Learning Nanotechnology through Multimedia Visualizations and Simulations

Funding provided by:
The National Science Foundation

Authors/Contributors:
Hyung-Seok Hahm, Imran Sobh, Yan Li, Slava V. Rotkin, Umberto Ravaioli
Presenter: Li May Goh (UIUC)

NCLT Nanomaterials Work Circle

ILLINOIS

MOTIVES

- Teach nanotechnology to high ~ grad school students using multimedia such as 3D simulations, animations and java applets that facilitate visual, haptic, and audio senses.
- Engage student's interest in nanotechnology and promotes active learning through interactive visualizations/simulations.
- Visualizations/Simulations help students make logical connections between the nano and macroscopic worlds.

INTRODUCTION

This poster presents visualizations that are developed to aid students in learning nanotechnology. Two recent programs developed are:

Band Structure of Carbon Nanotube in Perpendicular Electric Field

This is an interactive Java simulator that can perform Band structure calculations for zigzag and armchair carbon nanotubes (CNT) using the nearest-neighbor tight-binding method with hopping potential -2.5 eV is also developed for teaching nanotechnology. Java applets involve students' interactions and thus encourage active learning.

Visualizations to learn Scanning Tunneling Microscopy (STM)

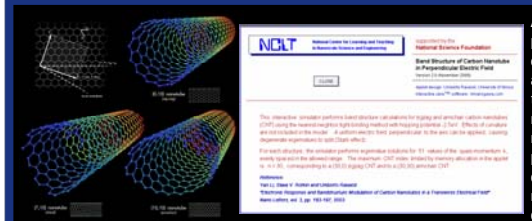
Three visualizations are developed to teach STM. An animation with 3D image of STM is developed to introduce students to STM and how it works. Another interactive simulator solves 1D time-dependent Schrodinger equation for motion of Gaussian wave packet across potential tunneling barrier. It is developed to show students how variation of parameters influences tunneling and quantum mechanical reflection which is essential to understanding STM. A third visualization contains 3D simulations which are designed to help students acquire hands-on experience on how STM operates.

Other visualizations are:

- An animation for students to relate the "smallness" of nanoscale relative to the things they can see.
- Wavelength and length conversion calculators to aid students in wavelength computation and units conversion.

PROGRAMS DEVELOPED

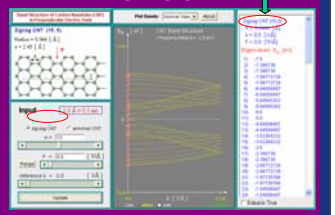
BAND STRUCTURE OF CARBON NANOTUBES (CNT) IN PERPENDICULAR ELECTRIC FIELD



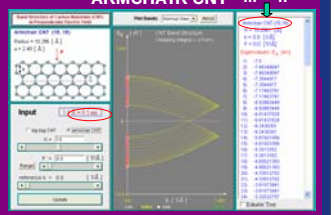
A simulator that can perform band structure calculations for zigzag and armchair CNT using the nearest-neighbortight-binding method with hopping potential -2.5 eV is developed for teaching nanotechnology. (See description in left fig.)

CNT are unqiue nanostructures that can be considered as a one-dimensional (1D) quantum wire. Most single-walled nanotubes (SWNT) have a diameter of close to 1 nanometer, with a tube length that can be many thousands of times larger. The structure of a SWNT can be conceptualized by wrapping a one-atom-thick layer of graphene into a seamless cylinder. The way the graphene sheet is wrapped is represented by a pair of indices (*n*,*m*) called the chiral vector. (See upper left fig).

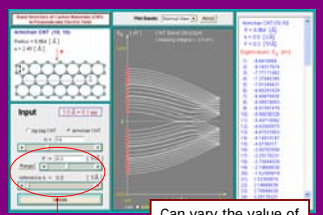
ZIGZAG CNT m = 0



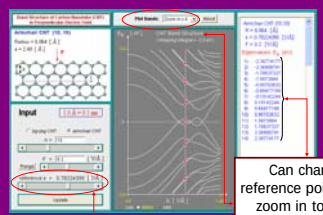
ARMCHAIR CNT m = n



INVESTIGATING BAND STRUCTURE BY VARYING INPUTS



Can vary the value of n and electric field.



Can change reference points and zoom in to read selected points.

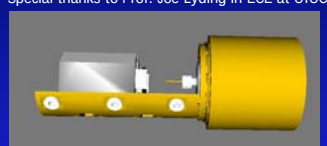
CNTs have many potential applications because of their strength, electrical and thermal properties. They can be used to make everyday items like clothes to combat jackets and light weight bicycle. They are also potential candidates as components of electrical circuits.

VISUALIZATIONS TO LEARN SCANNING TUNNELING MICROSCOPY (STM)

Description
60 second animation with 3D image of STM

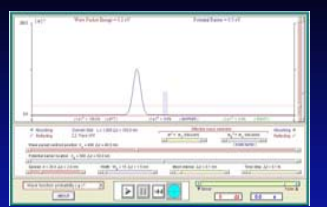
Design Goals
- Give an idea of what STM looks like
- Provide an overview of what STM does and how it works

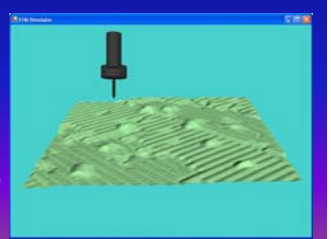
Special thanks to Prof. Joe Lyding in ECE at UIUC



Description
Interactive simulator that solves 1D time-dependent Schrodinger equation for motion of Gaussian wave packet across potential tunneling barrier

Design Goals
- Allow users to vary potential barrier and particle energy
- Show how variation of parameters influences tunneling and quantum mechanical reflection which is essential to understanding STM





Description
Simulation with 3D images of material sample and tip of STM

Design Goals
- Allow students to experience how STM works with haptic interface
- Support interaction to encourage active learning
- Accommodate video game features friendly to target users

Developed by:
Hyung-Seok Hahm[1,3]
Imran Sobh[2]
Umberto Ravaioli[1,3]

[1] Department of Electrical and Computer Engineering
[2] Department of Psychology
[3] Beckman Institute for Advanced Science and Technology

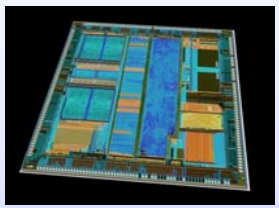
University of Illinois at Urbana-Champaign

OTHER SIMULATIONS

INTRODUCTION TO NANOSCALE

Description
80 second animation zooming-in from computer to molecules with narration

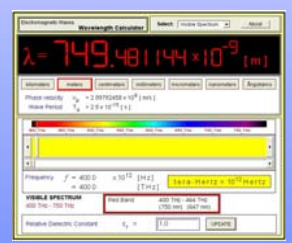
Design Goals
- Give smooth introduction to nano-world
- Deliver ideas of how small nano-scale objects are
- Inform that nano-technology is related to everyday things



WAVELENGTH CALCULATOR

Description
Wavelength calculator with scroll bar input of frequency

Design Goals
- Allow students to calculate wavelength without knowing complex physics formula
- Provide quick unit conversion from angstroms to kilometers
- Support specialized spectrums such as visible, optical and radio



LENGTH CONVERTOR

Description
Length conversion calculator between metric and British/USA units

Design Goals
Provide a prompt way of converting various units in metric and British/USA system