Department of Materials Science and Engineering

Gregory S. Rohrer, Head
Location: Wean Hall 3327
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materials.cmu.edu (http://materials.cmu.edu)

Materials Science & Engineering (MSE) is an engineering discipline that applies the tools of basic and applied sciences and engineering to the manufacture and application of materials and devices. The four broad classes of Materials to which this paradigm is applied are metals, polymers, ceramics, and composites. Essentially every technology (historical, modern, and future) depends on materials development and innovation.

The overarching paradigm of MSE is to determine and to exploit the connection between processing, structure, and properties of materials to engineer materials that fit the performance criteria for specific applications, which are useful for the technological needs of our society. In addition to this product specific knowledge, MSE is concerned with the implications of materials production and their sustainable use on the environment and energy resources.

Graduates of the MSE department are pursuing careers in an expanding spectrum of companies, national laboratories, and universities. Their activities cover a wide range of materials related endeavors that include microelectronics, energy production and storage, biomedical applications, aerospace, information technology, nanotechnology, manufacturing and materials production. Many of our undergraduate alumni choose to attend graduate school; they are accepted into the top Materials graduate schools in the country.

The standard curriculum of the department provides fundamental training for all materials science and engineering areas (See www.cmu.edu/engineering/materials/undergraduate_program/curriculum (http://www.cmu.edu/engineering/materials/undergraduate_program/curriculum/)). The core courses provide understanding and training on tools for working with the (atomic) structure of materials that governs their properties, the thermodynamic relationships that govern the stability of materials, and the rates at which changes take place in materials. Students complete their learning with a capstone design experience in the final year, which integrates their materials knowledge and training with engineering team skill development. To supplement the core course program, students may also participate in the current research programs of the faculty and conduct undergraduate research projects as part of their program of study.

While the core program is focused on the understanding of the internal or surface structure of materials in order to predict and engineer their properties, it is a flexible program that allows students to focus within a chosen material class, whether it is ceramics, semiconductors, metals, composites, magnetic or optical materials, bio-materials or polymers. The program also permits the option of cross concentration in the one or more of the areas of application such as electronic materials*, engineering design*, biomedical engineering*, environmental engineering*, manufacturing engineering*, mechanical behavior of materials*, biomedical and health engineering**, and engineering and public policy**, is also available. (* = Designated Minor, ** = Double Major). Our curriculum is designed to provide a strong foundation in fundamental knowledge and skills that provide an excellent base for our graduates planning to continue on to graduate studies. For our graduates who seek employment in industry, the program provides the foundation on which a graduate can build his/her domain specific knowledge. For students that develop or seek opportunities in other disciplines after graduation, the MSE curriculum provides a modern liberal education combined with the engineering rigor, i.e. one that inculcates upon a thoughtful, problem-solving approach to professional life. It is thus the goal of our education to provide a global and modern education in Materials Science and Engineering to support our graduates during their careers in materials industries or as a foundation for further studies in any of the leading global institutions of graduate education.

Accreditation
The MSE Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org.

Educational Objectives
The faculty of the Department of Materials Science and Engineering, in consultation with students, alumni and other interested parties, has decided that the overarching objective of the MSE curriculum is to provide an education that enables our graduates to be productive and fulfilled professionals throughout their careers.

Specifically, our program will produce graduates who:
1. are successful in a professional position and/or a top graduate school that builds upon their MSE background;
2. excel in professionalism and leadership in contemporary, interdisciplinary engineering practice based on materials, while accounting for the impact of their profession on an evolving, global society;
3. creatively advance our collective understanding of the principles of materials science and engineering and/or innovate the design of technological systems;
4. contribute effectively as an individual, team member, and/or a leader to effect global, economic, environmental, and/or societal impact.

Based on these objectives, our program is focused to allow our students to be successful regardless of their future career choice.

Student Outcomes
The Materials Science and Engineering Program has the following student outcomes to prepare graduates to attain the program educational objectives:
A. An ability to apply a 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 within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D. An ability to function on multidisciplinary 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, economic, environmental, and societal context
I. A recognition of the need for, and 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

Curriculum
Minimum units required for B.S. in Materials Science & Engineering 379

Standard Program

Freshman Year

<table>
<thead>
<tr>
<th>Fall</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21-120</td>
<td>10</td>
</tr>
<tr>
<td>27-100</td>
<td>Differential and Integral Calculus</td>
</tr>
<tr>
<td>99-101</td>
<td>Engineering the Materials of the Future*</td>
</tr>
<tr>
<td>xx-xxx</td>
<td>Computing @ Carnegie Mellon</td>
</tr>
<tr>
<td>33-141</td>
<td>General Education Course</td>
</tr>
<tr>
<td>46</td>
<td>Physics I for Engineering Students</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Spring</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>21-122</td>
<td>Integration and Approximation</td>
</tr>
<tr>
<td>xx-xxx</td>
<td>Second Introductory Engineering Course</td>
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### Sophomore Year

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Fall: 27-201 Structure of Materials</td>
<td>9</td>
</tr>
<tr>
<td>27-210 Materials Engineering Essentials</td>
<td>6</td>
</tr>
<tr>
<td>27-215 Thermodynamics of Materials</td>
<td>12</td>
</tr>
<tr>
<td>21-259 Calculus in Three Dimensions</td>
<td>9</td>
</tr>
<tr>
<td>09-105 Introduction to Modern Chemistry I **</td>
<td>10</td>
</tr>
<tr>
<td>or 15-110 Principles of Computing</td>
<td>10</td>
</tr>
<tr>
<td>or 15-112 Fundamentals of Programming and Computer Science</td>
<td></td>
</tr>
<tr>
<td>39-210 Experiential Learning I</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
</tr>
</tbody>
</table>

- **Fall:** 27-201 Structure of Materials
- **Units:** 9
- **Spring:** 27-202 Defects in Materials
- **Units:** 9
- **Spring:** 27-205 Introduction to Materials Characterization
- **Units:** 3
- **Spring:** 27-216 Transport in Materials
- **Units:** 9
- **Spring:** 27-217 Phase Relations and Diagrams
- **Units:** 12
- **Spring:** 21-260 Differential Equations
- **Units:** 9
- **Spring:** 39-220 Experiential Learning II
- **Units:** 0
- **Spring:** xx-xxx General Education Course
- **Units:** 9

### Junior Year

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Fall: 27-301 Microstructure and Properties I</td>
<td>9</td>
</tr>
<tr>
<td>xx-xxx MSE Restricted Elective [1]</td>
<td>9</td>
</tr>
<tr>
<td>33-225 Quantum Physics and Structure of Matter or 09-217 Organic Chemistry I or 03-121 Modern Biology</td>
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</tr>
<tr>
<td>xx-xxx General Education Course</td>
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<tr>
<td>39-310 Experiential Learning III</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>51</td>
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</tbody>
</table>

- **Fall:** 27-301 Microstructure and Properties I
- **Units:** 9
- **Fall:** xx-xxx MSE Restricted Elective [1]
- **Units:** 9
- **Spring:** 27-367 Selection and Performance of Materials
- **Units:** 6
- **Spring:** xx-xxx General Education Course
- **Units:** 9
- **Spring:** 27-xxx MSE Restricted Elective [2]
- **Units:** 9
- **Spring:** xx-xxx General Education Course
- **Units:** 9
- **Spring:** xx-xxx General Education Course
- **Units:** 9

### Senior Year

<table>
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<th>Course</th>
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<tr>
<td>Fall: 27-401 MSE Capstone Course I</td>
<td>6</td>
</tr>
<tr>
<td>xx-xxx General Education Course</td>
<td>9</td>
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<tr>
<td>xx-xxx General Education Course</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
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</tbody>
</table>

- **Fall:** 27-401 MSE Capstone Course I
- **Units:** 6
- **Fall:** xx-xxx MSE Approved Technical Elective
- **Units:** 9
- **Fall:** xx-xxx Free Elective [4]
- **Units:** 9
- **Fall:** xx-xxx Free Elective [5]
- **Units:** 9
- **Fall:** xx-xxx General Education Course
- **Units:** 9

### Notes on the Curriculum

#### Academic Advising
Paige Houser is the academic advisor for all MSE students.

#### Quality Point Average
In addition to the College requirement of a minimum cumulative quality point average of 2.00 for all courses taken beyond the freshman year, the Department requires a quality point average of 2.00 or higher in courses taken in the MSE department. Students may repeat a course to achieve the QPA requirement. Only the higher grade will be used for this departmental calculation.

#### MSE Approved Technical Elective
Students are required to take at least 9 units of approved technical electives. Students may take a course from another CIT department to fulfill this requirement or choose an additional 9 units of MSE Restricted Electives. Students who are pursuing an additional major or minor within CIT should check with their academic advisor regarding double counting of this course.

#### MSE Restricted Electives
Each student in the program must take at least 36 units of MSE restricted electives.

- All 27-xxx, 27-4xx, 27-5xx, 27-6xx (with the exception of 27-699) and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:
- **Units:** 60-609 Physical Chemistry of Macromolecules
- **Units:** 60-619 Semiconductor Processing Technology
- **Units:** 09-509 Physical Chemistry of Macromolecules
- **Units:** 12-411 Project Management for Construction
- **Units:** 12-631 Structural Design
- **Units:** 18-310 Fundamentals of Semiconductor Devices
- **Units:** 24-262 Stress Analysis
- **Units:** 24-341 Manufacturing Sciences
- **Units:** 33-341 Thermal Physics I
- **Units:** 33-448 Introduction to Solid State Physics
- **Units:** 42-411 Engineering Biomaterials

#### Integrated B.S./M.S. Program
Undergraduates who excel academically have the unique opportunity to receive simultaneously or sequentially both B.S. and M.S. degrees from the department. The primary purpose of the Integrated Master and Bachelor (IMB) Degree Program is to provide students with superior breadth and depth in technical material, which will better prepare them for careers in industry. Students interested in pursuing the IMB Degrees are encouraged to begin taking some of the required graduate courses before their last year.

The MSE department offers two M.S. degrees: one in Materials Science and Engineering (MSE), a coursework degree, and one in Materials Science (MS), a coursework + research degree. The IMB Degree Program to obtain an M.S. in MSE (MS) degree normally requires two (three to four) additional full academic semesters of coursework (coursework + research) beyond the B.S. Degree Requirements (normally eight academic semesters). Experience has shown that students complete the IMB program in eight to ten full academic semesters after enrolling at CMU.
Degree Requirements
IMB students can be enrolled in either the M.S. in MSE (coursework) or the M.S. in MS (coursework + research) degree programs, depending on their preference. Students must meet the requirements of either the M.S. in MSE or the M.S. in MS degree programs, as well as any specialty stated rules below.

Eligibility
The IMB Program is available to all undergraduates who maintain a cumulative GPA of 3.0 or better, including the freshman year and the years in which they are enrolled in the IMB. Exceptions can be made by the Department on the basis of other factors, including extenuating (e.g., medical) circumstances, improvement in grades, strong recommendation letters, etc.

Students become eligible to apply to the program during the spring semester of their junior year (5th semester), or the semester in which they accumulate 280 or more units, whichever is earlier.

Enrollment
Students interested in the IMB program are not required to follow the formal application process for acceptance into the MSE graduate program. There is no requirement to provide a formal application, application fee, GRE scores, recommendation letters, official transcripts, or a statement of purpose. Interested students are encouraged to request acceptance into the program by contacting the Department Head of MSE by email prior to the middle of the semester in which they become eligible.

Requirements to Enroll as a Graduate Student
If a student takes more than 8 semesters to complete both the B.S. and M.S. in MSE (coursework), then he or she must be a graduate student for at least one full-time 15-week academic semester (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MS (coursework + research), then he or she must be a graduate student for at least two full-time 15-week academic semesters (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

Tuition Assistance
When a student is a full-time graduate student through the IMB program, the department is able to provide some tuition assistance through optional Teaching Assistantships.

Additional Information
Once the student has been accepted, the student should meet with his or her IMB academic advisor(s) to determine a course schedule.

The student must indicate to the departmental program coordinator at which point they intend, if necessary, to register as a graduate student.

Once a student in the IMB program has completed all of the requirements for the B.S. degree, he or she should become a graduate student.

To determine the most appropriate time for an undergraduate student to become a graduate student, he or she should consult with Enrollment Services to understand how becoming a graduate student will affect financial aid.

Faculty
CHRIS BETTINGER, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–

MICHAEL BOCKSTALLER, Professor – Ph.D., Max-Planck Institute for Polymer Research; Carnegie Mellon, 2005–

ITZHAO COHEN-KARNI, Associate Professor – Ph.D., Harvard University; Carnegie Mellon, 2013–

ROBERT F. DAVIS, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

MARCE DE GRAEF, Professor – Ph.D., Catholic University Leuven (Belgium); Carnegie Mellon, 1993–

ADAM FEINBERG, Professor – Ph.D., University of Florida; Carnegie Mellon, 2010–

WARREN M. GARRISON, Professor – Ph.D., University of California at Berkeley; Carnegie Mellon, 1984–

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–

ELIZABETH A. HOLM, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2012–

MOHAMMAD F. ISLAM, Professor of Materials Science and Engineering – Ph.D., Lehigh University; Carnegie Mellon, 2005–

DAVID E. LAUGHLIN, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–

NOA MAROM, Assistant Professor – Ph.D., Weizmann Institute of Science; Carnegie Mellon, 2016–

MAREK SKOWRONSKI, Professor – Ph.D., Warsaw University; Carnegie Mellon, 1988–

REJEE JAYAN, Assistant Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

DAVID KINDERLEHRER, Professor, Mathematical Sciences – Ph.D., University of Pittsburgh; Carnegie Mellon, 1974–

STEPHEN GAROFF, Professor, Physics – Ph.D., Harvard University; Carnegie Mellon, 2016–

KLAUS-DIETRICH BURKHARDT, Professor of Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2016–

VINCENT SOKALSKI, Associate Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2011–

ANTHONY D. ROLLETT, Professor – Ph.D., Drexel University; Carnegie Mellon, 1995–

JOHN KITCHIN, Associate Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–
SHAWN LITSTER, Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

SARA MAJETICH, Professor, Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

CARMEL MAJIDI, Associate Professor of Mechanical Engineering – Ph.D., University of California; Carnegie Mellon, 2011–

JONATHAN MALEN, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2009–

KRZYSZTOF MATYJA, J.C. Warner Professor of Natural Sciences, Department of Chemistry and Materials Science and Engineering – Ph.D., Polytechnical University of Łódź, Poland; Carnegie Mellon, 1985–

MEAGAN MAUTER, Assistant Professor, Civil & Environmental Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2015–

ALAN MCGAUGHEY, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

O. BURAK OZDOGANLAR, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

ROBERT SEKERKA, University Professor, Physics, Mathematics and Materials Science – Ph.D., Harvard; Carnegie Mellon, 1969–

ROBERT SUTER, Professor, Physics – Ph.D., Clark University; Carnegie Mellon, 1981–

VENKAT VISWANATHAN, Assistant Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2013–

LYNN WALKER, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

NEWELL R. WASHBURN, Associate Professor of Chemistry, Biomedical Engineering and Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

LEE WEISS, Research Professor, ICES – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1983–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

DI XIAO, Associate Professor of Physics – Ph.D., University of Texas, Austin; Carnegie Mellon, 2012–

LINING YAO, Assistant Professor of Human-Computer Interaction Institute and College of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

JIAN-GANG ZHU, Professor, Electrical and Computer Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 1997–

Emeriti Faculty

RICHARD J. FRUEHAN, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1981–

THADDEUS B. MASSALSKI, Professor Emeritus of Physics, Materials Science and Engineering – Ph.D., D.Sc., University of Birmingham, England D.Sc. (h), University of Warsaw, Poland.; Carnegie Mellon, 1959–

PAUL WYNBLATT, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1981–