Session 3464

Materials Engineering Education for the New Millennium

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Abstract

Advances in engineering design have tested the limits of performance of traditional materials. Developments in design can only be implemented suitable high performance materials are developed in lock step. Engineering students of all disciples must be provided a sound training in materials engineering beyond the scope of traditional materials. A new research center on campus, devoted to advanced materials and smart structures, has enabled instructors to utilize state-of-the-art research facilities, tools and personnel to enrich the classroom learning experience. The authors describe how their department's undergraduate mechanical engineering curriculum is gradually being shaped to provide students with the necessary tools and information to understand, deploy and develop the materials of the new millennium.

Introduction

"Advanced materials are the building blocks of technology"[1]. Engineers of the next millennium, need to be aware that advances in design are starting to be limited by the performance of traditional materials. The development of advanced materials has been the enabler of never-before imagined performance. Electronic semiconductor-based circuits have been made much faster by gallium arsenide; fiber optics have made international communications cheaper and faster, and the development of heat-shielding ceramic tiles[2] have enabled the Space Shuttle to safely re-enter earth's atmospheres braving surface temperatures exceeding 1600 °C - far beyond the scope of any metal used in airframes. Materials science has justly earned its position as an important cross-disciplinary cornerstone of the engineering curriculum.

Many materials curricula within mechanical engineering tend to concentrate more on metallic materials because of their traditional use in machine design. The department's research focus on advanced ceramics, polymers and novel engineered composites affords undergraduate students a unique opportunity to be exposed to the state-of-the-art in terms of the applications and science of non-metallic materials. The growth of the research programs led recently to the formation of an NSF CREST Center for Advanced Materials and Smart Structures (CAMSS).
In the past two years, CAMSS has generated considerable infrastructural support for the development of undergraduate curricular content and for the training of a qualified pool of potential graduate students and researchers in materials science and engineering. This paper discusses the nominal structure of the curriculum, as well as the role of CAMSS in providing in-class and extramural opportunities for students to observe and participate in the exploration of advanced materials.

Materials Content of the Mechanical Engineering Curriculum

The curriculum aims to cover all four corners of the materials tetrahedron shown in Figure 1. It is supported by a sophomore level basic materials science course, a junior level manufacturing processes course, two laboratory classes and is capped with a senior level course in materials engineering. In addition, there are some technical elective courses in which the students are exposed to advanced materials. These are listed in Table 1 below.

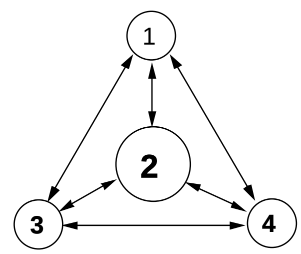

Figure 1
Materials Tetrahedron[1]

1. Advanced Processing
2. Materials Characterization
3. Modeling and Simulation
4. Properties, Performance and Device

Table 1 Materials-related courses[3]

Course #	Name	Coverage of Materials
ME 260	Materials Science	Fundamentals of physical, mechanical and chemical characteristics of materials
ME 300	Mech. Engr. Lab I	Materials processing and destructive testing of materials
ME 400	Mech. Engr. Lab II	Heat treatment and non-destructive testing of materials
ME 446	Manufacturing Processes.	Interaction between manufacturing processes and material properties
ME 560	Modern Engineering Materials	Role of materials in modern engineering practice, ferrous and non-ferrous materials systems and applications, selection and design
ME 645	Aluminum Based Part Design and Manufacturing	Materials and process design

ME 670	Internal Combustion Engines	Effect of coatings on engine wear performance and on emissions

As can be seen, even though there are only two courses explicitly labeled as materials courses, several other courses touch upon various aspects of the fundamentals of materials behavior and their selection for specific applications. The course, Modern Engineering Materials (ME 560) goes beyond discussing traditional topics such as mechanical properties, heat treatment and strengthening mechanisms for metallic alloys. About half the course is spent delving into the principles and applications of ceramics, polymers and their composites. Students are given overviews of various design considerations in selecting various materials systems including smart materials and other non-traditional engineered ceramics. The rest of this paper discusses how the classroom experiences are augmented with resources gleaned from the CAMSS center's research activities, both on-campus and through its major partner institutions, namely Oak Ridge National Laboratory and the Materials Science program at NC State University.

Background and Mission of CAMSS

CAMSS recently entered the 2nd year of its 10-year funding duration. It currently involves 15 faculty members at NC A&T State University from Mechanical Engineering, Electrical Engineering and Physics; three research scientists and three staff members. The Materials Science Department at NC State University is a partner institution in this Center and shares facilities with A&T. As stated in its vision statement, the Center aims to be an educational and research resource for the state of North Carolina and the nation in the field of advanced ceramic materials and their composites, through the collaboration of academe, private industry and the government in developing basic and applied research programs with a focus on student participation and learning.

The Center houses over $3.5 M in sophisticated research and test equipment. Table 2 lists some of the major facilities/laboratories under the NSF-CREST/CAMSS umbrella. Each facility is fully equipped with state-of-the-art instrumentation. A detailed listing of all equipment can be accessed through the Center's Web-site[4]. These facilities are available to all faculty and students and to the broader scientific community at large. Significant research equipment acquired recently includes a variable-pressure SEM and accessories, EDS system, C-Scan, nanoindentor, 4-point bending test machine with high temperature accessories. Equipment to be acquired for the research facility in the near future includes a plasma spray based thermal barrier coating synthesis facility, modifications to the existing combustion synthesis coating system, HIPing equipment, a laser joining system, photoluminescence and HiRes X-Ray attachment.

Table 2 CAMSS facilities

NC A&T State University	NC State University

• Mechanical Testing Lab • High-Temperature Materials Lab • Nanoindenter Facility • Microscopy and Sample Preparation Lab • Electron Microscopy / EDS Lab • NDT Facility • Diesel Combustion Lab • Coatings Synthesis Lab • Manufacturing Lab • Instrumentation and Controls Lab • Structural Mechanics & Control Research Lab • Electronic Materials Characterization Lab • Optics and Fiber-Optics Lab • Rockwell Solid-State Lab	• Laser & Optical Processing & Manufacturing Center • Laser Processing Lab • Materials Preparation/Characterization Lab • Measurements Lab • Bulk Processing Lab • Optical Characterization Lab • NSF – Ultra-High Resolution and Analytical TEM Center • Facilities of NCSU/MCNC Research Complex

The Center's facilities and staff have served leverage the intellectual and research potential of over 29 BS, 27 MS and 25 Ph.D. students in the last two years. Many of the undergraduates were influenced by the Center not only through their course curricula but also through research participation fellowships at A&T, NC State University and the Center's partnering and collaborating institutions: Oak Ridge National Lab, the University of Florida's Engineering Research Center, and other universities including Kumamoto University of Japan.

Fostering Interest in Materials Engineering Career

Research results are being transported to the curriculum through:

- incorporation of new lab experiences into related undergraduate lab courses
- development and modification of both existing and new curricula based upon an integrated approach of advanced materials development involving materials processing, characterization and modeling
- design of graduate courses and graduate options in smart materials and advanced structures.

Specifically, a cluster of courses from the existing course offerings has been identified for undergraduate and graduate students who can specialize in the advanced materials areas including the processing, characterization, modeling and testing of smart materials and devices. Faculty members are working collaboratively to enhance courses that transcend traditional departmental and institutional barriers. These courses, listed in Table 3, emphasize synthesis and processing, atomic level characterization, structure-property correlation and modeling. These activities are yielding a framework for further interdisciplinary research participation by students and faculty. Some courses will be team taught by researchers from NC A&T SU, NCSU and ORNL. The State of North Carolina's distance learning network has enabled courses originated at NC A&T State University and NC State University to be offered at remote sites.

Table 3 Materials Courses at CAMSS Institutions Targeted for Enhancement

NC A&T SU	
Mechanical Engineering 1. MEEN 400/500, Mech Engr Lab II & III 2. MEEN 446, Manufacturing Processes 3. MEEN 560, Modern Engineering Materials 4. MEEN 570, Internal Combustion Engines 5. MEEN 614, Engineering Modeling 6. MEEN 646, Adv. Manufacturing Processes 7. MEEN 650, Mechanical Properties and Structure of Solids 8. MEEN 716, Finite Element Methods	Electrical Engineering 1. ELEN 325, Principles of Electro-Magnetics 2. ELEN 470, Properties of Materials of EE 3. ELEN 602, Semiconductor Theory and Devices 4. ELEN 706, Semiconductor Material and Device Characterization 5. ELEN 707, Compound Semiconductor Material and Devices 6. ELEN 786, Electronic Ceramics
NCSU	
1. MAT-751 and 752: Thin Films I and II 2. MAT-760, Materials Science and Processing of Semiconductors	3. MAT-770, Defects, Diffusion and Ion Implantation in Semiconductors 4. MAT-792, Advanced Materials and Smart Structures

Research Experience for Undergraduate Students (REUs)

One of the strongest educational experiences an undergraduate can be offered is involvement in front-line research and this is most fruitful method in directing them into successful graduate study. In our summer undergraduate research program, qualified undergraduate students are being paired with graduate students to receive training in one of the thrust areas. This REU program is creating an atmosphere that can lead them to graduate studies in advanced materials and smart structures. The research projects are selected to provide a larger team atmosphere. Thus, while the undergraduate students work closely with a designated graduate student, other graduate students, postdoctoral fellows and faculty advisors aid in the development of the undergraduate researchers.

Student Participation

In addition to classroom activities and summer REUs, undergraduate students are encouraged and sponsored to attend on campus materials society dinner meetings where they are exposed to industry perspectives on modern material applications, opportunities and challenges. Several of the students also choose to perform undergraduate research work with the materials research centers and gain a deepened appreciation of the field. There is concrete evidence that this has motivated significant numbers of students interested in graduate study to choose materials as their area of specialization. The success of the current national efforts to revitalize engineering, science, and technology depends on the continued collaboration of a number of communities, including industry, K-12 school systems, community colleges, universities, government at all levels, and the public. The Center is acting to facilitate such collaborative efforts and this is expected to result in a multiplying effect - impacting the futures of many budding scientists from diverse backgrounds

Acknowledgments

The authors wish to acknowledge the continuing support of Oak Ridge National Laboratory, the National Science Foundation's CREST Program and of several other governmental, academic and industrial partners.

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3. Mechanical Engineering Undergraduate Student Handbook 1998-99, NC A&T State University, Greensboro, NC.

4. CAMSS Web site: http://www.ncat.edu/~camss

Biographical information

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