AC 2008-1229: TECHNOLOGIES OF NANOTECHNOLOGY

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Technologies of Nanotechnology

Introduction

A new course in the Department of Electrical and Computer Engineering Technology (ECET) which introduced our students to the emerging field of nanotechnology is discussed. As an interdisciplinary field, nanotechnology provides an interesting challenge for instruction at the undergraduate level. This course focuses on the technologies of nanotechnologies, with particular emphasis on the electrical components. It also covers the development of nanoelectronics and the electrical characterization of nanomaterials. Guest speakers in the fields on nanophotonics and nanomedical systems introduced these commercial applications and the electronic contributions of each were reviewed. The ethics of nanotechnology was also discussed. This course challenged the students to think on a new level and develop their skills in communications, teamwork and life long learning. Laboratory exercises were conducted in our new Scanning Probe Microscopy Laboratory within ECET as well as the Birck Nanotechnology Center (BNC). Hand-on experience included atomic force microscopy and use of the NanoHub simulations. This course represents a new direction in engineering education with many ideas and challenges to consider.

Course Design

As an emerging field with tremendous opportunity, nanotechnology offers a new frontier for education at the undergraduate level. Simply trying to identify where nanotechnology should be offered in the curricula is a significant area of study[1]. In the Department of Electrical and Computer Engineering, we chose to begin with an individual course centered on the technologies of nanotechnology. *Introduction to Nanotechnology* is a junior/senior year elective being offered for the first time during the spring 2008 semester. Two classes of 75minutes and a two hour lab are required per week for this three credit course. Freshman biology, chemistry or physics or approval of the instructor were the prerequisites. The syllabus was relatively minimal; attendance was assumed due to interest, professional conducted was expected of all and project/laboratory assignments were to be made throughout the semester. A text was not required. A tentative grading system was provided but the instructor reserved the right to make adjustments as the course developed. This approach was adopted from Singham[2] "to model the exhilaration of the life of the mind" rather than to stifle innovation through a "rigid rule-infested, watertight syllabus." Opinions of senior ECET faculty were elicited to insure our students could handle the challenge.

The tentative course schedule is presented in figure 1. The laboratory exercise occurred between the two lectures each week and the schedule was designed for this. The course was designed in the following sections: introduction, electrical, tools, materials, applications and others or miscellaneous. The first two week were devoted to providing the students an introduction to the course and nanotechnology as well as bring them all "up to speed" on the basics required to understand nanotechnology (i.e. chemistry, physics and biology.) As this course was offered in an ECET department, a second concentration was on the electrical components, materials and measurements involved in nanotechnology. Some of these ideas were presented during the third week, but also sprinkled throughout the rest of the semester as various subjects were studied.

The next group of topics was the technologies used to perform nanotechnology research. The premiere tool of nanotechnology, scanning probe microscopy was studied as well as a hands-on component provide during the laboratory exercises. This is described below. Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and other surface analysis techniques were also explored. Nanomaterials were reviewed with particular emphasis on electrical characteristics and measurements. Various applications of nanotechnology were introduced followed by a techniques lecture describing the electrical contributions to the applications. Finally, a miscellaneous category was included to account for areas of nanotechnology currently in debate or development. The schedule was presented as very tentative and the students were advised to remain flexible and open minded.

Many invited speakers contributed to the course in their respective areas of expertise. The instructor is highly involved with the ongoing internal nanoscience research and took advantage of these networks to provide real world applications and experience to the students. Curricula material was developed using the instructor's personal research experience, the guest speakers, the NanoHUB and the internet in general. All material was specifically referenced for students use and follow-up.

Laboratory Exercises

Laboratory experiences were another goal of this course. However, there are many challenges to providing hands-on experience in nanotechnology; including the availability of equipment, biohazard considerations and the number of students to be served or work stations to be developed. A scanning probe microscope (SPM) was purchased through funds awarded by an Internal Provost Initiative for Innovation in Instruction grant. The SPM lab is located in Knoy Hall of Technology and serves as the primary space for the laboratory exercises. The SPM labs occurred at the end of the semester (allowing time for SPM system install, calibration and training of the instructor and teaching assistant.) The student were instructed in the operation of the system and trained in smaller groups of four to five students. The students were then asked to image a standard calibration grid and a second material of their choice. The latter requires the student to consider sample preparation and experimental conditions. The Birck Nanotechnology Center (BNC) was an invaluable resource and was utilized to provide a real world experience in nanotechnology research development and the requirements for nanotechnology laboratory design and requirements. Additional nanotechnology equipment was demonstrated to the students by scientist responsible for the operation of these specialized instruments located in the BNC. The NanoHUB[3] which offers simulation tools among other things was used throughout the course. The simulation tools were used to demonstrate the ideas of carbon nanotubes and quantum dots as these materials are not sufficiently understood to allow undergraduate exposure at this time. Students used the NanoHUB to simulate various quantum dot and carbon nanotube configurations and investigate their electrical and/or optical properties. Two laboratory reports were required. One detailing the hands-on experience with the SPM and the other involving the use of the NanoHUB as s simulation tool.

Week #	Lecture A Tuesday 3-4:15	Lecture B Thursday 3-4:15	Lab Thurs. 9:30-11:20	Section
1	Course Introduction & Syllabus	Introduction to Nanotechnology	BNC Orientation Jennifer Monahan	Intro
2	Background Information	Nanoelectronics Supriyo Datta	NanoHUB Mark Lundstom	
3	Nano-Electrical Measurements David Janes	Nano Measurements, Pico Amp meter, Nanovoltmeter	Electrical Characterization Lab at BNC	
4	Scanning Probe Microscopy Ron Reifenberger	Atomic Force Microscopy	Knoy AFM Lab	Tools
5	XPS Surface Analysis Dmitry (Dima) Zemlianov	Other Surface Analysis Techniques, RAMAN,	XPS Lab BNC	
6	SEM/TEM Eric Stach	Nanoparticles	SEM/TEM Lab BNC	
7	Quantum Dots Gerhard Klimeck	Open	QD Lab	Materials
8	Carbon Nanotubes Sungwon Kim	CNTs, Bucky Balls	CNT lab	
9	Self Assembled Monolayers	Open	SAM Lab	
10	Spring	Break	Spring	Break
11	Nano Photonics Vladimir Shalaev	Techniques of Nanophotonics	Knoy AFM Lab	Applications
12	NanoMedicine James Leary	Techniques of Nanomedicine	Knoy AFM Lab	
13	Open	Open	Knoy AFM Lab	
14	Nanotechnology Ethics Andrew Hirsch	Commercialization Mark Jackson	Knoy AFM Lab	Other
15	Presentations	Presentations	Knoy AFM Lab	Students
16	Presentations	Presentations	Knoy AFM Lab	

Figure 1. Tentative Course Schedule for Introduction to Nanotechnology

Assessment

The objectives of this introductory course were stated as: After completing this course the student should be able to:

1. understand the basic concepts behind nanotechnology.
2. characterize electrical material at the nano regime.

3. analyze nanocomposite materials.
4. understand the tools of nanotechnology.

This course also serves the ECET program learning outcomes of communications, life-long learning and teamwork. All of these attributes will be assessed through formal and informal techniques. Three research papers are required, each with a specific purpose. The first, completed early in the semester will assess the student's initial understanding of any area of nanotechnology they choose. The second will be completed after the section on the electrical components, materials and measurements involved in nanotechnology. This paper will determine their understanding of this material in particular as it is applied to their field of study. A third paper on the applications of nanotechnology will determine their understanding of electronics applied outside of their major. Two lab reports will assess the understanding of the laboratory components of the course, i.e hands-on SPM experience and use of the NanoHUB as a simulation tool. Development of additional hands-on laboratory exercises is anticipated in the future and were addressed as part of the course projects. The project assignments paired students of similar interest to develop "typical" laboratory stations for their specific nanotechnology area. The students were instructed to consider test equipment required, the laboratory environment required for low level measurements and other required materials. The projects were the presented to the entire class for review and comments. The students communication and teamwork skills were tested with this process. An informal assessment was also performed to gain the students opinions of the course structure, lectures and laboratories. The students were well aware of the ongoing course development process and were encouraged to provide input throughout the semester. Life-long learning is difficult to benchmark. The results are not likely to be evident for many years. However an instructor and the students "feel" when a class has been successful, this was anticipated documented in the short term during the informal assessment.

Summary

At time of writing this course is half way through the semester. Eight students registered for the course in the fall 2007, two other students joined the course after the first lecture; and they all keep showing up for class! Thus far the process has been incredible and the instructor has maintained her sanity[4]. An initial assessment of the course was conducted on the seventh week of class. Students were asked to provide their opiniions on the usefulness of background information, guest speakers and laboratory exercises. The background material was well received however, as the course developed it became apparent additional material was need to bring all students "up to speed" in particular areas. These areas include Schrodinger wave equations, particle/wave theory and Fermi energy levels. For the most part guest speakers were considered positive as they provided expertise in the specific area of research. A few speakers were found to be to difficult to understand either by material presented or personal accents. Laboratory exercises were particular enjoyed by the students. They were surprised and impressed by the access provided to the BNC and a few of the students are pursuing summer research projects through this experience. The students also found the NanoHUB to be very useful in demonstrating the concepts. Finally the SPM lab was particularly enjoyed and each student is fully trained and working independetly. Overall the course thus far has been a success and has resulted in a number of the students pursuing research expereince and/or graduate school.

Bibliography

1 Imbrie, P.K., et al., Journal of Natural Resources and Life Sciences Education, V36, pp.58-65, 2007.
2 Singham, Mano, Liberal Education; Fall2007, Vol. 93 Issue 4, p52-56, 5p.
3 http://www.nanohub.org/
4 Felder, R.M., and Brent, R., Chemical Engineering Education, 41(2) 121-122 (2007).