Webcast Seminar Series</a> <a href="#">Connection Information</a>	

# NSF NISE network (2005)

**Informal Education  
on  
Nanotechnology**

## **The NISE Network Core Leadership Team**

- The Museum of Science, Boston
- The Science Museum of Minnesota
- The Exploratorium in San Francisco



The screenshot shows the NSF website header with the logo and tagline "WHERE DISCOVERIES BEGIN". A search bar is visible in the top right. A navigation menu includes links for HOME, FUNDING, AWARDS, DISCOVERIES, NEWS, PUBLICATIONS, STATISTICS, ABOUT, and FastLane. The main content area features a "News" section with a "NEWS" graphic. Below this is a list of news categories: For the News Media, Special Reports, Research Overviews, Priority Areas, Speeches & Lectures, Multimedia Gallery, and News Archive. A "News by Research Area" section lists various scientific fields. The main article is titled "New Grants Are Awarded to Inform the Public and Explore the Implications of Nanotechnology" (Press Release 05-179). It includes a photograph of people interacting with a large, glowing, abstract structure. The text describes a hands-on introduction to science at the San Francisco Exploratorium, with a link to a larger version. The date is October 6, 2005. The article text states that NSF has announced initiatives to expand public information about nanotechnology. It highlights the award of a \$20 million, five-year grant to the Nanoscale Informal Science Education Network, which includes the Museum of Science in Boston, the Science Museum of Minnesota, and the Exploratorium in San Francisco. The grant is part of NSF's multidisciplinary Nanoscale Science and Engineering Education program.

SEARCH  
NSF Web Site

HOME | FUNDING | AWARDS | DISCOVERIES | NEWS | PUBLICATIONS | STATISTICS | ABOUT | FastLane

News

News

For the News Media

Special Reports

Research Overviews

Priority Areas

Speeches & Lectures

Multimedia Gallery

News Archive

News by Research Area

Arctic & Antarctic

Astronomy & Space


Biology

Chemistry & Materials

Computing

Earth & Environment

Press Release 05-179  
**New Grants Are Awarded to Inform the Public and Explore the Implications of Nanotechnology**



A hands-on introduction to science at the San Francisco Exploratorium.  
[Credit and Larger Version](#)

**October 6, 2005**

The National Science Foundation (NSF) has announced a series of initiatives that will greatly expand efforts to inform the general public about nanotechnology, and to explore the implications of that fast-moving field for society as a whole.

**The Nanoscale Informal Science Education Network.** NSF has selected the Museum of Science, Boston, along with the Science Museum of Minnesota and the Exploratorium in San Francisco, to create and lead this network, which will also include many other science museums and research institutions (partial list below). The \$20 million, five-year effort represents the largest single award NSF has given to the science-museum community, and will be a cornerstone of the foundation's multidisciplinary [Nanoscale Science and Engineering Education](#) program. The award was made by NSF's Informal Science Education program, with additional funding provided by 12 research programs from across the foundation.



# For Students K-12 @ [www.nano.gov](http://www.nano.gov)

## For Students K-12

What's Your Nano IQ? Find out [HERE!](#)

Take a fun quiz on the National Institute of Standards and Technology web site!

[Main Street Science](#) has created a new science web magazine called [Nanooze](#), a project of the National Nanotechnology Infrastructure Network (NNIN) -- a great place to hear about the latest exciting stuff in science and technology that is too small to see.

Let a [click](#) of your computer mouse transport you to London, England to their Science Museum's fantastic exhibit on [Nanotechnology: Small Science, Big Deal](#) -- and, as long as you are visiting that side of the Atlantic Ocean, be sure to go exploring with [Duckboy in Nanoland!](#)

Check out [The Wonderful World of Carbon Nanotubes Presentation](#) at the Museum of Science, Boston along with other articles and features related to Nanotech!

"Discover the secrets of everyday stuff" on this SUPERCOOL web site [Strange Matter](#). The Strange Matter exhibit will soon be in Durham, North Carolina (October 1 to January 8). See the [Strange Matter web site](#) for details on upcoming exhibits near you.

Nanotechnology has become FUN! through these and other programs, such as the adventures of [NanoKids™](#), who materialize after a computer crashes in chemist Jim Tour's lab! (See the cool dancing Kids in the graphic below and the brains behind the Kids, chemist Jim Tour.) Video game lovers, this is for you!!

There are other great programs too. See also the [Science News for Kids](#) article about "[The Incredible Shrunk Kids](#)."

Atoms and molecules are the building blocks of nature, and a lot of kids worldwide are having fun using familiar blocks, such as Legos®, and computer generated figures made of these ultra-basic materials.

See [Exploring the Nanoworld with Lego® Bricks](#), an offering of the University of Wisconsin - Madison Materials Research Science and Engineering Center (MRSEC) Interdisciplinary Education Group (EG).

[NanoKids™](#) The [Nanobiotechnology Center](#) is located at Cornell University and is sponsored in collaboration with Princeton University, Oregon Health & Science University, Wadsworth Center, Clark Atlanta University, and Howard University.



# Nano IQ from NIST

[http://www.nist.gov/public\\_affairs/nanotechquiz.htm](http://www.nist.gov/public_affairs/nanotechquiz.htm)

What's Your Nano IQ?

**NIST**  
National Institute of  
Standards and Technology

[A-Z subject index](#)

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## What's your Nano IQ?

[\(get quiz answers\)](#)

1. The prefix “nano” comes from a Greek word meaning \_\_\_\_\_.

- a. billion
- b. dwarf
- c. invisible
- d. infinite

2. If a nanometer were as big as the width of a pin head, about how long would a meter be?



- a. as long as the pin shaft
- b. as long as a ladder
- c. as long as a blue whale
- d. as long as a trip between Washington, D.C. and Atlanta, Ga.

3. How many hydrogen atoms lined up “shoulder to shoulder” would fit in a one nanometer space?

- a. less than one
- b. ten
- c. 1 thousand
- d. 1 billion

4. Which of the following products contain nanoscale manufactured parts or materials?



- a. sunscreen
- b. khaki pants
- c. tennis balls
- d. devices that read computer hard drives
- e. all of the above



# Nanotech Gallery from NASA

<http://www.ipt.arc.nasa.gov/gallery.html>



Novel Data Storage System



## NANOTECHNOLOGY GALLERY

*Downloadable plug-ins:*

[PowerPoint Player](#)

[Adobe Acrobat Reader](#)

---

### IMAGES

- \* [Carbon Nanotube for Chip Cooling](#)
- \* [Carbon Nanotube Interconnect \(Image 2\)](#)
- \* [Nanolasers](#)
- \* [Nanopore Sensor](#)
- \* [Polymer-CNT composite](#)
- \* [An Engineered DNA Strand](#)
- \* Nano Flag - [Low Res](#) / [High Res](#)

HOME PAGE  
MISSION NEEDS  
NANOTECHNOLOGY  
GALLERY



## CNT

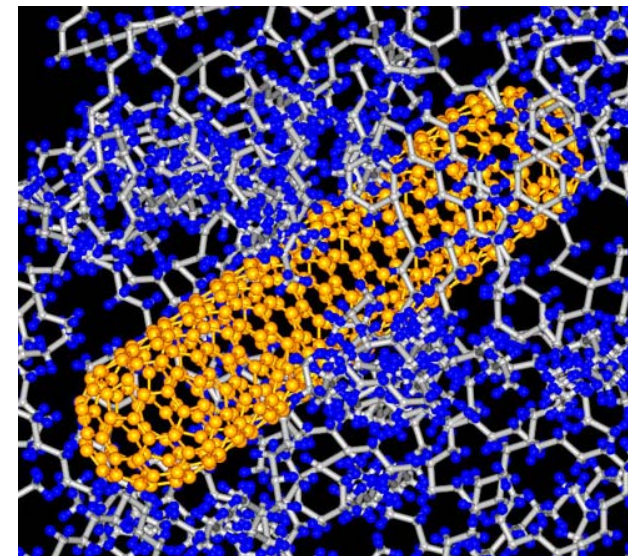
Center for **NANOTECHNOLOGY**

Director: Meyya Meyyappan  
NASA Ames Research Center  
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Phone: (650) 604-2616 FAX: (650) 604-5244  
Email: [meyya@orbit.arc.nasa.gov](mailto:meyya@orbit.arc.nasa.gov)

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[NANOTECHNOLOGY](#)  
[GALLERY](#)

### Nanotechnology Gallery

NASA Ames nanotechnology effort started in early 1996 and has steadily grown to establish a Center for

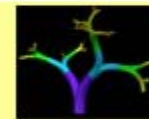
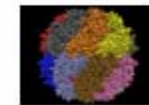
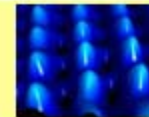


# NASA - continued

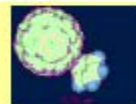
## MOVIE CLIPS

[Brief Video Descriptions of All Movies Listed Below](#)

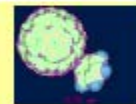
- \* [Molecular Electronics: Self Assembly and Transport by Tunneling Microscopy](#) - MOV  
Contributed by: Geetha R Dholakia
- \* [Protein Nanotubes](#) - Quicktime  
Contributors: Jonathan Trent, Andrew McMillan, Chad Paavola, Hiromi Kagawa, Suzanne Chan, Jeanie Howard, Yi-Fen Lee, Linda Molnar, Kira Foygel, Amy Ouellette, Amber Sanford, and Alessandro Airo  
<http://bionanex.arc.nasa.gov>
- \* [Biomimetic Computing and Logic Architecture Based on "Y-Branched" Carbon Nanotubes](#) - MPEG
- \* **Carbon Nanotube Gears - MPEG Movies**  
Contributors: Jie Han, Al Globus, Richard Jaffe, and Glenn Deardorff



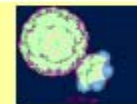
Benzyne Reacting with C60  
(Buckyball)



[377 KB]  
Slow (non-  
reactive)



[327 KB]  
Medium  
(reactive)



[669 KB]  
Fast  
(dissociative)

Benzyne Reacting with Carbon  
Nanotube



[184 KB]  
Slow  
(non-  
reactive)



[290 KB]  
Medium  
(reactive)



# Nano screen saver from NSF

<http://www.nsf.gov/news/overviews/nano/screensaver.jsp#pc>



The screenshot shows the NSF website header with the logo and tagline "WHERE DISCOVERIES BEGIN". A search bar is visible with "NSF Web Site" selected. Below the header is a navigation menu with links: HOME | FUNDING | AWARDS | DISCOVERIES | NEWS | PUBLICATIONS | STATISTICS | ABOUT | FastLane. A large green banner reads "NANOSCIENCE". At the bottom of the banner, it says "Nanoscience Home" on the left and "More Research Overviews" on the right.

## NANOSCIENCE SCREEN SAVER

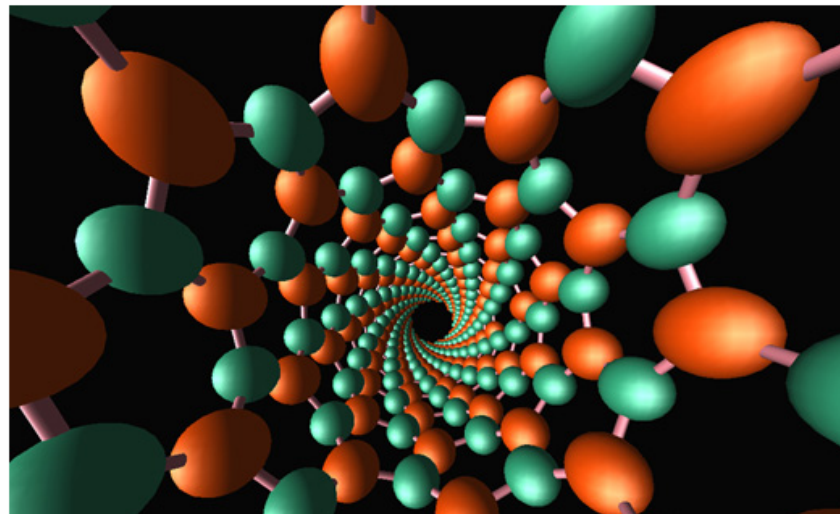
The images below represent just a tiny sampling of the marvels that scientists are discovering at the nanoscale. Many of them are from the [online gallery](#) of [Harvard physicist Eric J. Heller](#), who generates them in the course of studying wave behavior and chaos in the quantum realm. But they also include one example apiece from the work of [Vincent H. Crespi](#) at Pennsylvania State University; [Chad Mirkin](#) at Northwestern University; and [Ghim Wei Ho](#) and Mark Welland at the University of Cambridge.

Download the [screen saver for Windows](#) (2.59MB)

Download the [screen saver for Mac OS X](#) (2.53MB)

[Installation instructions](#)

### Boron Nitride Nanotube





# Nano\*High

[Schedule of Talks](#)

[Online Registration](#)

[Maps and Directions](#)

[Nanoscience Links](#)

[Nano\\*High Home](#)

[About the Berkeley Lab](#)

[Nano\\*High Archive](#)

[Information for Teachers](#)

## Nano\*High<sup>3</sup>: NanoScience for High School Students

Fourth in the 2005-2006 series  
February 25, 2006 10:00AM  
Professor Ehud Isacoff



Using Light to  
Watch and Control Biology.

October 28, 2005  
November 14, 2005  
November 17, 2005  
February 25, 2006  
April 20, 2006  
April 24, 2006

Nano\*High is a free, one-day event, and  
open to all high school students  
sponsored by UC's Berkeley  
Lab for High School Students of  
Berkeley. We welcome background checks.

For more information, visit  
[www.lln.gov/nanohigh3](http://www.lln.gov/nanohigh3)

Learning is limited to high school students and middle school and high school teachers.

Meet and talk with world-renowned UC Professors and Berkeley Lab scientists and graduate students. Learn about their research into the world of the ultra small and how it will affect our future. Nano\*High is sponsored by UC's Berkeley Lab for High School students of all interests and teachers of all subjects—no science background needed.

[REGISTER ONLINE](#)

Archive

## Nano\*High<sup>3</sup>: NanoScience for High School Students

First in the 2005-2006 series  
October 28, 2005 10:00AM  
Global Warming,  
the Energy Crisis and  
What We Can Do  
About It  
Steven Chu, Nobel Laureate  
Director, Lawrence Berkeley  
National Laboratory

October 28, 2005  
November 14, 2005  
November 17, 2005  
February 25, 2006  
April 20, 2006  
April 24, 2006

## Nano\*High<sup>3</sup>: NanoScience for High School Students

Third in the 2005-2006 series  
January 21, 2006 10:00AM  
Thomas Kail  
Special Assistant to the Chancellor for Science and Technology at UC, Berkeley  
Nanotechnology  
at the  
White House

October 28, 2005  
November 14, 2005  
January 21, 2006  
February 25, 2006  
April 20, 2006  
April 24, 2006

## Nano\*High<sup>3</sup>: NanoScience for High School Students

Second in the 2005-2006 series  
December 10, 2005 10:00AM  
Professor Gabor Somorjai  
Winner, National Medal of Science  
The Nanoscience Revolution:  
Catalysis, Chemistry for New Sources  
of Energy and a Clean Environment.

December 10, 2005  
December 14, 2005  
December 17, 2005  
February 25, 2006  
April 20, 2006  
April 24, 2006

## Nano\*High<sup>3</sup>: NanoScience for High School Students

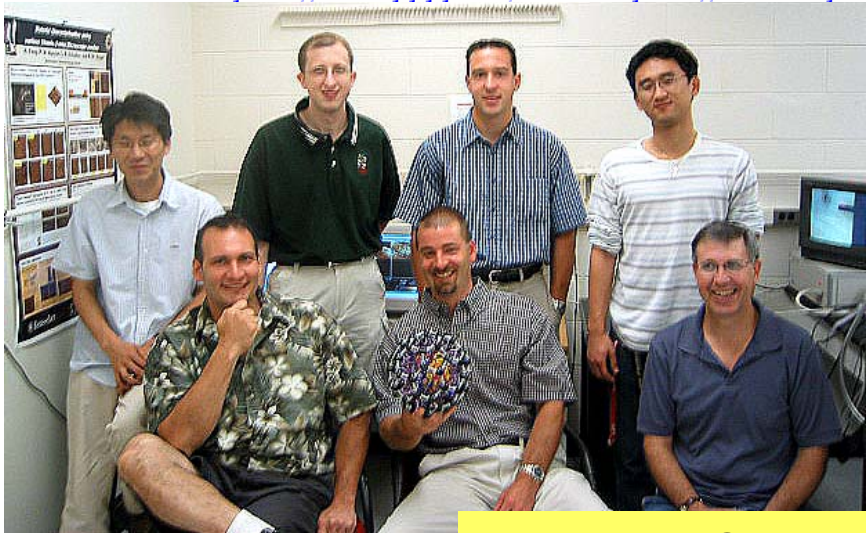
Second in the 2005-2006 series  
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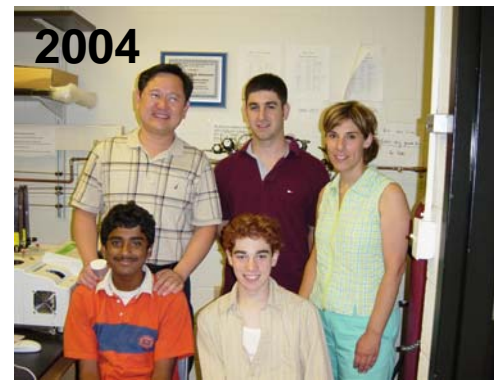
# Outline

- Brief Introduction on Nanotechnology
- Educational Resources on nanotechnology
  - [www.nano.gov](http://www.nano.gov)
- RPI Nanoscale Science and Engineering Center: High school outreach program
  - Bringing nanotechnology to the classroom (Program coordinator: Prof. Chang Y. Ryu ([ryuc@rpi.edu](mailto:ryuc@rpi.edu)))
    - Hands on module: Carbon nanotube synthesizer
    - Multimedia module: Virtual Scanning Electron Microscopy (SEM)
    - Lecture module: Atomic Force Microscopy (AFM)
    - Class supplementary information using nanoscale microscopy tools

# RPI NSEC High School Outreach

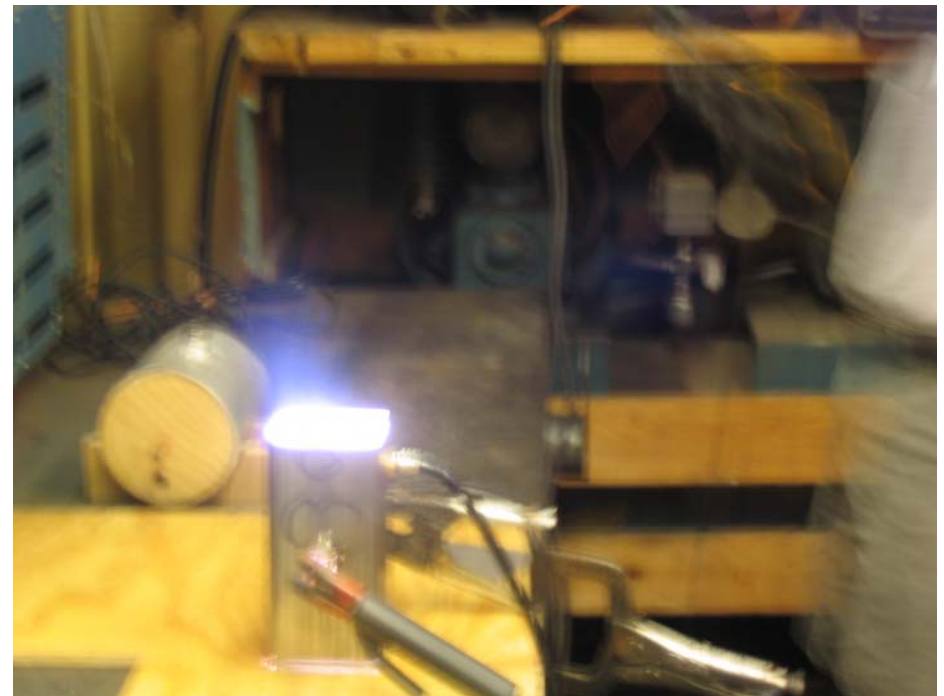


Summer, 2005  
(will continue in the summer of 2006)





# Hands on Module: Carbon nanotube synthesizer



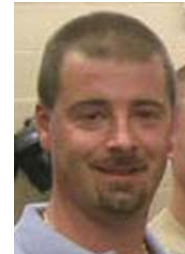
Tom Pittman, BHBL High School, “Metal-Tech” Teacher



# Actual module – CNT synthesizer

## 1.1.2 CARBON NANOTUBE SYNTHESIZER PROTOTYPE #2

Tom Pittman and Paul Fedoroff



### PURPOSE:

To determine if we could produce carbon soot and possibly carbon nanotubes using materials and equipment commonly found in a Technology Education classroom.

### MATERIALS:

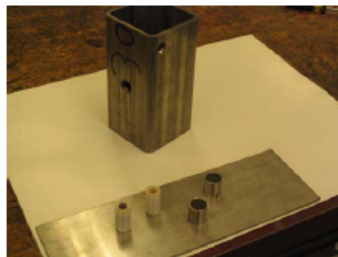
- Square stainless steel tubing 4"x 4"x 8"
- Two pieces of stainless steel plate 4"x 4"x 3/16"
- Two pieces of round stainless steel tubing 1" diameter, 1" long
- Two ceramic insulators
- Two 3/8" diameter carbon electrodes from a carbon arc torch (available at welding supply store)

### POWER SUPPLY:

- AC/DC arc welder

### SHIELDING GAS:

- Argon



### PROCEDURE:

- Drill a hole slightly larger than insulator diameter through both sides of square tubing
- Drill a third hole near the top of the square tubing for argon hose
- Weld round tubing outside the two opposing holes
- Place square tubing on top of 4"x 4"x 3/16" plate
- Insert insulators into round tubing
- Slide carbon electrodes through holes in the insulators to visually align tips, leaving approximately a 1/16" gap between electrodes
- Set other 4"x 4" x 3/16" plate on top of square tubing
- Clamp the leads from the arc welder to the ends of the carbon electrodes
- Insert argon hose, open tank valve, set flow control valve to 15 CFH
- Set welder to 60 amps ac and turn it on. To start the arc slide one of the electrodes into the other, then immediately separate the electrodes 1/16"- 1/8".
- The arc can be viewed through a welding helmet with at least a #10 lens by sliding the top back slightly

### RESULTS:

- Trial 1 – welder 60 amps AC, 15 minutes, access port closed, 1/8" electrode gap, 10 CFH Argon. No deposits.
- Trial 2 – welder 85 amps DC, 15 minutes, access port closed, 1/16" electrode gap, 15 CFH. Good results, soot deposits on bottom plate and on one carbon electrode.
- After the second trial the welder needed time to cool down.





# Virtual Scanning Electron Microscopy (SEM) Laboratory

- Developed by UIUC (Our RPI NSEC partner) –

<http://virtual.itg.uiuc.edu/downloads/>



**Imaging Technology Group**  
**Virtual Projects**

home software data training results **downloads**

## Virtual Lab Downloads

### Virtual Microscope Interface

The [Virtual Microscope interface](#) supports the browsing of [high-resolution, multi-dimensional image datasets](#) from our Scanning Electron Microscope (SEM) and our Light Microscope (LM). The download below comes with three specimens, but any one of the specimens on our [data page](#) can be downloaded and viewed with this interface.



The software runs in Java on any platform. If you don't already have Java installed, you can [download the Java Runtime Environment \(JRE\) here](#).

#### All Operating Systems (Windows, Unix, Mac)

- [Download version 3.0 of the Virtual Microscope, with two included samples \(25MB\) \[last updated 11/25/05\]](#)
- [Download \*\*upgrade only\*\* version 3.0 of the Virtual Microscope \(just the new .jar--replace old one\) \(450k\) \[last updated 11/25/05\]](#)
- [Installation Instructions](#)

#### Downloads Menu

- [Virtual Microscope Interface](#)
- [Source Code](#)
- [Data](#)
- [Data Collection and Stitching Tools](#)
- [Training Materials](#)
- [File Format Info](#)

#### Latest Specimens

- [VSEM: Starfish Arm Ventral](#)
- [VSEM: Starfish Arm Dorsal](#)
- [VSEM: Xyloplax Ventral](#)
- [VSEM: Xyloplax Dorsal](#)
- [VSEM: Beetle](#)
- [VSEM: House Fly \(3\)](#)
- [VSEM: Water Beetle](#)

#### Latest News

- [5 New Samples Posted](#)
- [Version 3 Released](#)

Go to [www.java.com](http://www.java.com)  
And download java program first.

Also download images from  
<http://virtual.itg.uiuc.edu/data/>



# Actual module on Virtual SEM

- Paul Fedoroff, BHBL Physics teacher -



## 1.2.1 Virtual Scanning Electron Microscopy

Paul Fedoroff

### Introduction

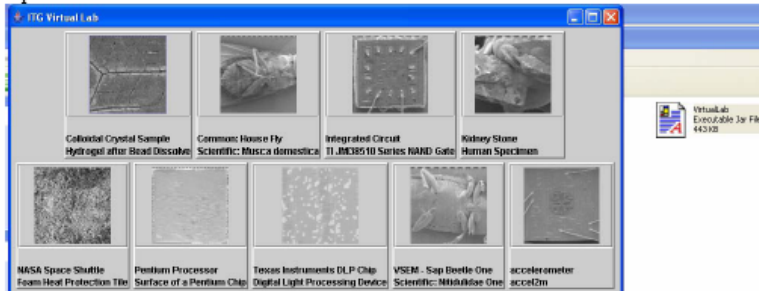
An optical microscope, the kind you might have used in biology class, uses a visible light source to reflect light off of a sample. Your eye then detects the reflected or emitted light from the sample. Lenses magnify the image. The magnification of an optical microscope cannot let you see what is happening at the nanoscale.

A Scanning Electron Microscope uses a beam of electrons that reflects off of a sample. The reflected or emitted electrons are detected and the signal is then converted into a picture, very similar to the way a television set works. The magnification is high enough to see what the surface is like at the nanoscale. Here is an animation of an SEM (<http://www.mos.org/sln/sem/sem.mov>).

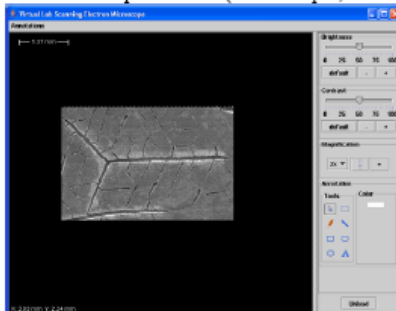
In order for the electron beam to work properly, the beam and the sample have to be in a vacuum. The sample also needs to be electrically conductive. This makes viewing a living sample impossible. Non-conducting samples can be viewed if they are first coated with a conducting film.

### Activity

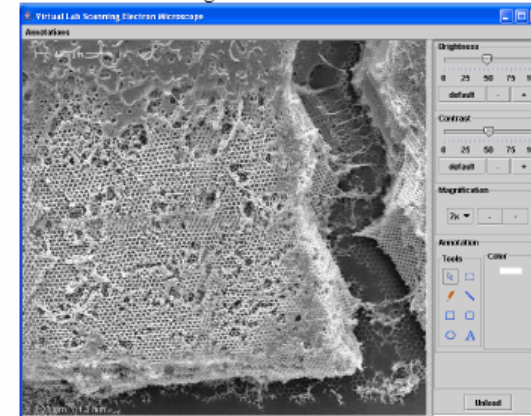
#### 1. Open Virtual Lab



#### 2. Choose a sample to view (For example, Colloidal Crystal Sample.)



#### 3. Zoom in with the Magnification button



4. You might need to adjust the **Focal Plane**
5. Left click on the image to re-center the screen
6. **Scale** is in the top left corner
7. **Answer the following questions on each sample**
8. **Unload** the sample when done

### Questions

#### 1. House Fly vs. Beetle

Based on the image, why might a fly be able to “stick” to walls?  
How small are these hairs?  
Do you think the beetle can stick as well as the housefly? Explain.

#### 2. Kidney Stone

Based on the structure viewed at high magnification, why might it be so painful to pass a kidney stone?

#### 3. NASA Foam

A sweater keeps you insulated by trapping little pockets of air in the numerous wool or cotton fibers. How does NASA employ this technique of insulation?

#### 4. Crystal Sample

Describe the material at low magnification.  
Describe the material at high magnification. Any difference?

#### 5. Pentium Processor and Integrated Circuit

How far apart are the circuit elements (wires, soldered points, etc.)?  
How can one piece of dust or hair (only 1 – 100 microns wide) affect these devices?

# Actual module on Virtual SEM

- Paul Fedoroff, BHBL Physics teacher -



## Virtual Scanning Electron Microscopy – Teacher Copy

Paul Fedoroff

- Virtual scanning electron microscopy is educational material development project by a team of people at the University of Illinois at Urbana-Champaign. This project will seed the development of “Virtual Nanoscope” program at the RPI-UTUC-LANL NSEC (<http://www.rpi.edu/dept/nsec/>). In order to receive a free copy of this software, please contact either Professor Paul Braun ([pbraun@uiuc.edu](mailto:pbraun@uiuc.edu)) or Chang Y. Ryu ([ryuc@rpi.edu](mailto:ryuc@rpi.edu)).
- We would like to encourage high school teachers to try it in his/her classroom. What you need is just a computer and students will experience a feeling like operating the SEM instrument.
- Java must be installed in your PC. Download java from <http://www.java.com/en/index.jsp>. It is free.

### 1. House Fly vs. Beetle

Based on the image, why might a fly be able to “stick” to walls?

*Tiny hairs on legs*

How small are these hairs?

*A few microns*

Do you think the beetle can stick as well as the housefly? Explain.

*Probably not, very few hairs compared to fly.*

### 2. Kidney Stone

Based on the structure viewed at high magnification, why might it be so painful to pass a kidney stone?

*Very jagged shape*

### 3. NASA Foam

A sweater keeps you insulated by trapping little pockets of air in the numerous wool or cotton fibers. How does NASA employ this technique of insulation?

*Many very small fibers trap gas to insulate the material*

### 4. Crystal Sample

Describe the material at low magnification.

*Smooth with a crack in it*

Describe the material at high magnification. Any difference?

*Porous, spongy, honeycomb*

### 5. Pentium Processor and Integrated Circuit

How far apart are the circuit elements (wires, soldered points, etc.)?

*A few microns*

How can one piece of dust or hair (only 1 – 100 microns wide) affect these devices?

*Short Circuit and one particle can affect many elements.*

# Atomic Force Microscopy (AFM) & Data Storage

## Paul Fedoroff & Dr. Hoichang Yang (NSEC staff)



### 1.3.3 Atomic Force Microscopy

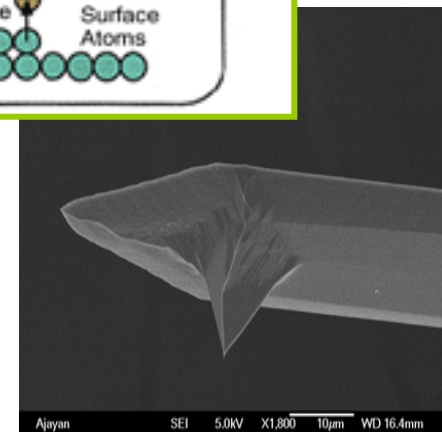
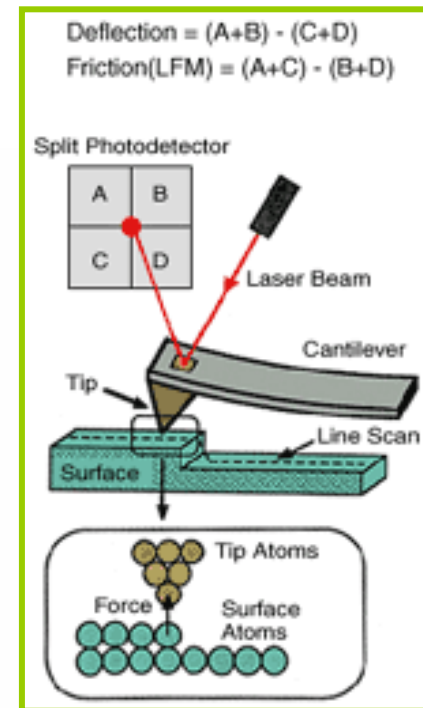
Paul Fedoroff

#### Note to teachers:

- Power point presentation file has been made for teachers' use. Specific comments are provided for each slide at the "notes" section. The following shows the carbon-copy of the slides.
- The actual PPT file can be downloaded from the web or CD.
- The following Supplementary Questions would be useful.

#### Atomic Force Microscopy

1. If you were to measure a force that is quite weak, would you want a large or small spring constant? Explain.
2. How would the spring constant affect the resonant frequency?
3. If you were to measure the magnetic force, would there necessarily be a difference in the topography?

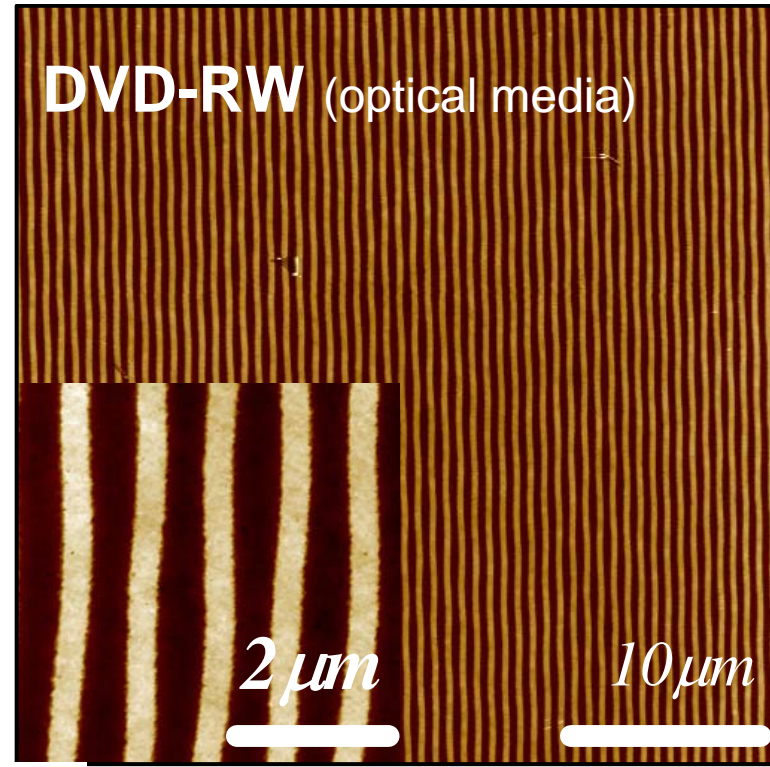
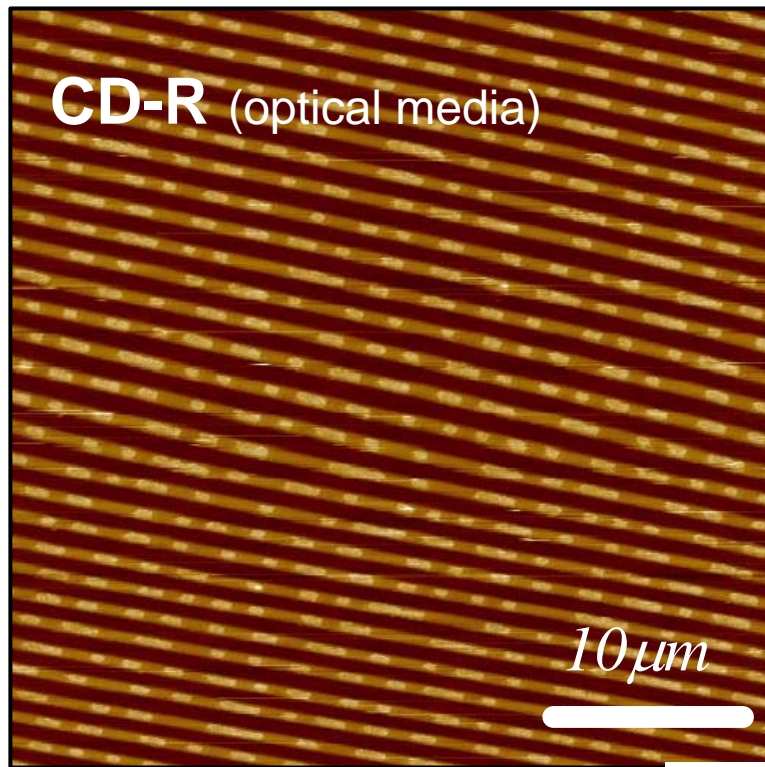




# Optical Storage media – Tapping AFM

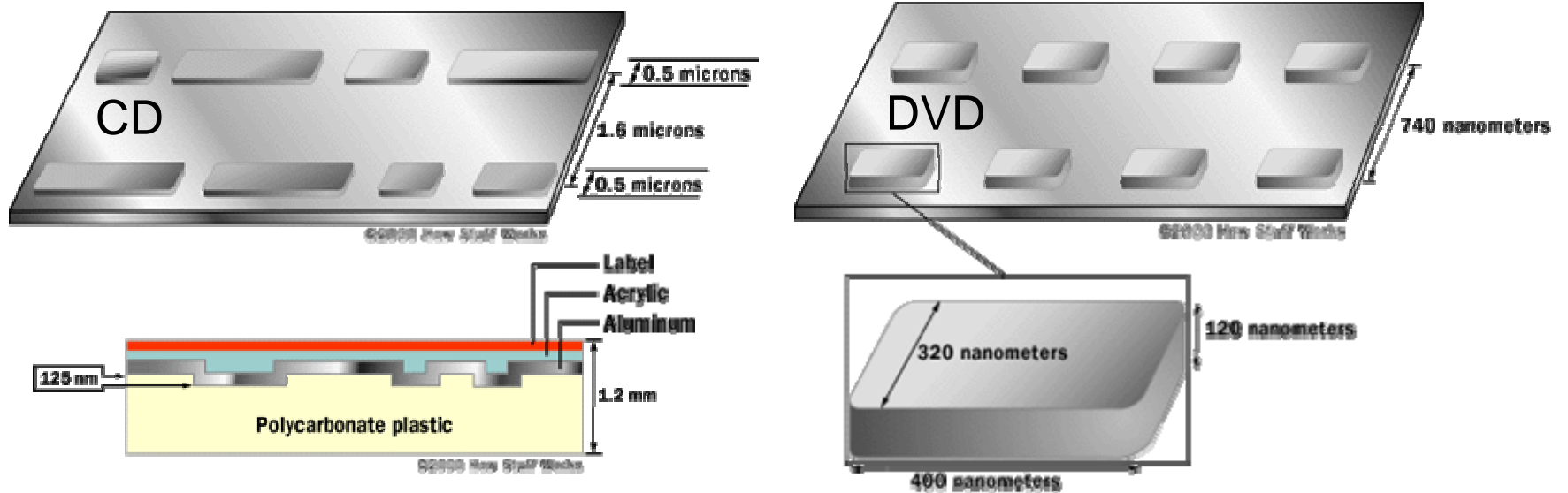


## Topography TM AFM





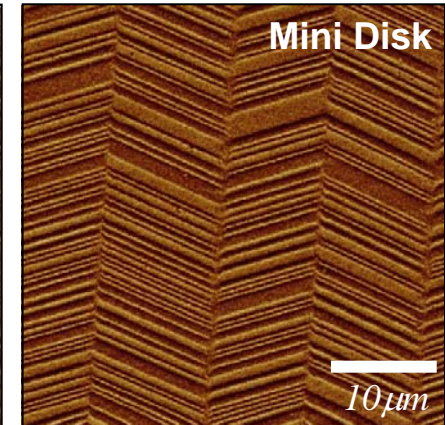
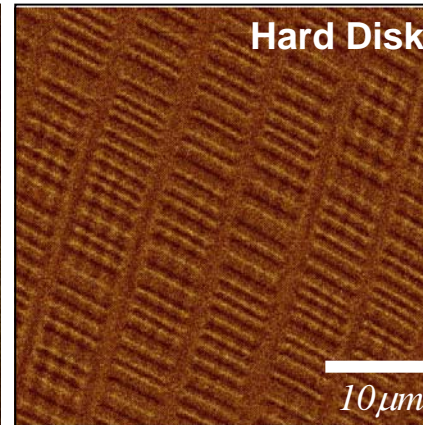
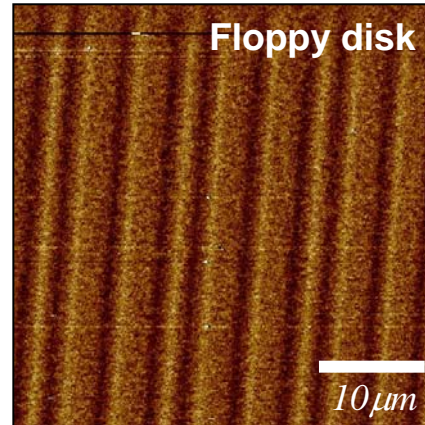
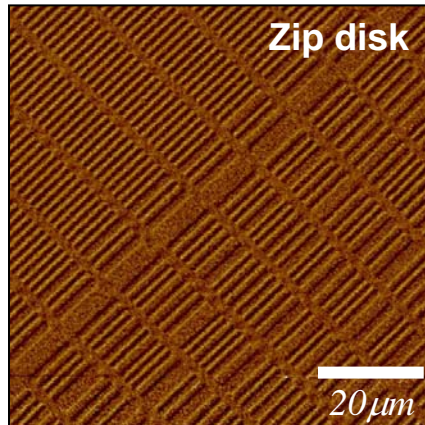
# CD vs. DVD



<i>Specification</i>	CD	DVD
Track Pitch	1600 nm	740 nm
Min. Pitch Length	860 nm	400 nm

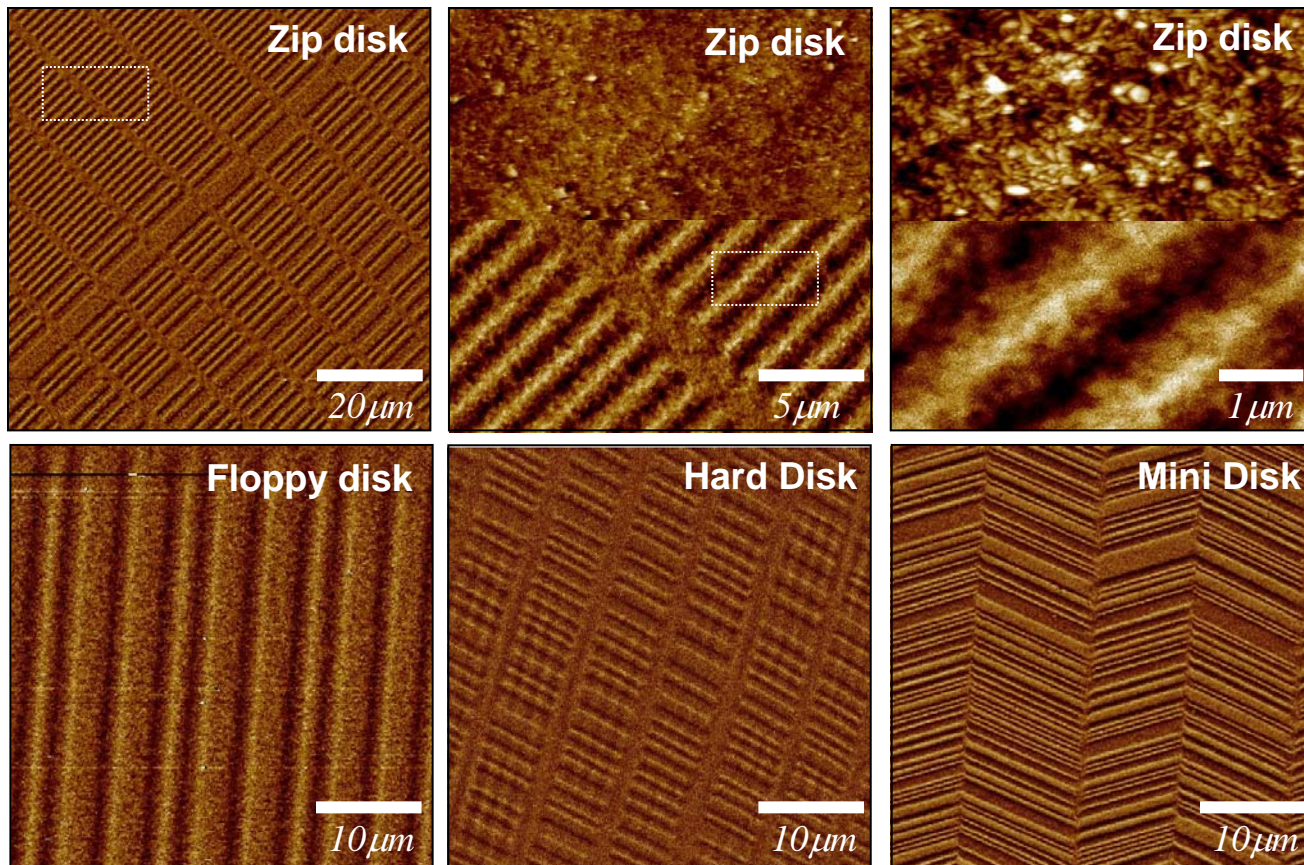
The schematic diagrams above were obtained from <http://www.howstuffworks.com/>

# Magnetic media - AFM





# Magnetic Force AFM



TOP:  
Topography

BOTTOM  
: “magnetic”  
Phase

# Summary

- Nanotechnology
  - K-12 educational resources are abundant
  - Many nano-research centers have HS outreach programs.
  - [www.nano.gov](http://www.nano.gov) is a good place to start.
- RPI Nanoscale Science & Engineering Center
  - “Bringing Nanotechnology to the Classroom”
    - Carbon nanotube synthesizer (Hands on activities)
    - Virtual SEM (Computer-based JAVA software)
    - AFM and other class supplementary materials using state-of-the-art nanoscale imaging tools at RPI
  - Contact me at RPI (Prof. Chang Y. Ryu ([ryu@rpi.edu](mailto:ryu@rpi.edu)))



NSEC:

[www.nano.rpi.edu](http://www.nano.rpi.edu)

My research homepage

<http://block.chem.rpi.edu>

# Acknowledgement

- NSF NSEC – Outreach Program “Bringing nanotechnology to the classroom”
- NSF-DMR CAREER Award (2005)
- BHBL High School
- GE Global Research Center