AC 2008-2510: TEACHING BASIC NANOFABRICATION PROCESSING USING CORE FACILITIES

James Ejiwale, Jackson State University

Teaching Basic Nanofabrication Processing
Using Core Facilities

Abstract

Nanofabrication is "manipulating and assembling materials atom by atom" and it is used to create materials, devices, and systems with new and unique properties. This involves the application of nanofabrication processing equipment, devices and materials. It behooves industrial technology programs to prepare students with skills necessary to supervise and manage the workforce of any organization that desire to implement nanofabrication technology. This paper addresses the educational aspects of research facilities and nano-research clusters for nanofabrication processing at Jackson State University (JSU).

Introduction

Nanotechnology and its capability to control the structure of matter precisely at the molecular level of the nanoscale presently is being explored for innovation in industry and learning institutions. The new industrial revolution has made possible the modification of materials and devices. Therefore, it is essential to prepare the present and future workforce with the required technical skills and knowledge necessary to support the emerging field. It is also our goal to make highly technical knowledge of nanotechnology modeling, visualization and fabrication a "common knowledge" for middle school, high school and community college students.

What is nanotechnology?

According to the Encyclopædia Britannica[1] (2008), nanotechnology is defined as "the manipulation and manufacture of materials and devices on the scale of atoms or small groups of atoms." Nanotechnology is the creation of materials, components, devices and systems at the atomic or nanometer level. Given this structural modification, products designed and created with materials at this scale will perform exceptionally. Nanotechnology as a buzz word is currently viewed from two major perspectives, science and technology. From the scientific perspective, it concerns a basic understanding of physical, chemical, and biological properties on atomic and near-atomic scales. On the technological perspective, it employs controlled manipulation of these properties to create materials and functional systems with unique capabilities.

Given the need to prepare IT program graduates with skills necessary to function in the capacity of a technologist, manager or supervisor in any organization that desire to implement nanofabrication technology, the Department of Technology has proposed a nanotechnology modeling course to enhance nanofabrication processing experience in the industrial technology undergraduate program. Hands-on activities on this course will be enhanced through interdisciplinary nano-research clusters utilizing the research facilities in the College of Science, Engineering and Technology (CSET) where research has currently begun. This approach will help prepare and put our graduates at the forefront of employment in the new industrial revolution.

Knowledge sharing and management among departmental scholars

Since nanotechnology is highly interdisciplinary, relevant activities on this new industrial revolution at JSU has synergized many disciplines such as physics, chemistry, biology, mathematics, technology and engineering with focus on the strength of the participants. This has led to the development and implementation of research clusters across science, technology, engineering, and mathematics (STEM) or simply the STEM fields. The research clusters listed in figure 1 with their subgroups depict the interdisciplinary areas of strength of the participants. Though most of the subgroups listed under each research clusters are not currently used to enhance nanotechnology modeling instructional delivery but would definitely become an asset to the new masters of science in technology interdisciplinary degree under development with nanofabrication as one of the concentrations to be offered. The diversification of the scholars in their areas of expertise with varying background in the STEM fields has made possible knowledge sharing and management in this emerging field, nanotechnology. This new mindset would help to enhance major interdisciplinary activities through the following research clusters:

1. Applied Computational Sciences & Engineering/High Performance Computing
2. Environmental Science and Environmental Engineering
3. Nanoscale Sciences and Technology
4. BioMedical Research
5. Data Information, Security and Management

The research clusters provide a way for departments to organize instruction and student experiences around cluster broad categories that encompass virtually all disciplines from entry through professional levels. This is a combination of engineering, physical sciences, electrical engineering, physics, chemistry and even molecular biology, and many more in STEM fields. Knowledge about manufacturing and product development--how to take technology and turn it into a product is essential. This led to the development of nanotechnology modeling and fabrication by a team of researchers at Jackson State University (JSU) led by James Ejiwale, a technology professor who now heads the Ronald Mason Jr. Nanotechnology Modeling Center (RMNMC) based at the School of Science and Technology at JSU. The center is one of many JSU initiatives to gain ground in nanotech education and research. The RMNMC is to support the teaching of ITMF 420 – Nanotechnology modeling, Fabrication/Rapid Prototyping course that has just been reviewed and modified to help inform and prepare majors in the industrial technology program in the department of technology and students across STEM fields with the knowledge and skills of nanotechnology design, modeling, visualization and fabrication process. Activities in this course includes training students to use two design software for modeling and design of nanotubes and the use of the SST 1200 3 – D Rapid Prototyping Printer to produce scaled 3 – D synthetic material models from three dimensional drawings and file.

Cluster	*Cluster Subgroups*
Applied Computational Sciences & Engineering/High Performance Computing – This cluster investigates High Performance Computing Modernization	Computational Nanoscience, Molecular Electronic Structure/Computational Quantum, Chemistry Computational Engineering & Technology, Bioinformatics/ Genomics
Environmental Science and Engineering – This cluster conduct research on today's environmental problems and appropriately disseminating research findings.	Bio-Phyto Remediation, Environmental Toxicology/ Envionrmental Chemistry, Environmental Impact Assessment, Environmental/Atmospheric Science/Observations, Industrial Waste Management/ Landfill Technology, Biomass/ Alternative Fuel/Renewable Energy, and Environmental Genomics
Nanoscale Sciences and Technology This cluster investigates interactions between noble metal, magnetic and organic nanostructures for developing new sensors; modeling visualization; experimentally developing suitable nanomaterials for the construction of integrated optic chemical sensors	Computational Nanoscience, Nanofabrication, visualization modeling, Nanophotonics, Nanosensors, Synthesis and Characterization, and Applied Material Science
Data Information, Security and Management – This cluster conduct research on nanostorage, nanoRFID, computer forensic and data security	Information Assurance and Computer Security, Information and Intelligent Systems Data, Information, Modeling and Visualization

Figure 1. Research Clusters and their subgroups

Similarly, Dr. Wilbur Walters of the Department of Physics, Atmospheric and Geosciences at JSU with a research interest in the development and characterization of novel advanced materials, focusing on thin films, coatings, and nanostructured materials has developed an undergraduate nanoscience curriculum (Introduction to Nanoscale Science). This course aims at enhancing student learning and research opportunities that relate to real-world applications and the use of state-of-the-art instrumentation (Walters[3] 2005). In addition, this course is meant to introduce undergraduate students to nanoscale processing and analysis techniques in the classroom. Through three consecutive NSF grants for Nanoscience Undergraduate Education (NUE) Walters has acquired four Nanosurf Scanning Probe Microscopes (SPMs), two Atomic Force Microscopes (AFMs) and two Scanning Tunneling Microscopes (STMs). This will enhance the teaching of principles of nanoscience and applications to aid hands-on processing laboratories, interactive microscopy learning experience and early research experiences at every level of the curriculum.

Most importantly, majors from the Department of Technology will benefit from the existing cross-teaching with the Department of Physics, Atmospheric and Geosciences that offers students a wide range of opportunities in materials processing, the use of advanced instrumentation, and exposure to cutting-edge topics in nanoscience. Experience using the AFM and STM tools has proven to be a valuable preparation for entering these other research arenas, as shown by feedback from various internship sponsors. Similarly, topics in nanoscale science and other cutting edge research are presented in a weekly seminar series and each semester the seminar features a number of presentations by outside speakers, and a forum where students present their research projects. Through this media, students from the Department of Technology taking ITMF 420 are required to participate in the lectures and seminars series to enhance the hands-on application of the AFM and STM tools as a partial fulfillment of the course.

Utilization of the core laboratories and facilities at JSU

The core laboratories and facilities at JSU provide researchers with adequate resources such as equipment, technologies, and support functions to enhance research capabilities and for instructional delivery on basic nanofabrication technology. Currently, cross-teaching is in existence among faculty members from Departments of Technology and Physics with the utilization of some of these facilities and laboratories to enhance nanofabrication hands-on experience. Some of the major laboratories and facilities are:

1) The Ronald Mason Jr. Nanotechnology Modeling Center (RMNMC)
2) Nanoscience Core Laboratory
3) Molecular Magnetic Resonance Core Laboratory
4) The Computational Modeling Core Laboratory/Supercomputer Center
5) The Visualization Core Laboratory
6) GIS Remote Sensing Laboratory.

Utilizing the existing core laboratories and facilities to enhance basic nanofabrication technology at JSU requires participating faculty members:

- To be able to explain concepts in physical science to both non-experts and experts acquiring knowledge of nanoscale science and technology with more emphasis on the "know how"
- To help set the directions and priorities of the use of core facilities to aid further research activities in nano-science and technology
- To facilitate learning by gaining experience in advanced micro- and nano-fabrication methods as applicable STEM fields
- To assist national users working on their nanofabrication projects in the core facilities
- To establish and maintain baseline fabrication processes as well as introduce and develop advanced process methods and train users in these methods.
- To support the mutual needs of business, industry, and academia by providing mechanisms for technical exchange and collaboration.

Given the aforementioned as laid down in the CSET at JSU, there is a need to develop a new academic program aimed at a commitment to undergraduate and graduate teaching in the emerging field. Currently, a new masters of science in technology degree (interdisciplinary curricula) to be offered at Jackson State University will serve as the pathway to an education in nanotechnology with nanofabrication as one of the concentrations. Therefore, there is a further need to hire individuals with demonstrated excellent research potential, teaching ability, with relevant industrial experience and expertise in the sub group areas.

Summary

Nanofabrication as the new industrial revolution has come to stay. Partnership among scholars from various departments (cluster groups) in the university will enable further knowledge sharing with effective cost saving in the preparation of the future workforce for the exciting field of nanotechnology. The masters of science degree in technology to be offered at JSU will serve as the pathway to an education in nanotechnology with nanofabrication as one of the concentrations. Given the fact that the equipment needed in any nanotechnology facility is expensive, the utilization of core laboratories and facilities could serve as the appropriate starting point.

Acknowledgements

This work is made possible through resources provided by the College of Science, Engineering and Technology (CSET) web site on research clusters at Jackson State University**.**

References

1. Nanotechnology. (2008). In *Encyclopædia Britannica.* Retrieved January 17, 2008, from Encyclopædia Britannica Online: http://www.britannica.com/eb/article-9384821.

2. Van, J. (2002, June). Racing toward a nanotechnology industry: Purdue facility to link scientists and entrepreneurs. The Chicago Tribune.

3. Walters, W. (2005). Nanoscience Education. Retrieved February 12, 2008, from http://www.nanoscience.com/education/profiles/Wilbur_W/WW-1.html

Appendix A:

Sample Course syllabus of Nanotechnology modeling, fabrication/rapid prototyping.

Course number: ITMF 420
Course Title: Nanotechnology Modeling, Fabrication/Rapid Prototyping

Course Description: A developmental analysis of nanotechnology fabrication developments with a focus on nanoparticles modeling, nanoscale devices, production techniques, rapid prototyping, and their interdisciplinary applications in various industrial fields such as material science, manufacturing, physical sciences, and electronic technology.

Course Rationale: This course is an introductory nanotechnology course, aimed at preparing students for further industrial or academic work in the field of nanotechnology fabrication. It helps graduates identify and subsequently advance their future interests either in research in new generation nanoscale device fabrication techniques or technical positions in manufacturing, quality control, sales and marketing of technical products.

Course Objectives: The course content has been structured to help the student achieve the following objectives:

1. To identify and develop a career path in the multidisciplinary field of nanotechnology.
2. To gain understanding of the principles of nanotechnology; characterization of nanostructured materials; imaging and manipulation techniques, and tools and equipment for producing and assembling at the nanoscale.
3. to provide training and experience in the utilization of scanning probe microscopy in a variety of modes.
4. To familiarize students with mechanical testing at the nanoscale
5. To appreciate the commercial potential of nanotechnology and the required ethics for its development, application and exploitation.
6. To engage students in micro/nanotechnology research through a final project consisting of the design of a novel lab experiment for future advancement.

Required Textbooks:

Ratner, D. & Ratner, M. (2003). *Nanotechnology: A gentle introduction to the next big idea.* New Jersey: Pearson Education Inc.

Additional Reading:

Nicolini, C. (1996). *Molecular manufacturing*. New York: Plenum Press.

Course Content:

- Introduction to Nanotechnology, History and Future
- Introduction to Nanodevices
- Visualization & Modeling of Nanostructures
- Introduction to Design and Modeling Tools & Software
- Introduction to AFM, SPM and STM