

AC 2009-899: CURRICULUM DEVELOPMENT IN NANOTECHNOLOGY

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Curriculum Development in Nanotechnology

Abstract

The field of nanotechnology crosses multiple disciplinary boundaries and requires a unique approach for curriculum development. The very nature of nanotechnology allows for courses in most colleges and departments and thus requires the material to be emphasized to align with the department offering the courses. The instructor and students must have basic understandings in math, physics, chemistry, biology and engineering. These can be required as prerequisites; however a session of basic information can be conducted to provide all students with the necessary background information. Laboratory or hands-on experiences are difficult to provide due to the large cost of the nanotech instrumentation, environmental conditions necessary and biohazards associated with nanomaterials. This report will present our efforts to develop a nanotechnology curriculum within the Department of Electrical and Computer Engineering Technology at Purdue University.

Introduction

The interdisciplinary field of nanotechnology provides many exciting challenges in curriculum development. A number of courses^{1,2} and curriculums^{3,4} are being introduced at this time. Books on the subject have been published⁵⁻⁷ although few with the feel of a textbook⁸, i.e. providing examples and homework problems. Nanotechnology concepts can be found in departments and colleges ranging from biology to physics, engineering, food sciences, and veterinary medicine just to name a few. Providing a nanotechnology course or curriculum which covers all these aspects is unreasonable thus the course/curriculum developed must be aligned with the department offering the course. The background material for any course in nanotechnology is also highly interdisciplinary, requiring, chemistry, biology, physics, math and engineering. These requirements can be met through prerequisites for the courses or by providing the necessary background material in the beginning of each course⁹. Laboratory components to these courses also provide a significant challenge in the cost of the equipment required¹⁰, the necessary environmental conditions¹¹ as well as issues of biohazardous materials¹² associated with nanotechnology.

Curriculum Development

Within the Department of Electrical and Computer Engineering Technology (ECET) a nanotechnology curriculum is being developed to complement our current areas of analog, digital, communications and power. Nanotechnology can actually be applied to each one of these areas or stand on its own as a separate area of concentration. Our spiral curriculum lends well to introducing nanotechnology in each one of these areas starting with the freshman year, leading to more advance nanotechnology courses as selectives during the junior and senior years. For instance, the very basic concept of resistance which is introduced in our freshman level courses has been altered by the idea of ballistic transport through nanoscale devices. While our previous understanding of resistance is sound for macro and micro scale devices, introducing the concepts at the nanoscale and how these differ provides additional understanding of the concept of resistance no matter what the scale. Course modules are being developed which will

become a part of our introductory courses to begin the process of introducing the field of nanotechnology.

Selective and graduate courses have already been developed to introduce nanotechnology as a complete course. To date these have been general introductory courses. An undergraduate version of the course was conducted during the Spring 2008 semester and another is ongoing during the Spring 2009 semester. A graduate version of the course was conducted during the Fall 2008 semester. As we are an ECET department we are specifically concentrating on the nanoelectronics, the electrical requirements for the tools of nanotechnology, electrical characterization of nanomaterials and the electrical aspects of nanotechnology applications. Figure 1 provides a typical semester schedule for the undergraduate version of these courses.

For the introductory courses we have required prerequisites of biology, chemistry and or physics to insure the students are willing to think outside the world of ECET and have a basic knowledge in these areas. A background lecture is also included the first week of the courses to bring all students to the level required to begin discussing the multidisciplinary aspects of nanotechnology. This session reviews biological concepts such as DNA hybridization, antibody/antigen attractions and binding constants. The periodic table and chemical bonding options are reviewed as well as the atomic structure which leads to the concepts of quantum physics. The particle wave duality and photoelectric effects are reviewed and the Fermi level energies are introduced. These are all required to begin the discussions in nanoelectronic development and testing.

In the area of nanoelectronics, students are introduced to electrical measurements at the nanoscale, the environmental conditions necessary to make these measurements and the design and fabrication of nanoscale electronics. Nanotechnology became a keen area of interest as the microelectronics industry began scaling down into the nano regime, also known as the top-down process. The requirements and techniques of this downscaling are introduced along with the changes in basic electrical properties. Alternatively the bottoms-up process is introduced which involves building electrical components atom by atom. In both cases, extremely controlled fabrication and testing environments are required. These include vibration, acoustic, electromagnetic and acoustic isolation.

The tools of nanotechnology are investigated, specifically the electrical components and how these systems are developed or repaired. Three nanotechnology tools are introduced which include scanning probe microscopy (SPM), Scanning and transmission electron microscopy (SEM/TEM) and X-ray Photoelectron Spectroscopy (XPS.) The SPM constitutes the laboratory component of these courses and will be discussed below. Demonstrations labs of SEM/TEM and XPS systems are provided through Purdue's state-of-the-art nanotechnology facility. For each system, the electrical phenomenon behind the systems is reviewed as well as the electrical component required for the systems.

Dates	Lecture A Tuesday 9-10:15	Lab Wed 11:30-1:20	Lecture B Thursday 9-10:15	Due Dates	Section
12-16 Jan	Course Introduction & Syllabus	BNC Orientation Mary Jo Totten BNC Room 1201	No Class		Intro
19-23 Jan	Introduction to Nanotechnology	Knoy SPM Lab Knoy B09	Background Information		
26-30 Jan	Nanoelectronics Introduction	Knoy SPM Lab Knoy B09	Nanoelectronics Supriyo Datta		Electrical
2-6 Feb	Building Nanoelectronics	Electrical Characterization Lab at BNC 2261	Nanoscale measurements		
9-13 Feb	Scanning Probe Microscopy	SPM labs at Birk and Bindley BNC 1031	Atomic Force Microscopy	Review paper #1	Tools
16-20 Feb	SEM/TEM Eric Stach	SEM/TEM/XPS BNC 1263	SEM/TEM electronics		
23-27 Feb	XPS Surface Analysis	Knoy SPM lab Knoy B09	XPS electronics		
2-6 Mar	Nanomaterials	Knoy SPM lab Knoy B09	Carbon Nanotubes	Test 1	Materials
9-13 Mar	Nanoparticles	Knoy SPM lab Knoy B09	Quantum Dots Gerhard Klimeck		
16-20 Mar	Spring	Spring	Break		Break
23-27 Mar	Hot Topics in Nanotechnology	Knoy SPM Lab Knoy B09	Techniques of Hot Topics	QD Sim Lab	Applications
30Mar 3Apr	Nanomedicine James Leary	Knoy SPM Lab Knoy B09	Techniques of Nanomedicine	Review Paper #2	
6-10 Apr	Student Presentations	Knoy SPM Lab Knoy B09	Student Presentations		students
13-17 Apr	Student Presentations	Knoy SPM Lab Knoy B09	Student Presentations		
20-24 Apr	Nanotechnology Ethics	Knoy SPM Lab Knoy B09	Commercialization Mark Jackson		other
27 Apr 1May	Other things...	Knoy SPM Lab Knoy B09	Course Wrap Up	AFM Lab	

Figure 1, Typical ECET-499N Introduction to Nanotechnology Course Schedule

Nanomaterials are introduced, emphasizing their electrical characteristics. Nanomaterials such as carbon nanotubes, quantum dots and nanoparticles of varying materials, sizes and shapes discussed. The fabrication, testing and application of each help the students understand the new properties and thus new capabilities available from these materials

A few specific applications of nanotechnology are presented to provide the students an understanding of the need for ECET education in the development and

commercialization of these products. These topics vary each semester dependent on the latest advances in the field. For instance, last year, nanophotonics was a hot topic as the proof of principal for a cloaking device was published. Of course this was extremely fascinating to any Star Trek fans, which includes most of the ECET students.

Nanotechnology applications in medicine are usually covered as this is of particular interest to the course instructor. The students have also found this application of particular interest as they did not see how an ECET graduate could be involved in medicine. Other topics such as ethics and commercialization of nanotechnology are discussed to complete the course.

Laboratory exercises are conducted in our new SPM lab developed for instruction. A Veeco DiInnova SPM system was procured to provide a hands-on experience for nanotechnology. SPM is the premiere tool of nanotechnology allowing the imaging and manipulation of samples at the nanoscale. Students learn the theory of SPM in lecture and are then trained on the SPM and use it to investigate a sample of their choice. SPM in contact mode is the prime technique used in the undergraduate course. The graduate course allows students to utilize more advance modes of SPM and has lead to discoveries and publications in a variety of applications. These include magnetic memory damage, bearing surfaces wear, solder reflow and electrical insulation damage.

The graduate version of this course provides additional challenges. Graduate students enrolled in this course come from departments such as mechanical engineering technology, mechatronics and industrial technology. This requires additional background material to again insure all students have the basic knowledge to understand the material to be presented. Similar topics are covered at a much faster pace requiring the student to search for supporting material and apply it to their particular fields of study. The graduate students are held to a much higher standard for reports and testing. They also assist in developing new laboratory exercises for the undergraduate course to demonstrate the concepts learned.

Additional courses with emphasis on specific areas of nanotechnology are planned for the future to continue the development of our curriculum in nanotechnology. These include advance courses in SPM, nanoelectronic fabrication and testing, power, communications, and biotechnology. As well, students are able to gain further knowledge in nanotechnology through courses offered in a variety of colleges and departments throughout the university.

The development of a nanotechnology curriculum with the ECET department at Purdue University has had a major impact on the students who have elected to participate in the current courses. They have become aware of the opportunities this new field offers and begun to think of the impact they may have outside the traditional employers of ECET graduates. Throughout the spiral curriculum the concepts previously learned have been enhanced by the new knowledge gained in the study of nanotechnology. We are working diligently to increase the number of nanotechnology courses available to our students.

Summary

Curriculum development in the emerging field of nanotechnology requires a unique approach. The interdisciplinary nature of the subject combined with the cost of equipment and laboratory space along with the unknown biohazards associated with nanomaterials leads to nontraditional course material and laboratory exercises. This ECET department has approached nanotechnology curriculum development using the spiral curriculum to introduce freshman to the ideas of nanotechnology and introductory courses at the graduate and undergraduate levels. These courses emphasize the electrical aspects of nanotechnology and nanoelectronics. Laboratory exercises center around an instructional SPM and demonstration laboratories. Future course in specific areas of nanotechnology are planned. Curriculum development in nanotechnology has provided exciting opportunities to affect the overall curriculum of this ECET department.

References

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