A. Title Page

International Seminar on Teaching Nanoscience with Scanning Probe Microscopy
Final Report

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B. Restatement of problem researched or creative activity

The field of nanoscience/nanotechnology has become an important area of science that has impacted the society both economically and socially. The administration at Arkansas Tech University has had the foresight to invest in some nanoscience equipment for use in a course for our students. The purpose of this proposal was to send the principal investigator to a workshop with other nanoscience educators to obtain new ideas in teaching the quickly evolving subject to our undergraduate students.

C. Brief review of the research procedure utilized

The 3rd International Seminar on Teaching Nanoscience with Scanning Probe Microscopy was organized by Nanoscience Instruments, the leading manufacturer of educational nanoscience instruments. The workshop took place in Chicago, Il.

D. Summary of findings

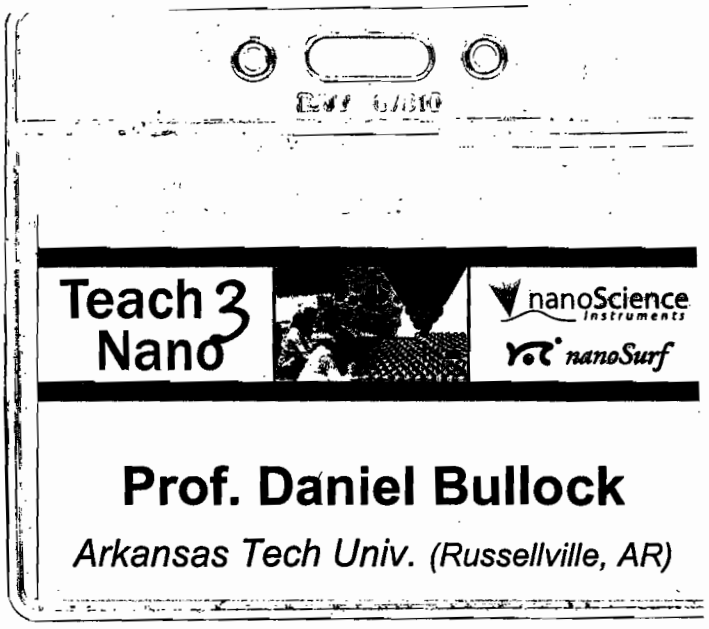
This workshop was probably one of the best professional experiences I have had, the chance to interact with others teaching nanoscience was a very rich experience. As a result of this conference I have set the following goals:

- Add synthesis techniques to the current nanoscience course. Specifically preparing colloidal quantum dots.
- Add spectroscopy techniques to the nanoscience course so that the students can measure the electronic characteristics of the nanoparticles they have prepared.
- Continue to include the STM and AFM for physical measurements.
- Prepare a Nanoscience Undergraduate Education (NUE) proposal to submit to NSF this fall.

- Prepare a presentation for next year's international seminar.

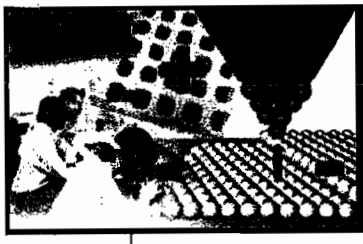
E. Conclusions and recommendations

In conclusion the workshop was extremely helpful in giving me new ideas to add to the current nanoscience course. Please find attached my name badge and notes from the conference as proof that I attended.



Prof. Daniel Bullock

Arkansas Tech Univ. (Russellville, AR)



Teach Nano 3

The 3rd International Seminar on Teaching Nanoscience with Scanning Probe Microscopy

March 28, 2007 2:00 - 8:00 PM Chicago, IL USA

Program Overview

2:00 PM	**Registration**
2:15	**Welcome/Overview**: Dr. Sebastian Kossek, *Nanoscience Instruments, Inc.*
2:30	**Prof. Roland Bennewitz**, *McGill University* (Invited Speaker) Teaching Force Microscopy
3:00	**Prof. Alan Szeto**, *Purdue University & NCLT* Improving NSE and STEM Education in the US
3:15	**Erin Iski**, *Tufts University* Single-Molecule Conductance: Utilizing STM in the Undergraduate Laboratory
3:30	**Prof. Nebojsa Jaksic**, *Colorado State University - Pueblo* Production of Carbon Nanotubes Using Arc-Discharge Method
3:45	**Prof. Lorraine Mulfinger**, T. Fitzsimmons, A. Oliveri, *Juniata College* (Invited Speaker) Keeping Curricula Current: Nanoscience Activities for Secondary Schools
4:15 - 5:00	Coffee Break / Snacks Nanosurf easyScan 2 AFM & STM Demonstration
5:00	**Prof. Leigh Smith**, *University of Cincinnati* (Invited Speaker) Combining Scanning Probe Microscopy with Optics in the Undergraduate Laboratory
5:30	**Prof. Kurt Winkelmann**, *Florida Institute of Technology* Development of a Nanotechnology Laboratory Course for 1st-Year Students
5:45	**Mozhgan Bahadory**, *Drexel University* Synthesis of Silver and Copper Nanoparticles
6:00	**Prof. Vladimir Mitin**, *State University of New York at Buffalo* (Invited Speaker) Undergraduate AFM/STM Laboratory
6:30	Conclusion / Discussions **Drawing of Nanosurf easyScan 2 STM Winner**
7:00 - 8:00	**Mixer / Reception** (food & drinks)

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Invited Speaker

Prof. Roland Bennewitz
McGill University
Department of Physics
Montreal, QC

Title / Abstract

Teaching Force Microscopy

We will discuss the structure of a successful introductory course in scanning force microscopy. A close interconnection of introductory lecture, hands-on session, and wrap-up session is found to be of great importance for the learning process. This will be exemplified for topics like tip-sample forces, feedback time scales, and spatial resolution. An interdisciplinary sample kit enhances the learning experience.

typically senior undergraduate

Notes

3 topics:
Tip Sample forces
Feedback & characteristics time scales
Resolution & Sample preperation

link lecture - lab - wrap-up and tell students

Intro class → Hands-on session → Wrap-up session

Motivate math
Gravity has no meaning in nanoscience
Pico N - soft material bonds
N ↑ - hard material bonds
Atomic core forces & Pauli exclusion forces - preventing finger from going through table
Van der Waals Force - dipole fluctuations - induce dipole
+Adhesion - Capillary force due to atmospheric humidity need to be below 50% humi
see ~20 nN
Feed back Controller - Proportional multiplying
Integral accumulated error signal
use step answer to help explain PI controller
P - too low - error will not b corrected
too high - error will b overcorrected
no derivitive because introduces too much noise in force microscopy
Interesting samples are important, Everyone touches all parts, CMOS structure, Carbon Nanotubes, Crystallized silica beads, staphylococcus Aureus

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Contributed Talk

Prof. Alan Szeto
Purdue University & NCLT
Department of Chemistry
West Lafayette, IN

Title / Abstract

Improving NSE and STEM Education in the U.S.

By the year 2015, it is estimated that newly-derived technologies and products from nanoscale science and engineering (NSE) will help to generate at least $1 trillion/year of new business such as pharmaceuticals, new materials, electronics, chemicals, etc. The new technologies promise to improve healthcare and the sustainability of agriculture, food, water, energy, environment, etc., and it is further estimated that two million nanotech workers are needed worldwide, of which 40% will be in the United States. To address such needs, the National Center for Learning and Teaching (NCLT) provides national leadership and resources for advancing NSE and STEM education, creates and implements professional development programs, develops inquiry-based and other instructional materials, and conducts relevant educational research. In this presentation, current NCLT educational and outreach activities including activities to introduce SPM in the high school curriculum will be highlighted and discussed. Attention will be given particularly to describe our initial effort to assess students' learning progress or conceptions in NSE using an educational research instrument called the concept inventory.

Notes

www.nanoed.org
Downloadable document at website

- Size & Scale
- Nature of Matter
- Properties of Matter
- Dominant Forces
- Self Assembly
- Quantum Mechanics
- Tools & Instrumentation
- Models & Modeling
- Technology & Society

Workshops at various locations

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Contributed Talk

Erin Iski,
M. El-Kouedi, C. Sykes
Tufts University
Department of Chemistry
Medford, MA

Title / Abstract

Single-Molecule Conductance: Utilizing a Scanning Tunneling Microscope in the Undergraduate Laboratory

A Nanosurf® easyScan 2 scanning tunneling microscope (STM) has been employed to obtain molecular resolution of self-assembled monolayers (SAMs) on a Au(111) surface. The low-current preamplifier option allows molecular resolution of SAMs with tail groups up to 8 carbon units long. An undergraduate physical chemistry lab was developed using this user-friendly STM to investigate coabsorbed octanethiol and decanethiol (C_8/C_{10}) SAM systems. Utilizing this instrument, students are able to measure height differences between the two different thiol regions on the Au(111) surface. In constant current mode, the measured height difference between the two thiol regions is less than the actual physical height difference because STM images combine both the topographic and electronic properties of a surface. This STM lab will help students understand fundamentals physical chemistry phenomena including electron tunneling, molecular conductance, and other quantum mechanical effects. In addition, students will gain experience in the use of STM and the interpretation of scanning probe images.

Notes

SAM - Self Assembled Monolayers

Thiol - SAMs, bonds well to Au

Requires low current capabilities, instrument must be fitted with a low current option

$C(4\times2)$ reconstruction

$h_{STM} = h_{film} + d_{gap}$

give students simple with 2 different chain lengths

C_8/C_{10} is optimal, longer chains the currents are too low

ase.tufts.edu/chemistry/sykes/research/smlab.pdf

Erin.Iski@tufts.edu

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Contributed Talk

Prof. Nebojsa Jaksic
Colorado State University
Department of Engineering
Pueblo, CO

Title / Abstract

Nanotechnology in Manufacturing Processes Laboratory: Production of Carbon Nanotubes Using Arc-Discharge Method

This work describes a laboratory experiment developed for undergraduate industrial engineering students for a course on manufacturing processes. There are two objectives of this two-hour laboratory experiment. The first objective is to introduce students to a method for production of a nano-material (carbon nanotubes) that is similar to an already familiar material removal process, electrical discharge machining (EDM). The second objective is to introduce engineering students to an instrument such as an atomic force microscope, capable of characterizing the produced nano-material.

Notes

Objective - put nanotechnology in engineering curriculum
Intro students processes specifically carbon nanotubes
Characterize using AFM - STM
What is taught - CNT Intro, Applications, Synthesis Methods, STM & AFM
- CVD
- Laser Ablation
- Arc Discharge

Teach3 Nano

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March 28, 2007 - Chicago, IL USA

Invited Speaker

Prof. Lorraine Mulfinger,
T. Fitzsimmons, A. Oliveri
Juniata College
Department of Chemistry
Huntingdon, PA

Title / Abstract

Keeping Curricula Current:
Nanoscience Activities for Secondary Schools

juniata.edu/services/ScienceInMotion/chem/

Notes

"Society is living on a cantilever supported by technology...."
- Charles Hosler
Penn State University

Penn State: Center for
Nanotechnology
Education and Utilization

Gold Nanoparticle Synthesis & Microscopy

"Nano" in curriculum - Physical Properties, Scale, Redox Reactions

size range at which properties of particles actually change

plate on mica

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Invited Speaker

Prof. Leigh Smith
Univ. of Cincinnati
Department of Physics
Cincinnati, OH

Title / Abstract

Combining Scanning Probe Microscopy with Optics in the Undergraduate Laboratory

Notes

General towards 2nd year students
Labs should have 3 components: 1: Synthesis . 2. Characterization 3. Optical or Electric
Carbon Nanotubes SEM, TEM, Measurement
Gold Nanorods SPM Absorption, Pl
Raman

3 Pillers of Nanophotonics

- Nanoscale Plasmonic Devices
  Gold Nanorods
  Control Electronic Wave Function
  & Dots
  Photonic Band Gap

Gold Nanoparticles

Bind of CTAB
To Au(100) Face, Synthesis,
Physical Characterize, AFM, TEM
Spectroscopy, Optical Absorption

Quantum Dots

w/ CdSe/ZnS Evidentech
Is structural Characterization
Spectroscopy

Photonic Band Gap Structures

periodic arrangements of a dielectric material that exhibits strong interaction with light
1D: Bragg Reflector
2D: Si piller crystal
3D: Colloidal crystal
Butterfly & Moth wings are PBG structures
Beetle shells

Spin Coating to do
1D structure

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Contributed Talk

Kurt Winkelmann,
J. Brenner, M. Zhang
Florida Institute of Technology
Department of Chemistry
Melbourne, FL

Title / Abstract

Development of a Nanotechnology Laboratory Course for 1st-Year Students

Typical nanotechnology courses are designed for juniors, seniors and graduate students. This presentation will describe Florida Tech's Nanoscience and Nanotechnology Laboratory course that is designed exclusively for freshman students. During the weekly 3-hour meetings, students synthesize ferrofluids, CdS nanoparticles, and carbon nanotubes. They also fabricate STM tips. Students analyze various nanomaterials and thin films using a scanning tunneling microscope (STM) and an atomic force microscope (AFM). Experiments are team-taught by faculty members of the physics, chemical engineering, and chemistry departments at Florida Tech. Equipment for this course was purchased through a grant by the National Science Foundation (#0303986). An outline of the course, summaries of the experiments, and the results of student surveys will be presented.

Notes

Lab Activities - prep ferrofluids
Characterize samples with STM & AFM
Synthesis of CdS & Au nanoparticles, carbon nanotubes & Au nanowires

Ferrofluids -
- Mix iron(II) & iron(III) chloride salts
- Slowly add NH_3, then separate Fe_3O_4
- Add surfactant to prevent particle growth

J Chem Education

http://mrsec.wisc.edu/Edetc/nanolab/gold

J Chem Ed 2007, 84, 709-710 Winkelmann

Then metal films → thermal evaporator & Sputter coater

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Contributed Talk

Mozhgan Bahadory,
S. Solomon
Drexel University
Department of Chemistry
Philadelphia, PA

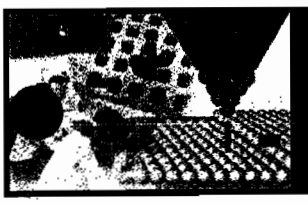
Title / Abstract

Synthesis of Silver and Copper Nanoparticles

Laboratory experiments for the synthesis of metallic nanoparticles introduce students to the unique properties of nanomaterials. Noble metal nanoparticles are synthesized with an easy and convenient method that uses simple equipment. Silver nanoparticles were prepared by borohydride reduction of silver nitrate, a method which produces particles with average size of 12 ± 2nm, determined by Transmission Electron Microscopy (TEM). The plasmon absorbance was at 397 nm. Results were used to design a laboratory experiment in which students synthesize colloidal silver and estimate particle size using visible spectroscopy. This experiment is used by Science in Motion, a van project that takes experiments to public schools. Copper nanoparticles were prepared by reduction of copper(II) sulfate in aqueous solution with: i) borohydride and potassium iodide as a protecting agent, ii) reducing sugars. The synthesized nanoparticles are chracterized by easyscan AFM and UV-VIS spectroscopy. The work to develop a laboratory experiemnt for synthesis of copper nanoparticles is in progress.

Notes

J Chem Educ 2007 84 322



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Invited Speaker

Prof. Vladimir Mitin,
X. Liu, D.Vo, H.Van, A.Verevkin
State Univ. of New York
Dept. of Electrical Engineering
Buffalo, NY

Title / Abstract

Undergraduate AFM/STM Laboratory

The early involvement in the field of nanotechnology with a practical lab approach will result in a revision on how other advanced fields can be taught in the future. We report on a newly developed EE342 Undergraduate Laboratory of Nanoelectronics Course, which will improve Nanotechnology education via development of the new experimental modules based on modern Scanning Probe Miscroscopy instruments. These experimental modules include five experiments with easyScan-2 Scanning Tunnel and Atomic Force Microscopes. We create not only new learning materials, including laboratory experiment manuals, but also a teaching strategy based on assessment procedure for the amount students learn in lecture and lab courses. This approach will help us to develop advanced faculty expertise and research on undergraduate teaching and learning, and to introduce teaching innovations in learning process.

Notes

Intro to Nanoelectronics: Science Nanotechnology

Mitin, Kochelap & Stroscio

Cambridge University 2007

www.eng.buffalo.edu/courses/ee240