PROPOSAL FOR THE ESTABLISHMENT
OF AN
UNDERGRADUATE CERTIFICATE
IN
MATERIALS SCIENCE AND ENGINEERING

AT THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF PUERTO RICO, MAYAGUEZ

SUBMITTED BY
DEPARTMENT OF GENERAL ENGINEERING
UPRM – FEB 2004
1. BACKGROUND

Material issues are quickly becoming the most vital part in engineering design and analysis. New materials are being sought for microelectronic packages, biomedical applications, superconducting films, spintronics, tool bit materials, cutting tools, fuel-efficient engines, etc. Furthermore, today's materials engineers, scientists and designers need to understand the unique world delimited by nanomaterials technology to successfully apply it to their own product research and development. Different principles of chemistry, physics and biology apply at the nanoscale level. Property interactions such as thermodynamics, kinetics, magnetic, adhesion, deformation, electronic and optical characteristics suffer substantial change at the nanometer scale.

Many engineers and scientists graduates do not have a sufficient materials background to answer the needs of industry. Many industries are facing the task of designing with new materials, selecting alternate materials or processing new materials. In addition, industry professionals' knowledge of the science and its evolving applications must remain up-to-date, which means they need access to career-long learning opportunities. Due to these needs and in compass with the targets sets by the engineering faculty approved Graduate Program in Materials Science and Engineering; the Department of General Engineering at University of Puerto Rico at Mayaguez (UPRM) is seeking to offer a Certificate in Materials Science and Engineering at the undergraduate level.

This certificate is designed to provide engineers with a concentrated focus on the topic of advanced materials synthesis, characterization and processing. It consists of engineering undergraduate and some graduate courses aimed at engineers and scientist who want to learn advanced characterization techniques, functional materials synthesis and processing techniques, materials transformations, nanostructured materials, etc.

With graduate committee approval, graduate students in other specialties may include some courses given in the MSE certificate as part of their study plan. Undergraduate students can enhance their knowledge in this area without seeking a graduate degree, and simultaneously build a strong foundation for a master's degree at a future date.

In summary, the goal of this program is to establish a set of integrated materials-related courses specifically designed for engineers who do not have a formal education in materials in order to increase their marketable skills and to develop a cross-disciplinary approach to problem solving. The program emphasizes the multidisciplinary nature of the study of materials and the engineering application of their properties.

2. GOALS & OBJECTIVES

The objectives of the Certificate in Materials Science and Engineering are the following:

A) provide students with a structured program for the study of materials-related topics and give them the theoretical foundation and practical knowledge needed to function in the rapidly developing field of modern materials.

B) induce and prepare students towards graduate degree programs with emphasis in Materials Science and Engineering.

C) develop student’s knowledge and skills that will help them to compete for job positions in materials-related industries.
D) contribute to the Puerto Rican society by setting up the basis for the implementation of emerging technologies and asserting students ties with the University.

3. ADMISSION REQUIREMENTS
Prior to starting work on a certificate, students must have completed at least two years equivalent of college credits in mathematics, chemistry, physics and/or engineering and they must have approved not less than 60 credits towards their engineering degrees.

To participate in the certificate program the student must fill out the application form and obtain the approval of the Program Coordinator. All applications forms must be submitted before deadlines of admission (suggested as the same deadlines for Graduate Admission).

Students working toward the certificate must have been admitted to the University of Puerto Rico, Mayaguez as undergraduate student or as a graduate student. All students must meet the minimum GPA admission requirement of 3.0 or higher to enroll in 5000 or higher level courses for the certificate.

4. STUDY PROGRAM
To be awarded the program certificate, the student must complete the following:
(a) all the graduation requirements of his/her discipline with a GPA of 3.0 or higher.
(b) twelve credits of certificate core courses,
(c) six credits of elective courses as recommended by the certificate program.
(d) achieve a GPA of 3.0 or higher in the certificate program courses.
(e) the student must earn at least a C or better in each of the certificate courses.

Usually of the 18 credits required for the certificate program, a maximum of 6 credits might be included in the student graduation requirements for his/her discipline. These courses should conform to the recommended electives courses set by the certificate program. Each engineering department has its own regulations on program curricula and elective courses.

The Materials Science and Engineering certificate requires a minimum of 9 core credit hours of theoretical and applied materials courses. The Materials Science and Engineering Certificate is designed to provide students with an opportunity to gain a focused introduction into a dynamic and explosively growing technological field. The certificate has been designed to be as flexible as possible thus allowing students from different disciplines to take advantage of the program. Enrollment is through the Department of General Engineering.

5. COURSES
To accomplish the stated goal, a set of key courses has been developed which are to be taught by a carefully selected team of highly qualified instructors representing many years of experience in materials research and industry. The program conforms to rigorous academic standards, as set by ABET, while providing knowledge of immediate applicability. The program has been designed to be completed within the span of two and a half academic years (five semesters).

The courses in the Materials Science and Engineering certificate program span a comprehensive spectrum of materials technology. The program includes:
In-depth study of alloy microstructures and their control through processing;
Examination of the principles and characteristics of the most commonly used processing and fabrication methods;
Thorough description of methods and techniques used in the analysis and assessment of mechanical performance under various conditions; and
Detailed study of engineering issues involved in the production, characterization and performance of materials.

On completion of the program, students will have the necessary know-how to actively and intelligently contribute to decision making processes involving the production and use of a wide variety of materials for different industry applications and integrating technical skills with business knowledge.

Courses for the certificate program will be taught by the organizing and affiliated faculty. These include four core courses in Introduction to Solid State Materials Science, Fundamentals of Advanced Materials, Laboratory Techniques in Materials Science and Engineering and Nanostructured Materials: Synthesis and Processing.

5.1 CORE COURSES
The following is the list of core courses available for the student. A minimum of three of these courses should be taken by the students pursuing a Certificate in the Materials Science and Engineering Program:


**INGE 5MNT: Micro and Nanotechnology** (3 credits) - This is an introductory course to the science and engineering of micro and nanotechnology. The course begins with the present micro and nanofabrication approaches. This is followed by the review of the materials issues at the micro and nanoscale. Subsequently, the fundamentals of micro and nanomechanics will be introduced before describing a range of micro- and nanodevices that include: sensors and actuators, mechanical, optical and thermal transducers and fluidic devices and systems

All the above core courses are new and will be opened at the 5000 level. The appendix A shows the topics and anticipated syllabus.

### 5.2 Elective Courses

Advanced undergraduate and graduate courses that may be used to satisfy program requirements are listed below. The actual courses selected for a coherent program of study will be determined by the program adviser based on the student’s inclination and major field.
**QUIM 5165 Polymer Chemistry:** Structure, properties, synthesis, reactions, and physical behavior of polymers. Experimental methods used in their analysis.

**FISI 5037 Introduction to Solid State Physics:** Introduction to X-ray diffraction, crystal structures, lattice energy and vibrations, thermal properties of solids, electrical and magnetic properties, free electron models of metals, superconductivity, photoconductivity and luminescence.

**INME 5008 Corrosion:** Electrochemical principles and corrosion mechanism; protection and prevention of corrosion in metals; the effects of temperature, environment, and metallurgical factors.

**INQU 5036 Particulate Systems:** Creation, characterization, separation and agglomeration of particles. Sizing fractionization of powders, surface area and pore size determination. Pulverization, crystallization, agglomeration, tableting and granulation.

**INQU 4016 Plastic Technology:** The properties, production and fabrication of natural and synthetic resins and polymers of industrial importance.

**INME 5018 Materials Failure Analysis:** Materials science concepts are used to identify, correct and prevent failure due to the improper use of materials or to problems in manufacturing processes. In depth study of failure mechanisms such as fatigue, wear, creep and corrosion.

**INEL 6055 (FISI 5011) Introductory Solid State Devices:** Solid state devices, dielectric, optical and magnetic properties of materials. Crystal structure and transport phenomena.

**INEL 6075 Solid State Device Fabrication and Technology:** Fabrication of solid state devices and integrated circuits, MOSFETs and microwave devices will be emphasized. Properties of materials such as, silicon and GaAS, lithographic process.

**INME 6015 Dislocation Theory:** Theory of dislocations in isotropic and anisotropic continua; dislocation reactions; the relation of theory to observed dislocation configurations.

**INME 6030 Mechanics of Composite Materials:** Anisotropic elastic materials; stress analysis for isotropic materials. Strohs formalism for anisotropic materials, singularities at free edges, stress analysis in composites, wave propagation in composites.

**INME 6009 Advanced Manufacturing Processes:** Developments in the removal and deforming processes of materials. Applications of these processes to hard, brittle, conducting and non-conducting materials.


**INCI 6023 Analysis of Structures of Composite Materials:** Study of composite materials related to civil engineering applications.

**INCI 6064 Advanced Concrete Technology:** Microstructure, physical and mechanical properties of concrete; fiber cementitious composites; fiber-reinforced shotcrete; fiber-reinforced plastics.

**INCI 6057 Theory of Elasticity:** Bending of prismatic bars subjected to axial and lateral loads; bucking of compression members on the elastic and inelastic ranges.
**INCI 6018 Finite Element Analysis II:** The finite element method and its application in the analysis of structures with elastic and non-linear behavior; solution of unitary stress and strain problems in flexion of plates, thin and thick shells, axisymmetric shells, and solids.

### 6. Educational Approach

The certificate program will educate students with the range of skills inherent to engineering graduates as indicated by the Accreditation Board of Engineering Technology Criteria 2000. These criteria establish that the engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering  
(b) an ability to design and conduct experiments, as well as to analyze and interpret data  
(c) an ability to design a system, component, or process to meet desired needs  
(d) an ability to function on multi-disciplinary teams  
(e) an ability to identify, formulate, and solve engineering problems  
(f) an understanding of professional and ethical responsibility  
(g) an ability to communicate effectively  
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context  
(i) a recognition of the need for, and an ability to engage in life-long learning  
(j) a knowledge of contemporary issues  
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

To these, we will add the following abilities and or skills:

- a capacity to understand and apply modern scientific principles;  
- skills in the retrieval and presentation of scientific information both orally and in writing to scientific and non-scientific audiences;  
- proficiency in critical analysis of information and capacity to solve problems;  
- an ability to analyze and evaluate numerical data;  
- competence in the practical use of relevant computer and information technology;  
- an ability to work effectively in a team;  
- an understanding of the ethical issues through the study of science  
- an appreciation of the role of science in society;

To develop these abilities and skills the students will participate in video conferences, make their own presentations in power point, publish their materials presentations in the program web-portal, and when the opportunity arises, they will participate in summer undergraduate research programs offered by materials departments in US mainland.

### 7. Budget

For the certificate program in materials science and engineering the following expenses:
<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library resources (Videos &amp; Multimedia)</td>
<td>$6,400</td>
</tr>
<tr>
<td>Plasma Unit for Video Conference Equipment</td>
<td>$8,200</td>
</tr>
<tr>
<td>Sponsoring Student Association to the American Society of Materials (ASM)</td>
<td>$1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$15,600</strong></td>
</tr>
</tbody>
</table>

8. BUDGET JUSTIFICATION

*Library Resources ($6,400):*

As the Certificate in Materials Science is depends on highly developed visualization tools the following library resources are necessary:

<table>
<thead>
<tr>
<th>Title and Type</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazing Materials: Properties of Matter: VHS</td>
<td>$119.00</td>
</tr>
<tr>
<td>Engineering Materials: CD-ROM</td>
<td>$129.00</td>
</tr>
<tr>
<td>Composites: Properties, Processing, and Uses: VHS</td>
<td>$139.00</td>
</tr>
<tr>
<td>Ceramic Science: VHS</td>
<td>$169.00</td>
</tr>
<tr>
<td>American Steel: Built to Last: VHS</td>
<td>$99.00</td>
</tr>
<tr>
<td>Mechanical Testing of Materials: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Mechanical Properties and Their Measurement: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Elasticity Theory for Advanced Composites: VHS</td>
<td>$259.00</td>
</tr>
<tr>
<td>Fundamentals Tension and Compression Testing: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Materials Engineering: VHS</td>
<td>$250.00</td>
</tr>
<tr>
<td>Materials Science a Multimedia Approach: CD-ROM</td>
<td>$119.00</td>
</tr>
<tr>
<td>Types of Failure and Stresses: VHS</td>
<td>$119.00</td>
</tr>
<tr>
<td>New Alchemist: VHS</td>
<td>$169.00</td>
</tr>
<tr>
<td>Solidification of Metals: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Physical Metallurgy: Structure and Properties: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Heat Treatment of Carbon Steels: VHS</td>
<td>$199.00</td>
</tr>
<tr>
<td>Diamond Makers: VHS</td>
<td></td>
</tr>
<tr>
<td>Nanotopia: VHS</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$108</td>
</tr>
</tbody>
</table>


*The Structure of Materials;* Samuel M. Allen, Massachusetts Institute of Technology; Edwin L. Thomas, Massachusetts Institute of Technology; (Book), ISBN: 0-471-00082-5 ©1999

<table>
<thead>
<tr>
<th><strong>Introduction to Nanotechnology</strong>: Charles P. Poole, Frank J. Jones, Frank J. Owens: Book</th>
<th>$79.95</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental Design for Combinatorial and High Throughput Materials Development</strong>: James N. Cawse (Editor); ISBN: 0-471-20343-2; Hardcover; 336 pages; January 2003</td>
<td>$100.00</td>
</tr>
<tr>
<td><strong>Transmission Electron Microscopy: A Textbook for Materials Science (4 volumes)</strong> by David B. Williams, C. Barry Carter</td>
<td>4x$75.00</td>
</tr>
<tr>
<td><strong>Molecular Devices and Machines: A Journey into the Nanoworld</strong>: Vincenzo Balzani, Alberto Credi, Margherita Venturi: Book</td>
<td>$120.00</td>
</tr>
<tr>
<td><strong>Nanostructures</strong>: A Synthesis, Properties, and Applications by A. S. Edelstein (Editor), R. C. Cammarata: Book</td>
<td>$70.00</td>
</tr>
<tr>
<td><strong>Nano-Optics</strong>: Satoshi Kawata, Masahiro Irie (Editor), Motoici Ohtsu (Editor)</td>
<td>$74.95</td>
</tr>
<tr>
<td><strong>Nanostructured Materials and Nanotechnology: Concise Edition</strong>: Hari Singh Nalwa (Editor): Book</td>
<td>$152.95</td>
</tr>
<tr>
<td><strong>Characterization of Nanophase Materials</strong>: Zhong Lin Wang (Editor)</td>
<td>$220.00</td>
</tr>
<tr>
<td><strong>Quantum Wells, Wires and Dots: Theoretical and Computational Physics</strong>: Paul Harrison, P. Harrison</td>
<td>$250.00</td>
</tr>
<tr>
<td><strong>Phase Equilibria, Phase Diagrams and Phase Transformations: Their Thermodynamic Basis</strong> by Mats Hillert (Book)</td>
<td>$55.00</td>
</tr>
<tr>
<td><strong>Phase Transformations in Materials</strong> by Gernot Kostorz (Editor) (Book)</td>
<td>$330.00</td>
</tr>
<tr>
<td><strong>Fundamentals of Semiconductors: Physics and Materials Properties</strong> by Peter Y. Yu, Manuel Cardona (Book)</td>
<td>$60.00</td>
</tr>
<tr>
<td><strong>Physics of Semiconductor Devices</strong> by Simon M. Sze (Book)</td>
<td>$115.00</td>
</tr>
<tr>
<td><strong>Introduction to Diffraction in Materials Science and Engineering</strong> by Aaron D. Krawitz (Author) (Book)</td>
<td>$115.00</td>
</tr>
<tr>
<td><strong>Electron Backscatter Diffraction in Materials Science</strong> by Adam J. Schwartz (Editor), Mukul Kumar (Editor), Brent L. Adams (Editor) (Book)</td>
<td>$97.00</td>
</tr>
<tr>
<td><strong>Computational Materials Science: From Ab Initio to Monte Carlo Methods (Springer Series in Solid State Sciences, 129)</strong> by K. Ohno, K. Esfarjani, Yoshiyuki Kawazoe (Book)</td>
<td>$120.00</td>
</tr>
</tbody>
</table>

*Sponsoring Student Association to the American Society of Materials (ASM) and Participation in Conferences ($1,000)*

Students that joint the American Society of Materials (ASM) will participate in conferences. A total of 4 students at $600 per participation has been budgeted in this program plus $400 destined to support the joining of students to the above association.

*Plasma Unit for Video Conference System ($8,200)*
The implementation of the video conference room is needed for lectures in materials science. Remote lectures are being arranged with The Boeing Co., RPI, Princeton University, etc. The acquired system consists on POLYCOM VSX 7000 with POLYCOM VISUAL CONCERT VSX, POLYCOM VSX Embedded Multipoint Software, POLYCOM VSX Second Display Adapter, POLYCOM Microphone and a Document Camera. A Plasma Unit for Video Conferencing is needed to complete the system.

9. EDUCATION AND INDUSTRY PARTNERSHIP

In education, partnership is being sought with the Department of Materials Science and Engineering at Rensselaer Polytechnic Institute and with the Princeton Institute of Materials at Princeton University. It is expected that some of the courses of the Undergraduate Certificate will be given via the live video conference modality by the above universities. Therefore, some of our core and elective courses will be replaced by the courses given by these universities.

In the industry, collaboration is being coordinated with Jose Font, 747 Electrical Systems Senior Manager at the Boeing Company and with other local industries.

10. FACULTY

10.1 ORGANIZING FACULTY
   o Dr. Pablo G. Caceres-Valencia (General Engineering Department)
   o Dr. Marco Arocha (General Engineering)

10.2 TEACHING FACULTY
   o Dr. Jaime Ramirez-Vick (General Engineering Department)
   o Dr. Maharaj Tomar (Physics Department)
   o Dr. Marcelo Suarez (General Engineering Department)
   o Dr. Oscar Perales (General Engineering Department)
   o Dr. Basir Shafiq (General Engineering Department)
   o Dr. Oswald Uwakweh (General Engineering)
   o Dr. Paul Sundaram (Mechanical Engineering)
   o Dr. Nestor Perez (Mechanical Engineering)
   o Dr. David Serrano (Mechanical Engineering)
   o Dr. Carlos Rinaldi (Chemical Engineering)
   o Dr. Juan Lopez Garriga (Chemistry Department)
Materials Science & Engineering Certificate Program
Application Form

Date: ________________ Student ID Number: ________________
Name: _______________________________________________________________________
e-mail: _______________________________________________________________________
Address: _____________________________________________________________________
Street: _______________________________________________________________________
City State: ___________________ Zip Code: ___________________
Phone: (H)___________________ (Cellular) ____________________
What is your Engineering Major? _______________________________
What is your GPA? ________________________________________
How many credits have you approved towards your engineering degree? __________________
Reason for Seeking a Certificate in Materials Science and Engineering:
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

What elective courses will you take?
_____________________________________________________________________________
_____________________________________________________________________________

Approved:
Signature of Student: ______________________________________
Signature of Major Advisor: ___________________________________
Email: __________________________________________
Comments: _______________________________________________________________

Approved (MSE):
Signature of Certificate Coordinator in MSE: ______________________
Date: ______________________
New Courses Format
(Syllabus, Request for Course Implementation Format)
COURSE SYLLABUS

1. General Information
Course Number: INGE 5ISS
Course Title: Introduction to Solid State Materials Science
Credit-Hours: 3

2. Course Description

3. Pre/Co-requisites
INGE 4001 or INGE 3045.

4. Textbook, Supplies and Other Resources
- Other resources:
  - N Ashcroft and D Mermin 'Solid State Physics' Saunders

Relevant research articles will be incorporated as part of the general teaching strategy. The UPRM Library provides additional resources that the students are encouraged to comprehensively use.

5. Purpose
This course provides a basic understanding of what makes solids behave the way they do, how they are studied, and their basic interactions, starting from an atomistic level to the formation of crystals structures. It is uniquely designed around the direct connection between physical and chemical properties of materials, their synthesis and their structural properties.

6. General Objectives and Student Learning Outcomes
After successfully completing the assignments and activities associated with this course, the student should be able to:
- Explain relationships between crystal structure, microstructure, defect structure and electronic structure of materials
- Predict electronic, optical and magnetic properties of a material from knowledge of its electronic structure
- Select and/or design a material for a specific application based on the required electronic, optical or magnetic properties

7. Requirements
All students are expected to:
- come to all classes and on time
- do all assignments and related homework
- do well in all tests to receive credit for the course.

8. Department / Campus Policies
Please refer to the Bulletin of Information for Graduate Studies. All the reasonable accommodations according to the Americans with Disability Act (ADA) law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.

9. Campus Resources
General Library and the Engineering Computer Center have materials to supplement the course. Individual instructors will advise the students about the availability of these materials.

10. Course Outline

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES AND SKILLS</th>
<th>HOURS</th>
<th>TEACHING/ LEARNING STRATEGIES</th>
<th>ASSESSMENT STRATEGY AND TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Introduction to solid state. Bonding. Crystalline state. Defect structures. Solid Solutions and Two-Phase solids</td>
<td>- Review solid state physics and chemistry principles in the context of materials science.</td>
<td>6</td>
<td>Lectures (*)</td>
<td>Exams, Quizzes, Team Assignments (*)</td>
</tr>
<tr>
<td>- Electrical and thermal conduction in solids. Drude model, Matthiesen rule, Hall effect. Elementary Quantum Mechanics.</td>
<td>- Relate the electrical and thermal properties of solids to their microstructure.</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Dielectric materials. Electric displacement. Polarization mechanisms. Capacitors. Piezoelectric, ferroelectric and pyroelectric crystals.</td>
<td>- Provide a perspective on the ranges of properties displayed by defect interactions in solid state materials.</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Synthesis of solids. High and low temperature. CVD. Intercalation chemistry. Topotactic reactions. Control of Size and morphology</td>
<td>- Describe the different preparation techniques and reactions leading to the formation of solid state compounds</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) Each instructor has the freedom to decide what additional teaching and learning strategies will be used for each topic beyond regular lectures and how those outcomes are to be evaluated (assessment tools) in addition to regular exams, quizzes and assignments.
COURSE SYLLABUS

1. General Information
   Course Number: INGE 5FAM
   Course Title: Fundamentals of Advanced Materials
   Credit-Hours: 3

2. Course Description

3. Pre/Co-requisites
   Graduate student with permission of the director.

4. Textbook, Supplies and Other Resources
   - Other resources:
   Relevant research articles will be incorporated as part of the general teaching strategy. The UPRM Library provides additional resources that the students are encouraged to comprehensively use.

5. Purpose
   The Introduction to Advanced Materials course is designed to act as a refresher course for materials engineering undergraduate and graduate students with varied engineering backgrounds. The course focuses on different aspects of materials, their critical properties, basic processing techniques, modern applications with novel and emerging processing techniques.

6. General Objectives and Student Learning Outcomes
   Upon completion of the course, the student should be able to:
   - describe fundamental materials structures and the interplay between this and the generation of hybrid materials under the category of composites materials.
   - analyze the basis for critical materials properties (such as the roles of structural defects, and methods of their control toward property and performance enhancement).
   - integrate design approach in property enhancement based on expected materials need in a given system (engineering products).
   - apply the principles of structure-property-processing-performance synergies in the development of advanced materials and their characterizations.

7. Requirements
   All students are expected to:
   - come to all classes and on time
   - do all assignments and related homework
   - do well in all tests to receive credit for the course.
8. Department / Campus Policies
Please refer to the Bulletin of Information for Graduate Studies. All the reasonable accommodations according to the Americans with Disability Act (ADA) law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.

9. Campus Resources
General Library and the Engineering Computer Center have materials to supplement the course. Individual instructors will advise the students about the availability of these materials.

10. Course Outline

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>OBJECTIVES AND SKILLS</th>
<th>HOURS</th>
<th>TEACHING/ LEARNING STRATEGIES</th>
<th>ASSESSMENT STRATEGY AND TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Materials categories. Structural bases of ceramics, composites, electronic, metals and polymer materials.</td>
<td>-Review of materials and their structures.</td>
<td>6</td>
<td>Lectures (*)</td>
<td>Exams, Quizzes, Team Assignments (*)</td>
</tr>
<tr>
<td>- Defects in crystals. Amorphous and semicrystalline materials.</td>
<td>-Review of materials defects. - Control of defects</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Phase Equilibria and Phase Diagrams. Kinetic and microstructure of structural transformations. - Hardening Mechanisms</td>
<td>-Describe Phase diagrams from a thermodynamic point of view. -Understand the kinetics of phase transformation. - Provide an insight on the different mechanisms for materials hardening and their effect on related properties.</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Mechanical properties and relationship to structure. Effects of processing and use advanced techniques property enhancements.</td>
<td>- Describe tensile, fatigue, fracture and creep tests. -Compare materials based on these tests. Relate behavior to structure, and processing techniques.</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Metals. Steels and others. - Ceramics and glasses - Engineering Polymers - Composite materials</td>
<td>- Identify and describe the different types of materials.</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Materials environment interaction - Materials Processing</td>
<td>-Analyze different processing techniques and their relation with the final properties of the materials. - Understand the different mechanisms of property deterioration by interaction with the environment.</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) Each instructor has the freedom to decide what additional teaching and learning strategies will be used for each topic beyond regular lectures and how those outcomes are to be evaluated (assessment tools) in addition to regular exams, quizzes and assignments.
1. **General Information**
   - **Course Number:** INGE 5LTM
   - **Course Title:** Laboratory Techniques in Materials Science and Engineering
   - **Credit-Hours:** 3

2. **Course Description**

3. **Pre/Co-requisites**
   Graduate students with permission of the director of the department.

4. **Textbook, Supplies and Other Resources**
   - **Other resources:**

5. **Purpose**
   This course serves to introduce students to the theory and methods of structural analyses based on crystallographic methods and applications of x-ray and electron diffraction methods in characterizing solids. Complimentary techniques such as, EDS, EXAFS, solid state NMR, Mössbauer, XPS and electron microscopy (with the emphasis on the nature of the information obtained not the technique) would be highlighted in order to help students gain understanding of potential applications.

6. **General Objectives and Student Learning Outcomes**
   After completing the course, the student should be able to:
   - describe crystal geometry in terms of lattice locations, directions and planes in the seven crystal systems.
   - demonstrate a basic knowledge of physics of x-ray and electron interactions with matter.
   - apply basic knowledge of electron interaction and matter for image and chemical analysis determination
   - apply basic knowledge of different experimental techniques to solve materials science problems.

7. **Requirements**
   All students are expected to:
   - come to all classes and on time
   - do all assignments and related homework
   - do well in all tests to receive credit for the course
   - have basic knowledge of crystal structures and crystal symmetry.

8. **Department / Campus Policies**
   Please refer to the Bulletin of Information for Graduate Studies. All the reasonable accommodations according to the Americans with Disability Act (ADA) law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.
9. Campus Resources
General Library and the Engineering Computer Center have materials to supplement the course. Individual instructors will advise the students about the availability of these materials.

10. Course Outline

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>OBJECTIVES &amp; SKILLS</th>
<th>LECTURE HOURS</th>
<th>LAB HOURS</th>
<th>ASSESSMENT STRATEGY AND TOOLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Crystallography, symmetry operations. Crystallographic calculations; common crystal structures of engineering materials</td>
<td>Distinguish between crystalline and non-crystalline solids based on symmetry operations applications</td>
<td>6</td>
<td>0</td>
<td>Lectures and laboratories (*)</td>
</tr>
<tr>
<td>- Stereographic projection. - Crystal Structure, X-ray Diffraction Theory. Calculation of structure. Reciprocal Lattice.</td>
<td>Identify crystal unit cells. Apply knowledge of Brillouin zones and extinction principles to structural determination.</td>
<td>3</td>
<td>5</td>
<td>Exams, Quizzes, Team Assignments (*)</td>
</tr>
<tr>
<td>- X-ray analysis techniques. Indexing of powder patterns, lattice parameter determination, phase identification, and determination of texture in materials.</td>
<td>Undertake the structural characterization or determination based on analyses of diffraction patterns, and its application in materials study.</td>
<td>6</td>
<td>10</td>
<td>(*) Each instructor has the freedom to decide what additional teaching and learning strategies will be used for each topic beyond regular lectures and how those outcomes are to be evaluated (assessment tools) in addition to regular exams, quizzes and assignments.</td>
</tr>
</tbody>
</table>
COURSE SYLLABUS

1. General Information

Course Number: INGE 5NSM
Course Title: Nanostructured Materials
Credit-Hours: 3

2. Course Description


3. Pre/Co-requisites

Undergraduate students: INGE 4001 or INGE 3045 or INME 4007 or equivalent.
Graduate students: with authorization of the director.

4. Textbook, Supplies and Other Resources

- Textbook: No textbook
- Other resources:

The UPRM Library provides additional resources that the students are encouraged to comprehensively use.

5. Purpose.

The aim of this course is to provide students comprehensive education in the fundamentals and technological issues in fine particles and nanostructured materials processing. The course will cover the mechanisms that govern the formation and stability of particles (micro-, submicro- and nano-size scales) and discuss how these factors are related to the functional properties of modern and newly developed materials.

6. General Objectives and Student Learning Outcomes.

After completing the course, the student should be able to:
- Identify the scientific and technological achievements and research challenges in the processing of ultrafine particles and nanomaterials.
- Understand the mechanisms involved with particle formation at different size levels.
- Analyze the different routes for size-controlled particles synthesis.
- Characterize the relationship between materials properties and particle size.
- Establish the environmental considerations involved in fine particles and nanomaterials processing.
- Understand the importance of particle size and morphology on the properties of nanomaterials.

7. Requirements

All students are expected to:
-come to all classes and on time
-do all assignments and related homework
-do well in all tests to receive credit for the course

8. Department / Campus Policies

Please refer to the Bulletin of Information for Undergraduate and Graduate Studies. All the reasonable accommodations according to the Americans with Disability Act (ADA) law will be coordinated with the Dean of Students and in accordance with the particular needs of the student.

9. Campus Resources

General Library and the Engineering Computer Center have materials to supplement the course. Individual instructors will advise the students about the availability of these materials.

10. Course Outline

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<tr>
<td>Introduction.</td>
<td>- Describe nano-world and nanotechnology perspectives and their future implications.</td>
<td>6</td>
<td>Lectures and Computer Labs (*)</td>
<td>Exams, Team and Individual Assignments (*)</td>
</tr>
<tr>
<td>-Building Blocks, atoms, nanoparticles, layers, self-assembly, Hierarchical structures, clusters.</td>
<td>- Describe the building blocks of nanostuctured materials. - Identify mechanisms involved in particle formation.</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Synthesis routes, CVD, PVD, mechanical milling, sol-gel, gas phase pyrolysis, electrodeposition,</td>
<td>- Identify particle synthesis routes, i.e. chemical alternative (colloids, micelles, polymers, glasses, zeolites hosts), mechanical alternative (mechanical attrition) and other physical routes.</td>
<td>6</td>
<td></td>
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</tr>
<tr>
<td>-Theory of nanoscale structures, Computer Simulation, Modeling.</td>
<td>- Discuss the options to produce and control monodisperse systems. - Discuss the options to control other particle characteristics, such as: morphology, structure, composition, structure, layered structures, and surface modification.</td>
<td>6</td>
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</tr>
<tr>
<td>- Structure, Characterization and Properties of Nanophase.</td>
<td>- Analyze the conditions for the formation and stabilization of clusters and nanoparticles. - Evaluate different characterization techniques to determine structures and crystal lattice, specific surface area, composition, morphology, and physical properties.</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Technological applications. Coatings, Thin Film, Sensors.</td>
<td>- Identify the technological applications of nanostructured materials.</td>
<td>6</td>
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(*) Each instructor has the freedom to decide what additional teaching and learning strategies will be used for each topic beyond regular lectures and how those outcomes are to be evaluated (assessment tools) in addition to regular exams, quizzes and assignments.