AN INTRODUCTORY COURSE ON NANOTECHNOLOGY TO FOSTER CREATIVITY AND ENTREPRENEURIAL THINKING

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Abstract *¾ The field of nanostructure science and technology has been growing rapidly in the past few years. Since 1998, such an elective course has been offered annually in the Department of Electrical Engineering for seniors and first-year graduate students.*

The course is divided in three parts: (a) Nanofabrication, synthesis and assembly techniques, (b) nanostructure materials and devices, and (c) creativity and new product development. The discussions on parts (a) and (b) rely heavily on the two reports published on NSF's website on the National Nanotechnology Initiative (www.nsf.gov/nano). Only the basic concepts and design principles are formally discussed in class (e.g., quantum confinement effects, low-dimensional phenomena, nanoscaling laws, etc.).

In part (c), students are encouraged to consider design problems with real financial consequences in their class projects. A required section in the project report concerns the preparation of patent disclosure, a physical prototype design and drawing, and a production plan. The final project presentation is an executive briefing, in which they must consider financial viability of their new products, as will their marketing strategies.

The course is open to students from any department at the University and is designed to attract students from arts and science, management, law, as well as engineering.

Index Terms ¾ Creativitiy, nanotechnology, nanostructural materials and devices.

INTRODUCTION

Nanotechnology is an excellent subject for students to learn about the processing and fabrication of new structures at molecular level and the creation of new materials with fundamentally different properties. The course offers an opportunity for students to exploit the physical, chemical and biological properties by gaining control of structures and devices at atomic, molecular, and supramolecular levels and to learn engineering applications of these devices. The course is divded into three sections. First, the synthesis and assembly of nanoscale structures based on top-down and bottom-up approaches are covered. These include the discussions on such critical issues as the control of the critical dimensions, compositions and interfaces of nanocomponents. The interactive cycle of characterization, understanding and enhanced control in synthesis and assembly is used as a deliberate strategy for the development of new enabling nanotechnologies. The second section of the class identifies major application areas of nanotechnology, including electronic, magnetic, optical and biological systems. Special attention is placed on the potential commercial developments in telecommunications, energy, environment, and medical areas. The third section requires the students to complete a class project in which a nanotechnological product is to be marketed. The importance of creativity to successful marketing management is emphasized.

Nanofabrication, Synthesis and Assembly

New developments in nanofabrication tools (e.g., lithography, surface nanomachining and etching) are first discussed. Issues related to scaling laws and size-dependent properties of isolated nanostructures, as well as tools for characterization are identified for the advancement of the state-of-the-art nanotechnology. Considerable time is spent on the usage of scanning probe microscopies which have revolutionized the synthesis and assembly of nanostructures. The applications of older tools, especially electron microscopy, x-ray crystallography and NMR spectroscopy are also included.

While much has been accomplished in the top-down processing, work has only begun in the fabrication of nanostructured materials and devices by the use of self-assembly techniques based nanosized building blocks. Fundamental properties of isolated nanostructures, as well as the assembled structures, are systematically presented. The tightly-coupled iteration among characterization, understanding of structure/property relationships, and better control as shown in Figure 1 are used constantly to, define the process of new developments in nanotechnology.

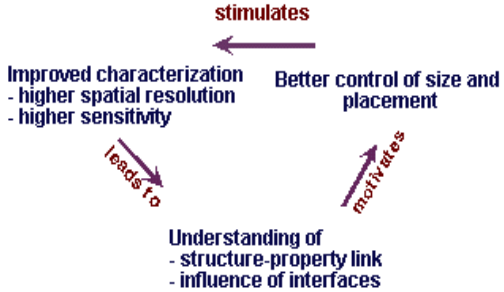

FIGURE 1.
PROCESS OF DEVELOPMENTS IN NANOTECHNOLOGY.

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Nanotechnological Applications

Four areas of applications are discussed in the course as shown in Figure 2. These are dispersions and coatings, high surface area materials, functional nanodevices, and consoladated materials. In each area, technological barriers and solutions are discussed for potential applications. Using functional nanodevices as an example, principles of single-electron devices (SEDs) are introduced theoretically, after brief discussions about the tunneling junctions and Coulomb blockade effects. Limitations of fabrication techniques for SEDs are reviewed based on their abilities for large-scale production. New information processing architectures, including quantum cellular automation, quantum computation, molecular electronics, and DNA based computation, and their implementations are explained in detail. Understanding the potential advantages and pitfalls of SEDs is enhanced by technical papers assigned as recording materials to students.

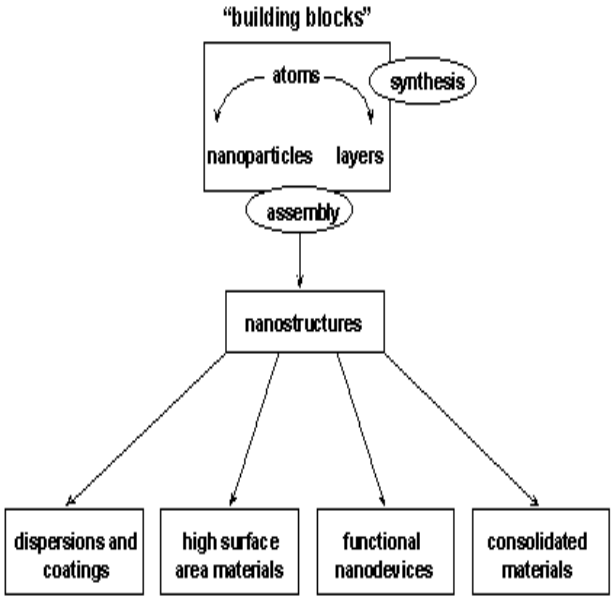

FIGURE 2.
RESEARCH AREA IN NANOTECHNOLOGY.

Creativity and Nanotechnology

The course starts with the introduction of 1959 Richard Feyhman's famous lecture on "There is plenty of room at the bottom". His vision on single-electron computation thirty years before it is experimentally demonstrated dramatically demonstrated the essence of creativity in science and technology.

To facilitate students in their course projects, ideas are generated for a product in nanotechnology. The objectives of this section of the course are:

- To help students understand the importance of creativity to successful marketing of a new product,
- To assist students understand obstacles to creativitiy and learn techniques for improving creative skills, and
- To provide opportunities for students to creatively apply nanotechnology to market a product.

The creativity strategy shown in Figure 3, is used by the Disney organization to illustrate a successful creative product requires the combined thinking from three very different viewpoints: The dreamer uses intention and feeling to respond to the overall problem, followed by the realist who develops the detailed step-by-step process to carry out the vision developed by the dreamer, and the critics act as the Devil's Advocats by constant asking questions to ensure the solution to the problem is competitive in the marketplace. Most of the course projects, which can be found in http://www-ee.eng.buffalo.edu/courses/ee550/index.htm, were able to find very creative solutions to difficult technical problems. Furthermore, they also demonstrate writing and presentation skills that directly benefit from creative thought and expressions.

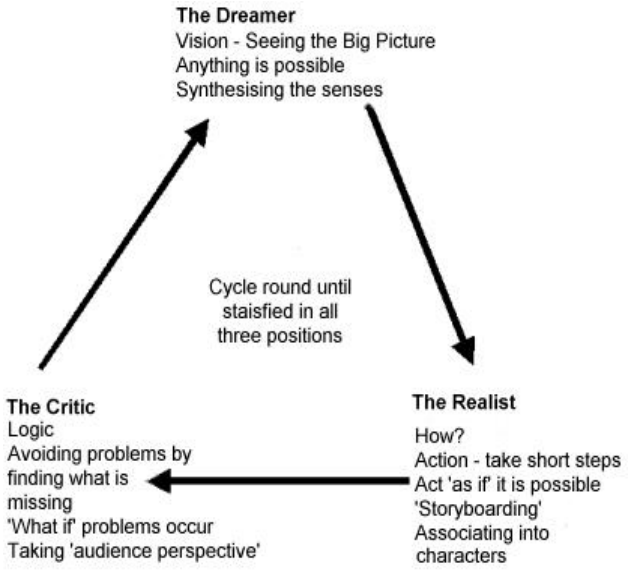

FIGURE 3.
DISNEY'S CREATIVE CYCLE.

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