Integrating Nanoscience Concepts and Skills in Upper Undergraduate Laboratories

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EPSCoR RESEARCH IN PUERTO RICO

Abstract

The current state of the teaching laboratories in advances courses is outdated. The curriculum teaches the core concepts and occasionally new applications. The laboratories lack modern infrastructure, modern equipment and innovative experiments that promote problem solving skills. The development of new experiments, bringing the most recent results in research in nanoscience and technology, will open a window to motivate students to pursue graduate careers in nanoscience in addition to providing the fundamentals to excel in industrial setting. By replacing outdated experiments in the established curriculum with experimental activities in nanoscience and technology the Laboratory Courses will be brought into the 21st Century milieu. Moreover, the development of new curricular materials that employ the new approaches and tools will vividly show and explore the fundamentals of science and will familiarize students with modern research topics and techniques. Alignment of the Physical Chemistry and Modern Physics curriculum and the results of this alignment with the "Big Ideas" identified by NCTL, was completed previous to the design of new laboratory experiences in order to ensure that the targeted concepts and skills are properly developed, while introducing them to a new area of expertise. This project has catalyzed the development of four new laboratory experiences and has fostered two new collaborations with Cornell University and University of Buffalo to implement materials already developed for this level. Assessment of student learning is underway and dissemination of these materials will be done via the IFN website and collaborators' web-based libraries.

Rationale
SAME PHENOMENA DIFFERENT SCALES

WATER WAVE (M) OBJECT | LIGHT(700 NM) [1] SMALLER OBJECT | X-RAY(0.3NM) [1] SINGLE NaCl CRYSTAL

GOALS

- Bring Modern Physics and Intermediate Chemistry Labs to 21st Century.
- Develop new Intermediate Laboratory Physics and Chemistry courses that employ the new approaches and tools made available by the advances in nanoscience and technology to vividly show and explore the fundamentals of science.
- Contribute to the NCLT clearinghouse to the benefit of other NCLT partners.

Education and Outreach Collaborators

UPPER UNDERGRADUATE LEVEL: TRADITIONAL COURSE TOPICS

- Solid State and X-rays
- Quantum Theory: Energy and Color
- Balmer Series
- Statistical Mechanics: Heat Transfer
- Optics: Interference and Refraction
- Rotational-Vibrational Theory: Infrared Spectra
- Kinetics (Chemical Reactions)

NANOSCALE RELATED CONCEPTS

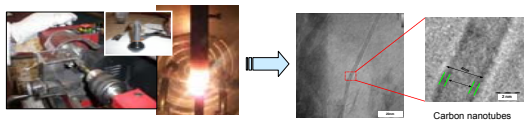
- Bonding
- Short Range Order
- Periodicity
- Radiation-Matter Interaction

NANOTECHNOLOGY NEW CONCEPTS

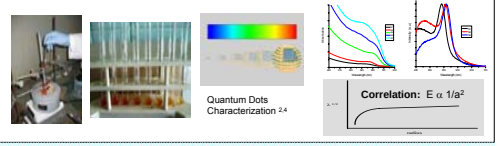
- Self-assembly
- Surface-to-volume Ratio
- Quantum Confinement
- Atomic Imaging

Experiments Developed and Implemented

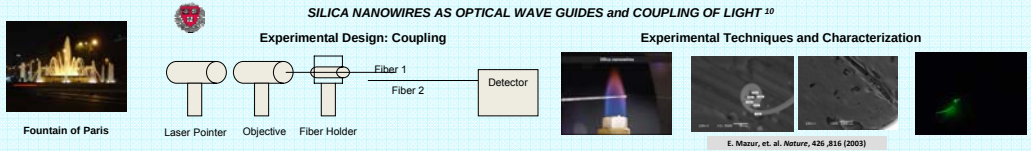
PLASMA SYNTHESIS AND CHARACTERIZATION OF SINGLE AND MULTIPLE WALLED CARBON NANOTUBES



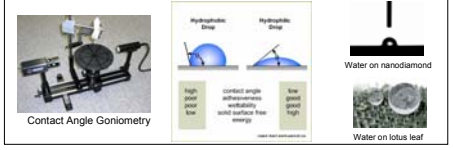
PARTICLE IN THE BOX: CdSe QUANTUM DOTS (QD): SYNTHESIS, CHARACTERIZATION, ABSORSION AND EMISSION SPECTRA



SILICA NANOWIRES AS OPTICAL WAVE GUIDES and COUPLING OF LIGHT [10]

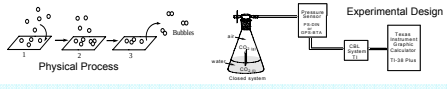


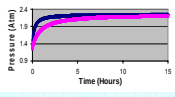
Surface Energy Measurements of Hydrophobic NanoDiamond

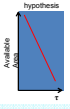


Remote Access Atomic Force Microscopy[15]

Nucleation: A Surface-to-Volume Ratio Kinetics Experiment



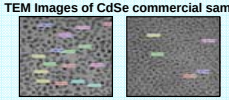




INTRODUCTION to the TRANSMISION ELECTRON MICROSCOPE (TEM) & COMPUTATIONAL NANOSCIECNE

The goal is to familiarize students with the use of state of the art instruments, characterization techniques and the use of computational tools in the field.

TEM Images of CdSe commercial samples[14]



TEM Images of sand particles[11]

Nanoparticles properties using the NanoHub [12]

QD's energy levels and characterization

COURSE OBJECTIVES

- Teach experimental design and methods using nanosubjects
- Teach fundamentals Physics and Chemistry concepts using nanotechnology
- Comparison between classical and nanotechnology experiments
- Address cross-disciplinary topics
- Improve science communication skills
- Integrate concepts learned during the semester

Assessment Tools

- Pre and Post test to probe student learning in selected experiments as these are implemented
- Rubrics to probe science communication skills and laboratory techniques
- Comprehensive final exam to probe integration of concept

Outcomes

2007-08

- **79 undergraduate students enrolled**
  - **72 Physical Chemistry**
    - **2 experiments**
  - **7 Modern Physics**
    - **2 experiments**
  - **65% female**

2008-09

- **62 undergraduate students enrolled**
  - **57 Physical Chemistry**
    - **2 experiments**
  - **5 Modern Physics**
    - **4 experiments**
  - **67% female**

Evaluation Results (Spring 2008)
Administered in Physical Chemistry to 72 students

Criteria	Excellent	Good	Poor	N/A
Learned New Concepts	54	42	4	
Meet your Expectations	21	61	17	
The material was presented effectively	21	63	16	
Time Management	16	61	23	
Facilities	7	40	51	2

Lessons Learned in Nanoscience Education

- When properly adapted, it is instrumental in enhancing science learning and clarifying key concepts.
- Nanoscience can be used to explain concepts in science as it serves as a model to explain phenomena at the sub micron scale.
- Incorporating nanoscience into the curriculum serves as a medium to promote interdisciplinary thinking.
- It is best to introduce nanoscience in the curriculum rather than teaching a dedicated course. However, advanced nanoscience course are necessary at the advance level.
- The biggest challenge in introducing nanoscience at the undergraduate level is to adapt it to the appropriate educational level.
- Resistance to change difficult implementing nanoscience in the curriculum.

By integrating nanoscience into the curriculum you enhance learning and promote interdisciplinary thinking.

Future Plans

- Develop more experiments for upper undergraduate level courses
  - Self-Assembly
  - Viscosity of polymers
  - Magnetic Properties
  - Characterization tools at the nano scale
- Simplify selected experiments to incorporate these in General Chemistry, Physics and Biology courses
- Implement the remote access experiments in Upper Level undergraduate courses
- Implement developed experiments at other UPR campuses and other institutions
- Disseminate the materials tested
  - IFN Website
  - NCLT

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