

# NYCCT/CUNY

**Electrical and Telecommunications Engineering technology**  
in collaboration with  
**BMI and Honors Students Department**



## **Visit to Brookhaven National Laboratory**

April 30<sup>th</sup>, 2010

# The group



- A group of ~25 students from several departments and organizations within NYCCT / CUNY considered that a visit to a place where they could see technicians, engineers and scientists to work would enlarge their vision in their field and also inspire them to pursue a higher degree in engineering, physics and applied sciences. So their professors thought about it and concluded that one of the largest and most advanced science center to visit in New York state is the Brookhaven National Laboratories
- So they set out on this venture early morning on April 30<sup>th</sup>, 2010

# Agenda



9:50 a.m. Arrival – Security Trailer – Main Gate – Photo ID required

10:00 a.m. Berkner Hall – Room B

To 10:30 Welcome

Brookhaven National Laboratory Overview

Elaine Lowenstein

10:40 a.m. Center for Functional Nanomaterials – Bldg 735, Lobby, ext. 7031

To 11:30 Michael Schaeffer (ext. 7941)

11:35 a.m. National Synchrotron Light source – Bldg 725, Lobby, ext. 4791

To 12:15 Emil Zitvogel (ext. 7703)

12:20 p.m. Lunch – Berkner Hall Cafeteria

To 1:15 Meet at the upper lobby of Berkner Hall

1:20 p.m. New York Blue Supercomputer – ITD – Bldg 515, second floor conference room

To 2:00 Nicholas **D’Imperio** (ext. 8607), Tom Schlagel (ext. 8765)

2:00 p.m. Departure

# The group













# Center for Functional Nanomaterials



- The Center for Functional Nanomaterials (CFN) at Brookhaven National Laboratory provides state-of-the-art capabilities for the fabrication and study of nanoscale materials, with an emphasis on atomic-level tailoring to achieve desired properties and functions.
- The CFN is a science-based user facility, simultaneously developing strong scientific programs while offering broad access to its capabilities and collaboration through an active user program.
- The overarching scientific theme of the CFN is the development and understanding of nanoscale materials **that address the Nations' challenges in energy security**, consistent with the Department of Energy mission.





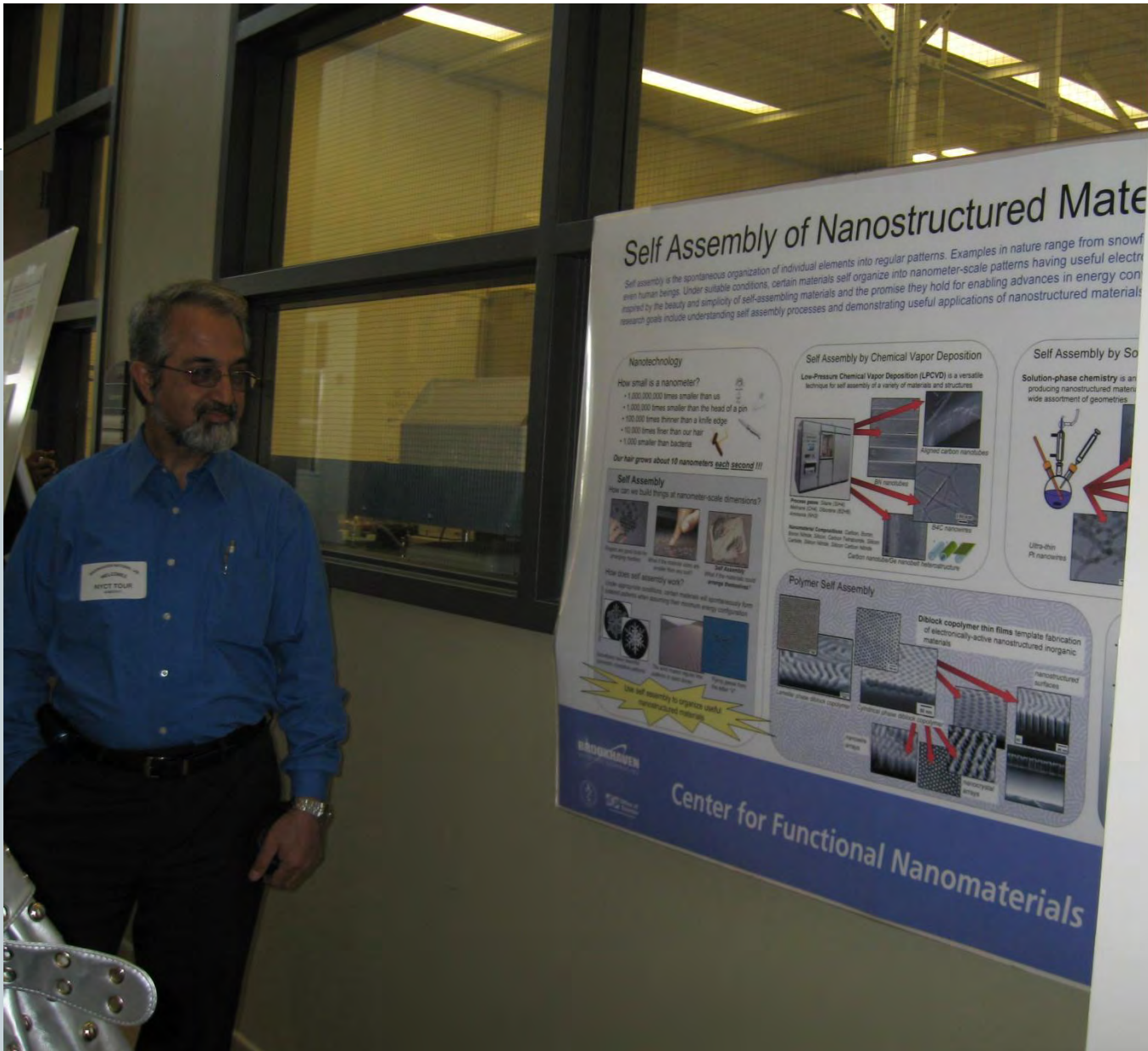












# Self Assembly of Nanostructured Materials

Self assembly is the spontaneous organization of individual elements into regular patterns. Examples in nature range from snowflakes to even human beings. Under suitable conditions, certain materials self organize into nanometer-scale patterns having useful electrical and optical properties. Inspired by the beauty and simplicity of self-assembling materials and the promise they hold for enabling advances in energy conversion and storage, research goals include understanding self assembly processes and demonstrating useful applications of nanostructured materials.

### Nanotechnology

How small is a nanometer?  
+ 1,000,000,000 times smaller than us  
+ 1,000,000 times smaller than the head of a pin  
+ 100,000 times thinner than a knife edge  
+ 10,000 times finer than our hair  
+ 1,000 smaller than bacteria

Our hair grows about 10 nanometers each second!!!

### Self Assembly

How can we build things at nanometer-scale dimensions?  
Top-down lithography  
Bottom-up self-assembly  
Self-assembly

How does self assembly work?  
Under appropriate conditions, carbon molecules will spontaneously form nanotubes. How do we assemble them into a specific configuration?

Use self assembly to organize useful nanostructured materials

### Self Assembly by Chemical Vapor Deposition

Low-Pressure Chemical Vapor Deposition (LPCVD) is a versatile technique for self assembly of a variety of materials and structures

Aligned carbon nanotubes  
Si nanowires  
SiC nanowires  
Carbon nanotube networked heterostructure

### Self Assembly by Solution-phase chemistry

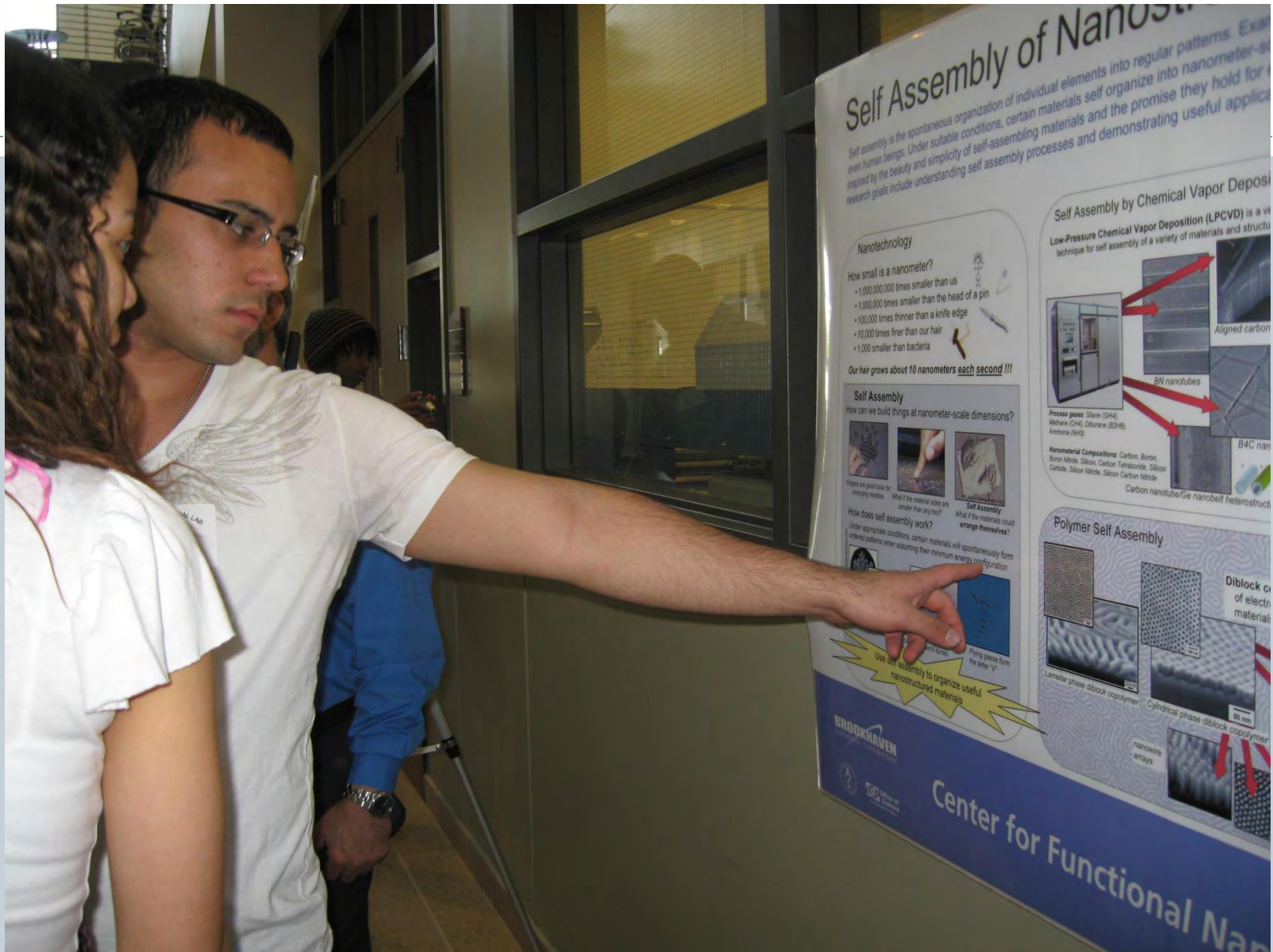
Solution-phase chemistry is an effective technique for producing nanostructured materials with a wide assortment of geometries

Ultra-thin Si nanowires

### Polymer Self Assembly

Diblock copolymer thin films template fabrication of electronically-active nanostructured inorganic materials

nanotubular surfaces  
nanowire arrays



# Self Assembly of Nanotechnology

Self assembly is the spontaneous organization of individual elements into regular patterns. Even human beings. Under suitable conditions, certain materials self organize into nanometer-scale patterns. Inspired by the beauty and simplicity of self-assembling materials and the promise they hold for nanotechnology, research goals include understanding self assembly processes and demonstrating useful applications.

## Nanotechnology

How small is a nanometer?

- 1,000,000,000 times smaller than us
- 1,000,000 times smaller than the head of a pin
- 100,000 times thinner than a knife edge
- 10,000 times finer than our hair
- 1,000 smaller than bacteria

Our hair grows about 10 nanometers each second !!!

## Self Assembly

How can we build things at nanometer-scale dimensions?

Figures are good tools for arranging molecules. What if the material itself is smaller than any tool? Self Assembly: What if the materials could arrange themselves?

How does self assembly work?

Under appropriate conditions, certain materials will spontaneously form ordered patterns when assuming their minimum energy configuration.



Use self assembly to organize useful nanostructured materials.

## Self Assembly by Chemical Vapor Deposition

Low-Pressure Chemical Vapor Deposition (LPCVD) is a versatile technique for self assembly of a variety of materials and structures.

Process gases: Silane (SiH<sub>4</sub>), Methane (CH<sub>4</sub>), Diborane (B<sub>2</sub>H<sub>6</sub>), Ammonia (NH<sub>3</sub>)

Nanomaterial Compositions: Carbon, Boron, Boron Nitride, Silicon, Carbon Tetrafluoride, Silicon Carbide, Silicon Nitride, Silicon Carbon Nitride

Carbon nanotube/Ge nanobelt heterostructure

## Polymer Self Assembly

Diblock copolymer of electron materials

Lamellar phase diblock copolymer

Cylindrical phase diblock copolymer

nanowire arrays



Center for Functional Nanotechnology







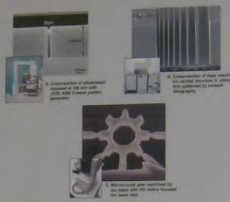




# Nanopatterning Facility

The Nanopatterning Facility will make it possible for the scientific community to fabricate and analyze, under one roof, a variety of materials with nanoscale dimensions. The Facility will house patterning tools such as electron-beam, ion-beam, and optical lithography; materials preparation methods to etch fine patterns and deposit thin-film metals and dielectrics; and analytical instruments for x-ray analysis, scanning electron microscopy, and optical and electrical characterization.

## Capabilities



- The ability of electron or ion beams to be precisely deflected with nanometer accuracy and nanosecond response times enables the fabrication of intricate patterns in masking layers known as photoresist. (A)
- The patterned masks can then be used for subsequent plasma etching steps to create 3-D nanostructures in selected materials such as silicon. (B)
- In some cases, ion beams can be used to directly fabricate nanoscale devices with no intermediate steps. (C)
- All of these nanofabrication methods will be available at the Nanopatterning Facility.

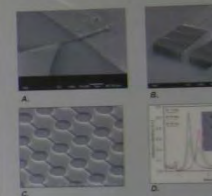
## Equipment



Nanopatterning equipment can be divided into 3 major categories. Primary patterning equipment such as electron-beam and ion-beam lithography, both fabrication equipment used in the optical lithography and plasma etching, and analytical instruments used in characterizing the fabricated nanostructures.

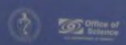
Category	Equipment	Manufacturer	Model
Electron-Beam Lithography	Electron-Beam Lithography	JEOL	EBL-8500
	Electron-Beam Lithography	JEOL	EBL-8500
	Electron-Beam Lithography	JEOL	EBL-8500
	Electron-Beam Lithography	JEOL	EBL-8500
Ion-Beam Lithography	Ion-Beam Lithography	JEOL	IBL-8500
	Ion-Beam Lithography	JEOL	IBL-8500
	Ion-Beam Lithography	JEOL	IBL-8500
	Ion-Beam Lithography	JEOL	IBL-8500
Plasma Etching	Plasma Etching	JEOL	PE-8500
	Plasma Etching	JEOL	PE-8500
	Plasma Etching	JEOL	PE-8500
	Plasma Etching	JEOL	PE-8500

## Science Examples



- Electron beam lithography used to place electrode on a BaTiO<sub>3</sub> nanorod with <math>\lt; 20\text{ nm}</math> accuracy (S. Wang, Stony Brook U.)
- Light-house Fresnel lens used for focusing X-rays at the NSLS fabricated by deep etching (K. Evans-Lutterodt, BNL)
- Prototype microfluidic DNA separation chip fabricated with electron beam lithography and plasma etching (H. Sheng, Stony Brook U.)
- Simulation of transmission characteristics of polarization-sensitive plasmonic nanocavity fabricated with electron beam lithography (R. Osgood, Columbia Univ.)

BROOKHAVEN  
NATIONAL LABORATORY



Center for Functional Nanomaterials



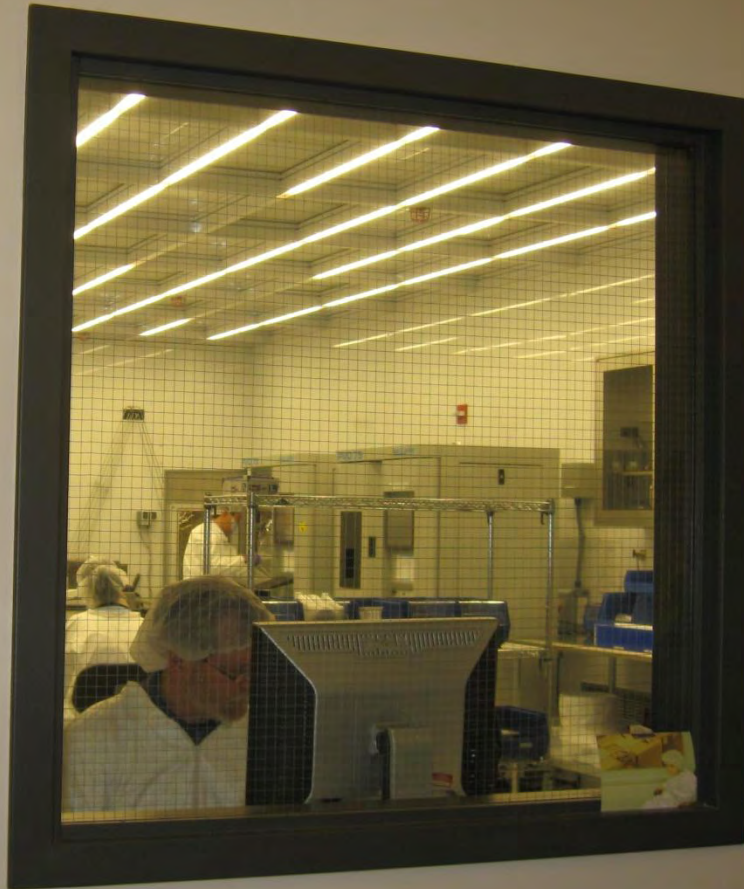
BROOKHAVEN  
NATIONAL LABORATORY

roscope

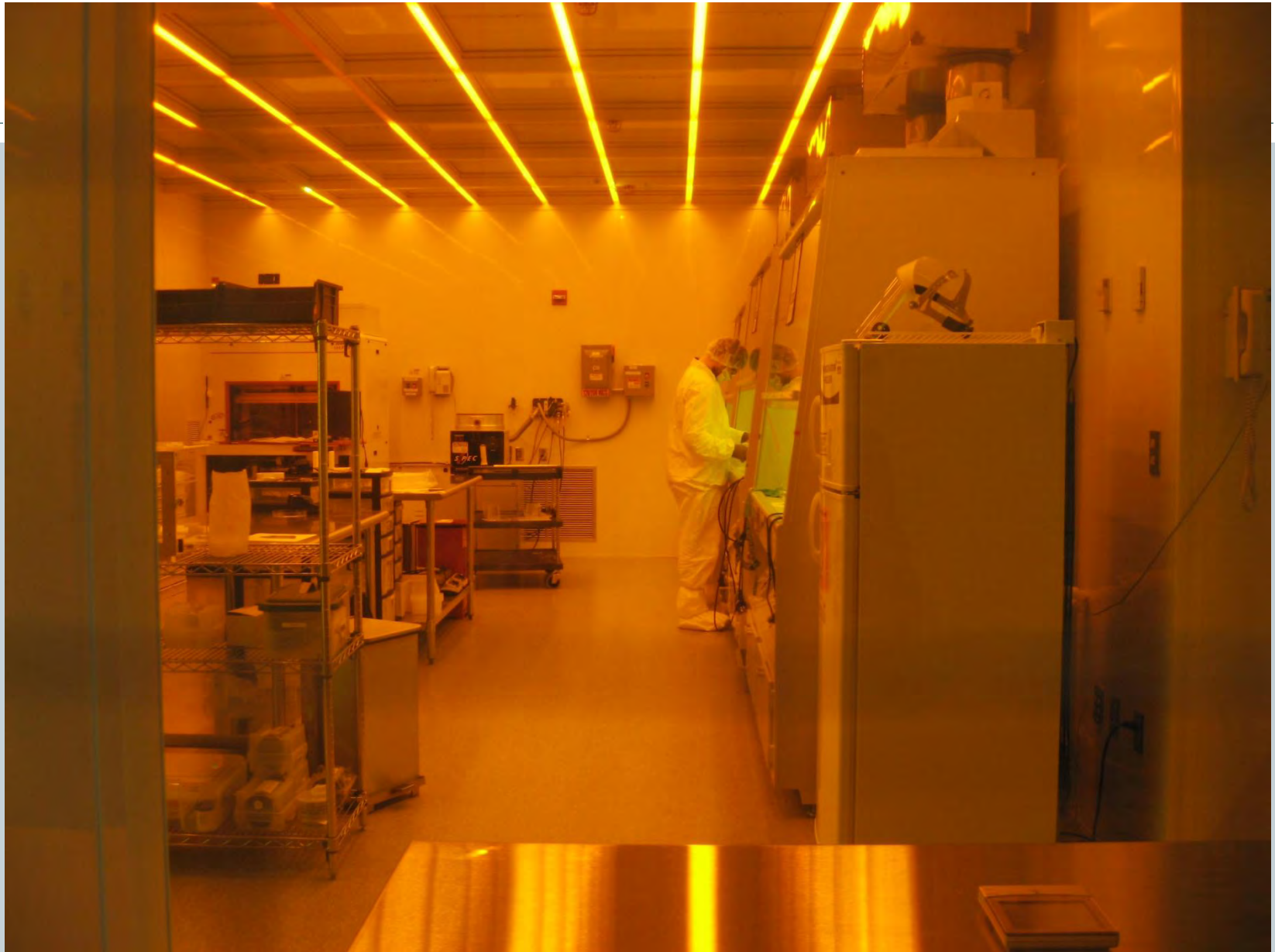
Electron beam column with  
in-line detector: high  
resolution imaging



STEM detector: imaging in  
transmission mode









# National Synchrotron Light Source



- In 1945, the ***synchrotron*** was proposed as the latest accelerator for high-energy physics, designed to push particles, in this case electrons, to higher energies than could a ***cyclotron***, the particle accelerator of the day. An accelerator takes stationary charged particles, such as electrons, and drives them to velocities near the speed of light. In being forced by magnets to travel around a circular storage ring, charged particles tangentially emit electromagnetic radiation and, consequently, lose energy. This energy is emitted in the form of light and is known as synchrotron radiation.
- The General Electric (GE) Laboratory in Schenectady built the world's second synchrotron, and it was with this machine in 1947 that synchrotron radiation was first observed. Radiation by orbiting electrons in synchrotrons was predicted by, among others, John Blewett, then a physicist for GE who went on to become one of Brookhaven's most influential accelerator physicists, working on both the Cosmotron and the Alternating Gradient Synchrotron.
- For high-energy physicists performing experiments at an electron accelerator, synchrotron radiation is a nuisance which causes a loss of particle energy. But condensed-matter physicists realized that this was exactly what was needed to investigate electrons surrounding the atomic nucleus and the position of atoms in molecules. So, in the early days, the two branches of physics worked together in so-called "parasitic" operation, where synchrotron light illuminated the condensed-matter physicists' experiments while particle physicists used the electron beam.



# NSLS cont'd



## **Decision to build the NSLS**

- When the U.S. Department of Energy's Office of Basic Energy Sciences recognized the need for "second generation" electron synchrotrons dedicated to the production of light, it budgeted construction funding for Brookhaven's National Synchrotron Light Source (NSLS), beginning in fiscal year 1978. Ground was broken for the NSLS on September 28, 1978, and the vacuum ultraviolet (VUV) ring began operations in late 1982, while the x-ray ring was commissioned in 1984.

## **The Chasman-Green lattice**

- Before the light at the NSLS was turned on, however, the two inspired scientists responsible for the ingenious design of the two storage rings had died. The late Renate Chasman and G. Kenneth Green had designed the "double focusing achromat," or what is more commonly known as the Chasman-Green lattice. The lattice is the periodic arrangement of magnets that bend, focus and correct the electron beam, and their simple yet elegant design included straight sections for the insertion of equipment.
- When special magnets are inserted into two straight sections in the VUV ring and five straight sections in the x-ray ring, the electron beam "wiggles" and, therefore, emits even more intense synchrotron radiation. Chasman and Green's inclusion of these devices in their design of the storage rings enables the NSLS to deliver world-class beams of light today.



















# NSLS Control Room



# NSLS Control Room





# New York Blue Supercomputer



- New York Blue/L is an 18 rack IBM Blue Gene/L massively parallel supercomputer located at Brookhaven National Laboratory (BNL) in Upton, Long Island, New York. It is the centerpiece of the New York Center for Computational Sciences (NYCCS), a cooperative effort between BNL and Stony Brook University that will also involve universities throughout the state of New York. Each of the 18 racks consists of 1024 compute nodes (a total of 18432 nodes) with each node containing two 700 MHz PowerPC 440 core processors and 1 GB of memory (a total of 36864 processors and 18.4 TB of memory). The racks are arranged as six rows of three racks each.
- In addition to New York Blue/L, there is New York Blue/P which consists of two racks of the Blue Gene/P series. Each BG/P rack contains 1024 850 MHz quad-processor nodes with each node having 2GB of memory.

# New York Blue



**New York Blue** is critical for computations in biology, medicine, materials, nanoscience, renewable energy, climate science, finance and technology. It is the centerpiece of the New York Center for Computational Sciences (NYCCS).

## Features of New York Blue/L

- IBM Blue Gene
- 100 teraflops
- 18-rack configuration
- 36,864 processors



























# Conclusions



- It was motivating and inspiring to see all the technicians working hand in hand with the engineers and scientists.
- There are plenty of learning opportunities for everyone (students and teachers) through the BNL educational programs. For more information regarding the programs and internships please visit <http://www.bnl.gov/education/programs.asp>

# Reflections



- **“The Brookhaven National Laboratory (BNL) field trip was an exciting** adventure into the world of science. BNL provides its scientists, engineers, technicians and guest researchers with facilities for advanced scientific studies that lead to ground breaking discoveries. Six Nobel prizes have been awarded for discoveries made at BNL. Some main facilities that led to such advancements are the Relativistic **Heavy Ion Collider (RHIC) which is the world’s biggest partial** accelerator, the Center for Functional Nanomaterials (CFN) which provides state-of-the-art capabilities for the study of nanoscale materials, the National Synchrotron Light source (NSLS) which provides scientists with the ability to analyze new nano materials, and the New York Blue supercomputer which provides computations critical for research in biology, medicine, materials science, nanoscience, renewable energy, finance and technology.



# Reflections cont'd



- The main focus of our visit consisted of the National Synchrotron Light source and the New York Blue supercomputer. I was stunned that when one of the physicists was describing the NSLS he mentioned the right-hand rule method to determine the direction of electrons when it comes to velocity, magnetic field and force. When I learned this method in class I thought it was just a dumbed down method to help students. I was also surprised at the fact that no matter how advanced and scientific something is, it can still be covered in aluminum foil like a baked potato to keep the **temperature like the NSLS...**

I learned a lot from our field trip and was delighted when Professor Vladutescu asked the troubleshooting engineer technicians their educational background and most had associates in electrical engineering. Working at BNL is definitely something to shoot for and I look forward to applying for their summer internship program. BNL is like a Disney world **for the mind.**”

- *CC, freshman full time student, Major: Electrical Engineering Technology, ETET*

# Reflections cont'd



- **“.....Another thing impressed me in this visit was the education background of the technicians. When we were in the control center of the Synchrotron Light source, we learned that four of the five technicians working there have the associate degrees in engineering and another one has the bachelor’s degree, but at the same time we also learned that they have much related experience before working in this laboratory. This showed us that both the education and experience contribute the future of our career after we graduate. I hope that on some day I can have a professional job like them.”**

*XC, senior full time student, Major: Telecommunications Engineering Technology, BT, ETET Dept*



# Special thanks to



- BMI and Citytech Foundation for financial support
- Provost Bonne August
- Professors Viviana Vladutescu, Reginald Blake, Janet Liou Mark, Mohammad Razani, Muhammed Ali Ummy
- Sonia Johnson, Elaine Lowenstein and all the BNL supporting crew without which this wonderful experience would not have been possible