NanoUndergraduate Education Techniques at the University of New Mexico

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Abstract

This paper describes an approach that introduces undergraduate students to the field of nanotechnology with emphasis on Nanosystems and Nanodevices. Our novel approach is the utilization of *hands-on experience in the field of nanotechnology in several undergraduate courses.* The approach entails the introduction of "*Nanotechnology Discovery Courses*" that comprise of interlocking undergraduate Engineering Materials Science **core** courses enriched with nanotechnology. Upon moving to senior level courses students can tie the fundamental nanotechnology concepts and the experimental skills acquired in the discovery courses to a "*Nanosystems and Nanodevices Design Course*".

Introduction

The issue of introducing nanotechnology to the engineering curriculum is as old as the nanotechnology field itself [1]. One of the first stand alone nanotechnology undergraduate degrees in the world was established at Flinders University (Australia) in 2000[2]. The pioneers at Flinders raised a valuable concern "*The field (nanotechnology) is currently in its infancy and is incredibly broad, spanning chemistry, physics, biology, mathematics and engineering. This is in fact probably an incomplete list but it makes the point. How do you possibly teach all these areas to students in a four year honors degree?*"[2]. Alternatively, other investigators proposed, utilizing lower division courses as a departure course to familiarize undergraduate students with concepts of nanotechnology[3]. All these successful pioneering experiences developed new undergraduate courses, but most only offered these new courses as "*optional*" or technical electives. Additionally, most of these courses were developed by a single-department, although offered to several other departments.

All efforts to teach nanotechnology to undergraduates can be broken into two main categories: *strictly theoretical/computational* and *hands-on approaches*. Example proponents of the strictly theoretical/computational (hands-off) approach are Chang et al[4]. They argued that "… *nanotechnology experiments are delicate, limited in availability, and expensive to set up and maintain. The use of a web-based approach circumvents these drawbacks and enables the experiment to be run securely, safely, and on a 24/7 basis.*" Meanwhile, other investigators stressed

the importance of bringing hands-on experience to integrate nanotechnology to the undergraduate curriculum. The current authors agree that a hands-on approach benefits the students more than a strictly theoretical/computational approach. Several articles in the engineering education literature support this position We argue that a hands-on approach provides students with a memorable experience that is always refreshed with continuing other theoretical and practical experiences on the subject matter [5, 6].

The next section describes a plan to integrate nanotechnology into existing core courses in the Mechanical and Civil Engineering Curricula at the University of New Mexico. This will be accomplished by adding new lecture components to materials science core courses to introduce the students to a particular aspect of nanotechnology and then reinforce this learning experiences by hands-on experiments that utilize the University of New Mexico's existing Nanotechnology Infrastructure. These Discovery Courses are prerequisites for an additional newly-developed course on the theory, fabrication, and characterization of Nanosystems/devices. This course also has a laboratory component where students fabricate Nanostystems/devices in the cleanroom.

Proposed Approach

To better convey nanotechnology courses that focus on devices and systems to undergraduate students, we will adopt Materials Science courses as our "*Discovery Courses*". Naturally, all materials and systems establish their foundation at the nanoscale. For example, studying the properties and behavior of materials at nanometer scale will assist in designing basic devices like transistors with feature size of nanometer (called nanotechnology for electronics or nanoelectronics[7]). We envision Undergraduate Engineering Materials science is our "*warehouse*" to introduce nanotechnology to undergraduate students. Material science is inherently multidisciplinary; it incorporates physics, chemistry, mechanical, civil and electrical engineering. Moreover, it is a required **core** course for two engineering departments at the University of New Mexico (mechanical and civil engineering). Furthermore, materials science is the most crucial design parameter to successfully transfer the knowledge gained during freshman year physics and chemistry into applied engineering nanosystems and devices. The Mechanical and Civil Engineering Departments at the University of New Mexico currently offer their upper-division undergraduate materials science (ME370 / CE305) and a lab course (ME 352 Experiments in Materials Science and a laboratory component in CE305) in the format of one-semester courses.

In order to continue their nanotechnology education, undergraduate students can elect to take ME 461-E. This course is a hands-on laboratory course on the physical theory, design, analysis, fabrication, and characterization of Nanoelectromechanical Systems (NEMS) and Microelectromechanical Systems (MEMS). This course is highly multi-disciplinary due to the cross-listing of the course with the Electrical and Computer Engineering Curriculum (ECE 519).

What makes this approach unique is that: while familiarizing student with nanotechnology, it will not strain the general outline of classical materials science course for being introduced as a set of separate modules. Moreover the proposed integration of nanotechnology into materials science core courses and interdepartmental technical electives will readily provide students with different backgrounds from crosscutting programs (mechanical and civil engineering) with nanotechnology experience that is naturally interdisciplinary.

Sample: Nanotechnology Module Development in Undergraduate Course

Two pre-existing UNM courses are being modified significantly to include nanotechnology components both theoretically and experimentally. The Mechanical and Civil Engineering Departments currently offer their upper-division undergraduate courses and their lab components (in the format of one-semester themed modules) that tackle the typical issues in metals and ceramics structure/properties and other materials at the macroscale. This course is required for all seniors majoring in Mechanical and Civil Engineering. Upon introducing Nano-modules, the lecture portion of these two classes ME 370 and CE305 will include more in depth discussion of inter-atomic forces and atomic arrangements relating material behavior across scales. This bottom-up approach will enable the students to develop a fundamental understanding about material properties and how they evolve from their atomic structure. To reinforce the concepts instilled during lecture the lab components ME 352/CE305L are being modified to include the following modules:

1. Hardness and Young's modulus measurements of ceramics at nanoscale
2. Fatigue of metals in MEMS devices
3. Atomic Force Microscopy and Scanning Electron Microscopy.

Sample Module: Nano characterization of human enamel, dentine and dental fillings

The authors have piloted introduction of nanotechnology modules in materials science class during spring 2007 session and this effort yielded an excellent outcome. Undergraduate research students have been an integral part of this curriculum development project. During this class students gained hands-on experience operating a Nano Test Systems, atomic force microscopes (AFM), and fabricating nanocomposites based on ceramic nanoparticles.

During these module students from Mechanical and Chemical Engineering were involved in applying three dental fillers (silver, ionomer and epoxy) to cavity in human teeth using the assistance of a local dentist. Students prepared the sample (cutting, polishing) and ran several nanoindentation tests to examine the hardness and modulus for these materials. Students also carried out nano-fatigue tests to test the integrity of the filler/dentine interface. Upon submission the abstract of this work to peer review, the students results were presented at the American Society of Mechanical Engineers International Conference (November 2007, Seattle, Washington) [5].

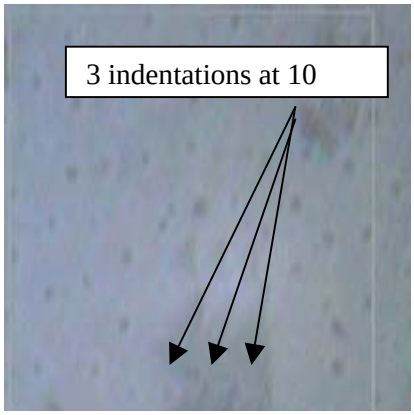

Figure 1. Indentation of Human teeth enamel

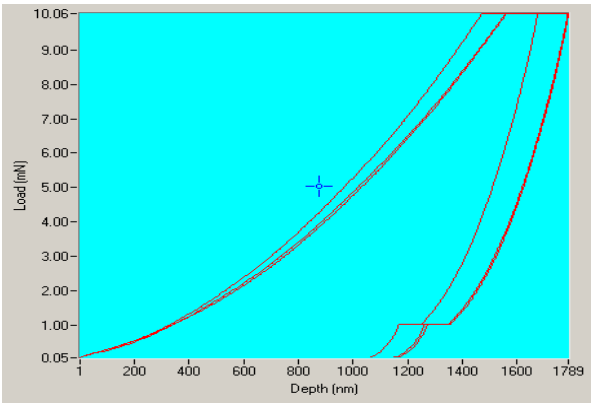

Figure 2. Indentation tests on the surface of enamel

Summary

As future scientists and engineers, students should be prepared to enter a workforce that requires knowledge of nanotechnology. Faculty members from two engineering programs are employing their collective knowledge in nanotechnology to develop new experiments methods that will help introduce undergraduate students to this field of cutting edge research by no later than their junior year. We foresee that our proposed activities to tie the material science curriculum across the school of engineering (SOE) at the University of New Mexico through a group of integrated learning modules focused on nanoscience and nanotechnology.

Our vision is to create a series of interlocking courses for undergraduate nanoscience education. This development is already underway, and will leverage two programs at the University of New Mexico: Mechanical Engineering and Civil Engineering.

References

1. Han, D. Naimipour, K. and Chen A., "Engineering and scientific curriculum issues of including nanotechnology, robotics, life extension, & virtual reality in basic requirements," in IEEE Frontiers in Education Conference, 1993, p. 822.
2. Shapter, J. G., Hale, P., Maddox L. M., Ford, M. J., and Waclawik, E. R., "Teaching Undergraduates Nanotechnology," in Materials Research Society Symposium. vol. 827E: MRS, 2004.
3. Uddin, M., and Chowdhury, A. R., "Integration of nanotechnology into the undergraduate engineering curriculum," in International Conference on Engineering Education (ICEE), Oslo, Norway, 2001, pp. 8B2-6 - 8B2-9.
4. Chang, T., Jaroonsiriphan, P., and Sun, X., "Integrating nanotechnology into undergraduate experience: a web-based approach," International Journal of Engineering Education, vol. 18, pp. 557-565, 2002.
5. Al-Haik, M., Trinkle S. S., Garcia, D., Yang, F., Martinez, U., Sumali, H., and Miltenberger, S. "Investigation of the nano-mechanical and tribological properties of tooth/ fillings materials," in 2007 ASME International Mechanical Engineering Congress and Exposition, Seattle, Washington, USA, 2007.
6. M. M. Reda Taha, Sheyka, M., Su, M. F., El-Kady, I., Khraishi, T. , Verleyd, J.C. , "An Integrated Numerical Approach for Microdamage Detection Using Nano Photonic Sensors," in SPIE Conference on Advanced Sensor Technologies for Nondestructive Evaluation and Structural Health Monitoring II, San Diego, USA, 2006, p. 617907.

7. Choudhury, J., Rawat, K., Seetharaman, G. and Massiha, G., "Initiating A program in nanotechnology through a structured curriculum," in 2003 IEEE International Conference on Microelectronic Systems Education (MSE '03), 2003.

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