

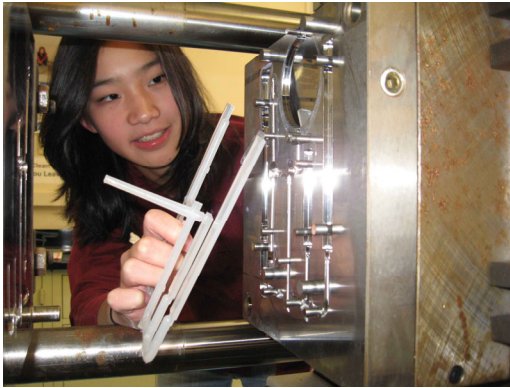


RUTGERS

Undergraduate Handbook

Materials Science & Engineering

2023-2024



Materials Science and Engineering – Enabling the Future

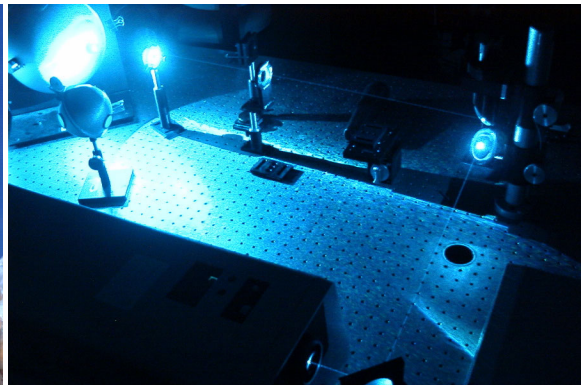


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Welcome to the Materials Science and Engineering Department at Rutgers University!

Materials Science and Engineering is the discipline in engineering that combines chemistry and physics to produce all of the devices, gadgets, structures, and inventions that enable our lives. Just think, if not for the strong, fracture-resistant glass on the surface of your smart phone, you would not be walking around with a powerful computer in your pocket. That is just one example of how an advance in materials made it possible to assemble this device, without which most of us cannot survive. The Materials Science and Engineering Department has been at the forefront of new materials for over a century. To be sure, engineering is an interdisciplinary endeavor, and engineers work in teams with expertise in design, electronics, applications, and processing. As a materials engineer, you are the key component of the team, and in many ways, you make everything, and everyone work together.



Here at Rutgers-MSE, we have state of the art laboratories and several major research and education centers focused in critical areas, including energy storage, nanomaterials, optical composites, lightweight armor, and computational materials science. Most of our undergraduate students have an opportunity to take on an independent research project, initially with the help of graduate students and postdoctoral scientists. Ultimately, our students pursue original research, which often results in publications and opportunities to present their results at national and international meetings. We encourage our students to become involved in their professional societies, to begin building their network with alumni and practicing engineers. Placing our students in internships in industry and in research laboratories is a common outcome of the relationships that our students form with their faculty mentors.

We realize that Fall 2020 is different from previous semesters because of the COVID Pandemic. Nevertheless, we have worked through the summer to prepare for on-line teaching this Fall. All of our faculty have become familiar with the enhanced technology we will be using starting in September. These are challenging times for educators and students, but I can say with confidence that your educational experience this Fall will keep you on track to achieve your professional goals. We encourage you to communicate with your professors to be sure that we meet your expectations.

Please, take a look at our website and reach out to us if you have any questions. And in 2022, we expect to have a grand salute to materials when our department celebrates its 120th Year.

Lisa C. Klein
Professor & Chair

Undergraduate Program Director's Message

We, the faculty, are very excited that you have chosen Materials Science and Engineering as your major. It is a great pleasure welcoming you to our department which will be your home-away-from-home in the next three years. Above all, you have become a member of the Rutgers MSE family – a bond that will continue after your graduation as well. We pride ourselves for being an egalitarian, diverse, inclusive, and agreeable close-knit group of Rutgers Materials Engineers who endeavor to make the world a better place. Our MSE family is dispersed to all four corners of this nation and around the world, making a difference in peoples' lives every day. MSE is a department with an exceptionally favorable student-to-faculty ratio. As such, we will learn your name, address you as such, and treat you as a soon-to-be fellow Rutgers Engineers from the beginning. You will receive outstanding personal attention, mentoring and guidance from faculty that will help you succeed not only in your coursework but also in chartering a career path for yourselves. Rest assured that we will support you any way we possibly can during your journey in Rutgers MSE.



We are dedicated to providing you a top-notch and world-class science & engineering education in materials which is the backbone of all other engineering disciplines. Hence, we designed a curriculum that strikes a balance between theoretical in-class instructions and hands-on learning in state-of-the-art laboratories. We provide an intellectually stimulating environment for learning and professional preparation in which you will be taught and trained by world renown faculty. We encourage our students to immerse themselves in research projects, which are offered by MSE faculty, early in their sophomore year. Moreover, we help our students find sought-after summer internship and co-ops.

We designed an MSE curriculum that is highly customizable for your personal interests and needs. As a result, you will be able to double major or minor in subject matters such as physics, computer science, mathematics, and business administration, among others, should you wish to do so. We pursue an educational approach that substantially increases our students' chances in landing highly desirable jobs upon graduation. Our graduates are known to rise to leadership positions in industry, government, and academia with whom you will be able to network through various departmental social functions in the next three years, and beyond.

I invite you to the [Rutgers MSE](#) web page and to follow us on [Instagram @rutgers_mse](#) where you can gain insights about "your" department. Please feel free to contact me at eka@soe.rutgers.edu should you have any questions or comments. I will be looking forward to the day we return to campus and meet you all in person, all the best!

E. Koray Akdoğan
Associate Professor & Undergraduate Program Director

Faculty Directory

Name	Room	Phone (848-445 xxxx)	E-mail
Akdoğan, E. Koray	CCR-114	4513	eka@soe.rutgers.edu
Birnie, Dunbar P.	CCR-129	5605	dbirnie@rutgers.edu
Amatucci, Glenn	Tech Ctr.	932-6850 x 601	gamatucc@rutgers.edu
Garofalini, Stephen H.	A-217	2216	shg@glass.rutgers.edu
Goel, Ashutosh	CCR-212	4512	ag1179@soe.rutgers.edu
Haber, Richard A.	FO-201	4931	rhaber1@rutgers.edu
Klein, Lisa C.	CCR-204	2096	licklein@rutgers.edu
Lehman, Richard L.	CCR-102	2317	rllehman@rutgers.edu
Mann, Adrian	CCR-214	8421	abmann@rutgers.edu
Matthewson, M. John	A-133	5933	mjohnm@fracture.rutgers.edu
O'Carroll, Deirdre M.	CCR-218	1496	ocarroll@rutgers.edu
Riman, Richard E.	CCR-106	4946	riman@rutgers.edu
Safari, Ahmad	CCR-118	4367	safari@rutgers.edu
Sills, Ryan	CCR-108	4942	ryan.sills@rutgers.edu
Tsakalagos, Thomas	A-133	2888/2873	tsakalak@rutgers.edu

Administrative Staff

Name	Room	Phone (848-445 xxxx)	E-mail
Assal, Nahed	CCR-212	1651	naheda@rutgers.edu
Beyoglu-Siglam, Berra	CCR-202	3931	bbeyoglu@soe.rutgers.edu
Kaul, Srishti	CCR-220	2159	Sk1668@rutgers.edu
Sole, Michelle	CCR-203	5924	msole@rutgers.edu

SCHOOL OF ENGINEERING

Instruction in engineering began at Rutgers in 1864 when the state of New Jersey designated the Rutgers Scientific School as the State College for the Benefit of Agriculture and Mechanic Arts. The present School of Engineering became a separate entity in 1914 and continues to maintain two principal objectives: the sound technical and cultural education of the student and the advancement of knowledge through research.

The School of Engineering has designed each of its engineering curricula to contain three types of courses; (1) courses covering the basic scientific principles essential to advanced study in any field of science or engineering; (2) nontechnical courses which, with the basic sciences, are a part of the common heritage of educated persons; and (3) technical courses in which the basic scientific principles are applied to problems in a particular engineering field. Throughout all courses, the emphasis is on a thorough understanding of fundamental principles and engineering methods of analysis and reasoning. All curricula are sufficiently comprehensive to form a foundation for the more advanced scientific and technical research, the more specialized professional engineering fields, or the business and management opportunities of industry. In any curriculum, students receive a sound education in the fundamental principles, which helps them develop competence in their engineering fields. The basic nature of the courses and the mental discipline of modern engineering education constitute excellent preparation for a satisfying career, even in fields of endeavor other than engineering.

ACADEMIC PROGRAMS WITHIN THE SCHOOL

Four-year undergraduate curricula leading to the degree of Bachelor of Science are offered in the fields of applied sciences in engineering, bioenvironmental engineering, biomedical engineering, chemical & biochemical engineering, civil & environmental engineering, electrical & computer engineering, industrial engineering, materials science and engineering, and mechanical & aerospace engineering. Several areas of specialization are available within these disciplines, such as, solid-state electronics, packaging engineering, and engineering physics.

A five-year, dual-degree program is offered by the School of Engineering in cooperation with three liberal arts colleges in New Brunswick: Douglass College, Livingston College, and Rutgers College. This program leads to a Bachelor of Science degree in any of the engineering fields listed above (except applied sciences in engineering) and a Bachelor of Arts degree from the cooperating liberal arts college in any major in which that college confers the B.A. degree.

ACCREDITATION OF OUR MSE PROGRAM

The Department has an accredited degree program in Materials Science that is valid through July 2019. The program in Materials Science & Engineering is presently being reviewed for renewed accreditation to take effect in August 2019. Accreditation for engineering programs is through the Accreditation Board for Engineering and Technology (ABET). According to ABET each program must have Program Educational Objectives and Student Outcomes that we seek to provide for our students. These are published on our website at

<http://mse.rutgers.edu/abet-accreditation-mse-specific>

In addition, an assessment process is required to assist us in determining the degree to which we accomplish the Student Outcomes and to comprise a continuous feedback loop to improve the program.

Our Assessment Plan

We use a combination of assessment measures to determine if the appropriate outcomes are being achieved. Some of these methods are direct, some are indirect. Plus, they incorporate a combination of qualitative and quantitative means. The following specifics are used to collect data, assess the data, and take action to revise and improve our program.

1. **Sampling:** Data are collected in a quasi-random fashion so that a range of student performances can be assessed without requiring an undue, non-sustainable amount of data. In some instances, such as in coursework assessment of student outcomes, the entire population of the course is used.
2. **Responsibility:** For course Student Outcome assessments, the faculty instructor is responsible for collecting, assessing, and implementing continuous improvement. We use this method since our instructors do not typically rotate among courses, as might be commonly practiced in other programs. This in part results from the specialty nature of MSE—the instructors are the proper experts to make these evaluations. Other forms of assessment, review, and action are conducted by the ABET Coordinator, the Undergraduate Director, and the Department Chair.
3. **Timing:** Each of the assessment categories has its own intrinsic time scale, i.e. enrollment occurs in the fall, our Board meets biennially in November of odd years, and courses occur on a varied semester basis. Overall, we seek a minimum of three assessments over the six-year evaluation period, which will ideally occur in an evenly distributed pattern. For the Advisory Board, this assessment is straightforward and given by the meeting cycle. For courses, the instructor is given the latitude to decide the timing based on the dynamics of the course. A similar logic is used for the other assessment categories.
4. **Actions:** Taking action is an essential part of the continuous improvement process. The responsible individual, noted above, is accountable for taking action to improve the program and to document these actions. The full faculty is ultimately responsible for all continuous improvement efforts based on the many assessments, as developed through discussions at monthly faculty meetings and annual department retreats.

HISTORY OF THE DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING

Assistant Professor of Chemistry William S. Myers in 1901 conceived the idea of establishing a course in clay working and ceramics similar to that offered by Ohio State University. Prof. Myers, with the approval of the trustees, proposed a bill to the NJ legislature to provide the facilities for such a course. His intensive campaign of letters and influence of personal friends and leaders of the ceramic industry resulted in the passage of an act on 17 March 1902 that required the “Trustees of the State Agriculture College of NJ” to establish a School of Ceramics and provided \$12,000 to equip a laboratory and \$2,500 for annual operating expenses. This was the first expenditure of funds by the State on behalf of Rutgers College and was one of the initial steps toward becoming Rutgers, The State University. The annual

operating budget was increased an additional \$2,500 on 14 March 1907. The Department of Clay-Working and Ceramics (first located within the Agriculture College), later to become the Department of Ceramics (reporting directly to the Dean of Rutgers College), was the third such institution of its kind to be established in the country. For twenty years a 1600 sq ft two-story brick building that formerly served as a stable housed the newly formed Department of Ceramics. Later an additional 1600 sq ft was added. The first floor had a machinery room, store room, and a drying & kiln room. The second floor had a classroom, library/museum, and the director's office/laboratory. A complete description of the building and the equipment can be found in the 1904/05 Rutgers College Catalog, pages 148-9. This building along with another addition and some renovation now houses the offices of the University College, which is the continuing education arm of Rutgers. It is located west of College Avenue across from Old Queens Campus in the interior of the block.

In 1914 the Department of Ceramics invited key men in the industry to attend a Clayworkers Institute on 25 June, the outcome of which was the founding of the New Jersey Clayworkers Association. Prof. Parmelee was elected the secretary/treasurer. In June of 1932 the name was changed to the Ceramic Association of New Jersey to embrace the much wider field of ceramics than the name *clayworkers* indicated. The Association played an important role in helping to solve many of the Department's problems. A fine example was the campaign launched in 1919 for a much needed new building. By 1919 it was realized that the building and facilities of the Department of Ceramics were entirely inadequate to handle the increased student body and the research programs underway. Thomas Brown, then Senator of Middlesex County, sponsored the project for a new ceramics building. Representatives of practically every ceramic concern in the state lent their aid to the measure. Bill No. 17 appropriating \$100,000 for the erection of a building and equipment was made a law on 23 March 1920; and on Commencement Day, 13 June 1922, the completed building was dedicated. The same law appropriated at least \$12,000 annually for operational expenses. Some 80 State manufacturers to complete the project donated an additional \$30,000 in money, materials, and services. The stable of 1902 was a direct contrast to the modern 29-room structure. The 45 by 102 ft. building was constructed entirely of ceramic products representing every line of ceramic manufacture in the state of New Jersey. Located on George Street of the College Avenue Campus (formerly the Neilson Campus), this building is still in use by the University and is now home to the School of Social Work.

The Department of Ceramics joined the College of Engineering by action of the Board of Trustees in October 1945 and was designated as the School of Ceramics. Although joining the College of Engineering in 1945, the Department was not fully integrated until 1948. The School physically joined the College of Engineering in 1963, when the College moved to Busch Campus (formerly University Heights; formerly River Road Campus), with the School of Ceramics occupying the A-wing. Although the Department still occupies a portion of the A-wing in the School of Engineering building, the office of the Chair moved into the new Malcolm G. McLaren Center for Ceramics Research building when it opened in 1988.



The SOE in 1964, the original complex was four interconnected buildings



The MSE Complex is a grouping of three buildings including most of A-wing of the 1964 building along with the Center for Ceramic Research and Fiber Optic Materials Research Buildings.

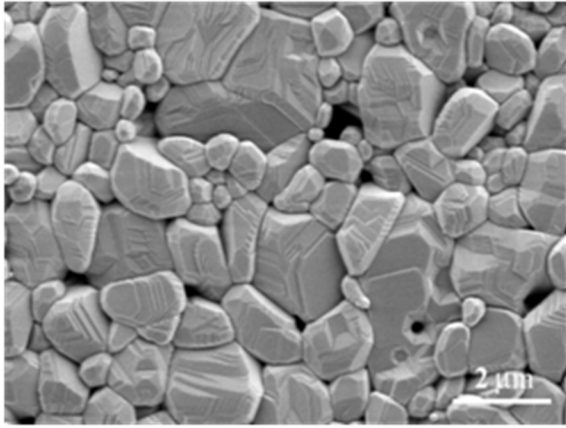
Although Prof. Myers, then head of the Chemistry Department, organized the new Department of Ceramics, the first Director was Mr. Cullen W. Parmelee, an Instructor in Chemistry, who held that position until 1916 when George H. Brown succeeded him. Edward P. McNamara, a member of the staff, served as Acting Director after the death of George Brown in 1943. He resigned in 1944 to accept a position in industry. During the interim years (WW II) without a director the efforts of Emma Nawrot Stett were vital in keeping the Department alive. Dr. John Koenig became Director in 1945 and was succeeded after his retirement in 1969 by Dr. Malcolm G. McLaren who served until 1994. Dr. Dale Niesz, performed the duties of chairman from 1994 until 2000, when Dr. Stephen Danforth took over the duties. Dr. Danforth served until 2006. Professor Dunbar Birnie, III served as chair from 2006 to 2010 at which time Professor Richard Lehman became chair.

The faculty submitted a request to the University to have the Department of Ceramics name changed to Department of Ceramic & Materials Engineering. This change was approved and became effective 1 July 1997. The faculty approved an additional name change in the Spring of '04 to the Department of Materials Science and Engineering. This change was approved and became effective July 2005.

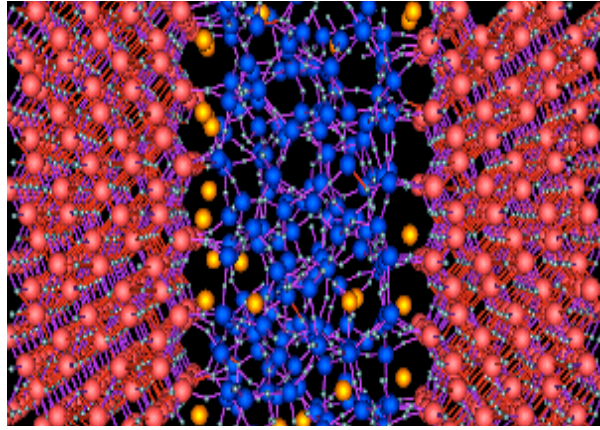
MATERIALS SCIENCE & ENGINEERING PROGRAM

The undergraduate and graduate curriculum in the Materials Science & Engineering program embodies the interplay between structure, processing, properties and performance of engineering materials, with emphasis on applications and materials design. While all materials are addressed within the curriculum there is a strong emphasis on ceramic materials. Here, the high-temperature phenomenon in the entire field of inorganic chemistry and physics is no longer limited to the traditional field of clay products.

The curriculum embraces both the crystalline and glassy phases of the materials concerned. The core courses and research projects include studies of phase assemblages, the interaction of materials to radiation of all frequencies, from the gamma ray to microwaves; and the increasingly important relation of properties to structure. In the junior year, the undergraduate can select an Area of Concentration. These Areas represent new cutting edge technologies that provide the student with a choice of electives in a specific area. For each Area of Concentration, a minimum of three integrated series of electives exists. The current Areas include: 1) Biomaterials, 2) Energy Storage and Conversion, 3) Electronic and Optical Materials, 4) Nanomaterials, 5) Polymers, and 6) Packaging Materials.



A micrograph of the surface of Al_2O_3

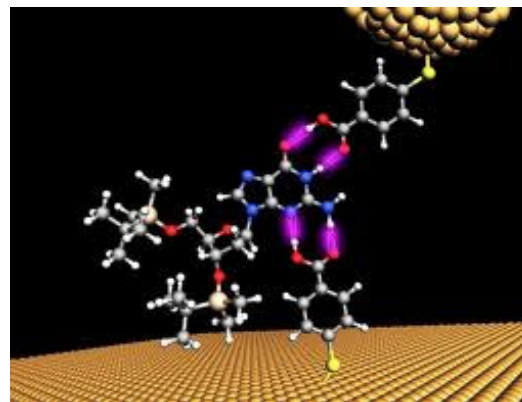


Simulation- 2micron glassy intergranular film between crystals

FACILITIES

The Department of Materials Science & Engineering contains extensive instructional and research facilities focusing on the manufacturing, control and analysis of the wide variety of conventional and advanced materials including: ceramics, glasses, composites and electrical, optical and magnetic materials required by modern technology. Students that utilize the laboratory equipment and facilities learn to solve problems related to the design, processing and evaluation of advanced materials. Special equipment exposes our students to the preparation and evaluation of the newer types of ceramics, metals, polymers, semiconductors and composites required in aerospace, advanced engine, biotechnology, photonics, and electromagnetic applications.

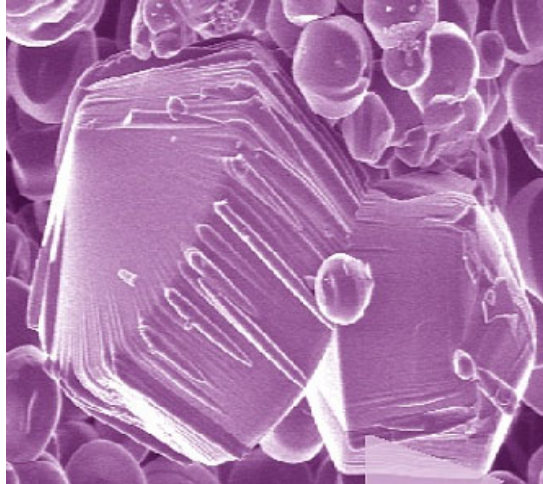
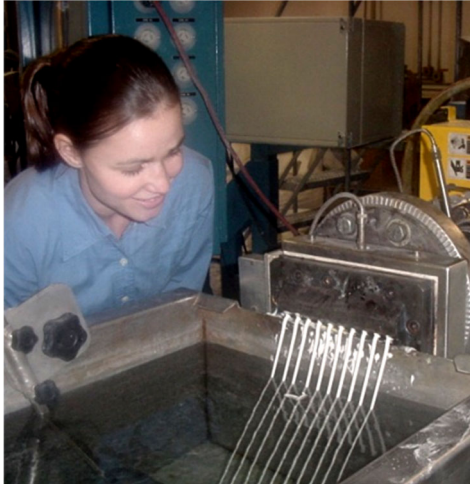
An attractive feature of our Department is the small class size, which makes instruction more interactive. The curriculum includes several laboratory courses that provide hands-on experience and learning to our students. The laboratories are located within the A-wing of the Engineering Building, the Malcolm G. McLaren Center for Ceramic Research Building, and the Fiber Optic Materials Research Building. Lectures are typically held within two buildings, SERC - Science and Engineering Resources Center and ARC – Allison Road Classroom.



The Nanomaterials Courses allows students to study nanomaterials and nanostructures used in electronic, photonic, chemical, structural and biological applications. Facilities in MSE allow researchers to synthesize, characterize and evaluate the performance of these new and exciting materials.

Equipment is housed in an instructional facility and several advanced technology centers including: the McLaren Ceramic Composite and Optical Materials Research Center, the Fiber

Optic Materials Research Center, and the Center for Advanced Materials via Immiscible Polymer Processing (AMIPP). Recent major grants from industry and the New Jersey Commission on Science and Technology have provided these instructional and research facilities. In 2002, the New Jersey Commission on Higher Education Workforce Excellence Program provided \$2.5million for the creation of the Nanomaterials Courses, including laboratories.



New polymeric materials and processes are being developed within the AMIPP Laboratories.

FACULTY

One of the most important elements in any Department is its Faculty and we have good reason to be extremely proud of ours. Our Faculty are nationally and internationally known experts in their fields. The Faculty's expertise encompasses a wide breadth of areas including: glass engineering, ceramic composites, piezoelectric and ferroelectric materials, advanced thin-film engineered materials, nanomaterials and nanostructures, photonics and fiber optics, microelectronic materials, electroceramics and battery materials, ceramic and metallic surfaces, theoretical and computational modeling, processing technology and minerals technology.



The student/faculty ratio is the lowest within the School of Engineering. This provides our students with the opportunity to work directly with the faculty and provides a private school type atmosphere within the expansive facilities of a large state university.

Most importantly, our Faculty is an assemblage of outstanding educators who are adept at transferring their knowledge and the benefits of their experiences to their students through formal and informal interactions. A directory of MSE Faculty is listed in the appendix. You should feel free to contact any faculty member to discuss academic or career matters.

SPECIAL PROBLEMS 635:491/492

A student wishing to register for Special Problems must complete a registration form available in CCR 203. This form must be signed by the faculty member who is serving as the project advisor and then be submitted to the Department Undergraduate Office. A student cannot register for this course without completing the form.

ADVISING SYSTEM

Each undergraduate class has a Faculty Advisor. This is a person with whom you will have important interactions at Rutgers. While each student is required to meet with their Advisor at least once a semester, students should take every opportunity to become better acquainted with this person. Students are assigned a Faculty Advisor in their sophomore year and retain this Advisor through graduation. As a result, curriculum planning is optimized and a close personal relationship develops which is of mutual benefit to the student and faculty member.

The following list shows the Faculty responsible for advising our current students. You may find this list useful if you should ever need advising or counseling while your own advisor is unavailable. Any Advisor will be happy to assist you in whatever way possible. In the appendix is a complete list of all Faculty and staff along with office addresses, phone numbers and email addresses. Should you ever be unable to contact your advisor directly, just inform the Undergraduate Secretary your need to arrange for an appointment and the message will be promptly relayed.

Faculty Advisor	Class	E-mail
Prof. D. Birnie	2024	dunbar.birnie@rutgers.edu
Prof. R. B. Sills	2025	ryan.sills@rutgers.edu
Prof. A. Goel	2026	ag1179@soe.rutgers.edu
Prof. E. K. Akdoğan	Undergraduate Director	eka@soe.rutgers.edu
Prof. L. C. Klein	Department Chair	licklein@soe.rutgers.edu

If your Advisor cannot resolve any problem, either academic or personal, or if you cannot make contact with that person or an alternate quickly enough, the Undergraduate Director or Department Chair happily will be of assistance. You may also contact Ms. Nahed Assal, the Undergraduate Program Administrator.

COMPUTING LABORATORY

The Undergraduate Computer Laboratory is located in ARC –Allison Road Classroom. In addition, there are various computing facilities available to students working within the Department throughout the various labs. One such Lab is located in CCR 211.

UNDERGRADUATE SCHOLARSHIPS

The Department maintains an outstanding scholarship program for its students. Undergraduate Scholarships are available to students based on their cumulative grade point average or financial need. Scholarships exist to help students regardless of gender, race, or ethnic background. Benefactors and corporate sponsors fund scholarships. Awards may range from \$500 to \$1,500 depending on scholarship specifications. Students interested in these scholarships should contact the Undergraduate Office for details.

STUDENT EMPLOYMENT

Each year the Department offers student employment in the Undergraduate Lab Technician Program. This program offers real world experience in state of the art research laboratories. This program is for undergraduate MSE majors who apply for part-time work in the Departmental laboratories to assist the graduate students and faculty with their research. Ten hours per week is the maximum lab time in order to prevent interruption of a student's studies.

CAREER AND SUMMER PLACEMENT

By the efforts of the Department, a dedicated student has laboratory and industrial employment opportunities available to exercise and apply his or her knowledge and skills. In the course of the academic year, companies from New Jersey and surrounding states contact the Department to arrange interview sessions with undergraduate students for career employment. Summer internships offered by various companies throughout the country are posted on MSE website. Students are encouraged to speak with their Advisors regarding questions about employment.

Engineering Career Services holds annual orientation meetings for seniors, which constitutes a valuable opportunity for becoming familiar with creating a resume and interviewing. It is advisable to be registered with the Career Services Office as early as your sophomore year as Co-op and Summer Internship opportunities often exist. Placement personnel are willing to provide assistance and guidance whenever necessary.

ACADEMIC INTEGRITY

New Brunswick Campus Policy on Academic Integrity for Undergraduate Students: "Academic freedom is a fundamental right in any institution of higher learning. Honesty and integrity are necessary preconditions for this freedom. Academic integrity requires that all academic work be wholly the product of an identified individual or individuals. Joint efforts are legitimate only when the assistance of others is explicitly acknowledged. Ethical conduct

is the obligation of every member of the university community and breaches of academic integrity constitute serious offenses” (Academic Integrity Policy, p1).

The principles of academic integrity entail simple standards of honesty and truth. Each member of the university has the responsibility to uphold the standards of the community and to take action when others violate them. Faculty members have an obligation to educate students to the standards of academic integrity and to report violations of these standards to the appropriate deans. Students are responsible for knowing what the standards are and for adhering to them. Students should bring any violations of which they are aware to the attention of their instructors.

STUDENT ORGANIZATIONS

We are fortunate to have several very active student organizations in which our majors can participate. Student professional societies include: the student branch of the American Ceramic Society (ACers), which is part of the Material Advantage Program, the student branch of the National Institute of Ceramic Engineers (NICE), the National Professional Ceramic Engineering Fraternity (KERAMOS), the Ceramic Association of New Jersey (CANJ), and the student branch of the Materials Research Society.

A person from one or more of these organizations typically contacts students. That person would be very pleased to discuss the activities and membership procedures with you. Each year the undergraduate officers of these organizations changes, however, each organization has a Faculty Advisor that provides class-to-class continuity. These Faculty members would be happy to discuss these organizations with any interested student.

The Advisors are as follows:

Faculty Advisor	Organization
Prof. A. Goel	International Congress on Glass
Prof. E. K. Akdoğan	Materials Research Society
Prof. R. Sills	Materials Advantage/Keramos
Prof. R. Lehman	Society of Plastics Engineers
Prof. D. O’Carroll	SPIE, Society for Optics and Photonics

The benefits, both immediate and long-term, from participation in these organizations cannot be overemphasized. Included among the dividends are: the chance to become acquainted with other students and the staff members of the Department, some excellent insight regarding the nature of your field, an early and continuing exposure to the practical and applied aspects of the materials disciplines through plant trips and attendance at national or regional meetings, and finally, beneficial contact with practicing engineers. These organizations also provide their members with effective mechanisms for interacting with Faculty and the Departmental Administration.

KERAMOS

Keramos is the National Professional Ceramic Engineering Fraternity founded in 1902 at Ohio State University. The members of Keramos include undergraduate and graduate students, faculty, staff, and alumni. The goal of Keramos is not so much an award for accomplishment as a banding together of persons of common professional goals and high expectations of service and achievement in their professional life after leaving campus. In other words, our goal is to increase the prestige of the ceramic engineering profession rather than simply set apart those students who have achieved academic excellence. These objectives provide the basis for the various semester activities.

TOURS AND ENGINEERING OPEN HOUSE

Every Friday the Department provides a tour of the facilities to prospective students. This, along with Open House, is a great opportunity to tour labs and meet Faculty and students. Engineering Open House is an annual event sponsored by the School of Engineering. Each department offers exhibits and tours to the many visitors, which the event attracts. We are proud of the involvement of our students. Under the guidance of our Faculty, our undergraduates are our greatest ambassadors. Close to 100% of our students will volunteer some of their time to act as a tour guide, man exhibits, or help set up displays and exhibits for these events.



All MSE students have the opportunity to participate in a variety of undergraduate activities. Our students are active in providing tours for high schools as well as coordinating Open House.

UNDERGRADUATE CURRICULUM

The MSE Department offers an undergraduate curriculum in Materials Science & Engineering. This area of study leads to a Bachelor of Science degree. The curriculum is designed to allow the student tremendous flexibility in designing a program that fits his/her specific needs, interests and goals. The curriculum is designed to exceed the requirements necessary for accreditation by the Accreditation Board for Engineering and Technology (ABET). The curricula sheets (following pages) illustrate the nature of the course selection and planning with which you will be involved throughout your undergraduate career.

PROGRAM OBJECTIVES

The Materials Science & Engineering Department is committed to provide qualified students with a relevant education in Materials Science & Engineering preparing them for a productive and rewarding career. This mission is consistent with the overall mission of the University and the School of Engineering. The Department provides an education that is both learning and practice oriented. With its high faculty to student ratio, the Department provides unique course options, extensive laboratory experiences, along with research and co-op internships that have adapted to the changing requirements of employers and graduate schools.

Through continuous feedback from students, alumni, industry and employers the Department has developed a curriculum that emphasizes basic science, engineering and design. But moreover, the curriculum provides flexibility and diversity in allowing students to select areas of concentration that are in the forefront of technology today.

Within the scope of the MSE mission, the objectives of the Materials Science & Engineering Program are to produce graduates with an education relevant to current science and engineering, and an education that will lead to a productive and rewarding career. Specifically, the MSE department has program education objectives such that graduates of the program are expected within a few years of graduation to have:

- Used their engineering skills, enhanced through the onset of life-long learning, to apply innovative solutions to assist in solving critical engineering problems to provide economic, ethical, environmental, and societal value.
- Worked individually or with teams of professionals to provide innovative concepts and technologies that address the scientific or engineering needs of academia, industry, commerce, and society.
- Demonstrated a track record of professional leadership characterized by scientific or engineering accomplishments and productivity in one or more of the broad industries for which Materials Science and Engineering is the enabling foundation.

ACADEMIC PERFORMANCE AND REQUIREMENTS FOR GRADUATION

In order to earn a B.S. in Materials Science and Engineering, students must earn a minimum cumulative GPA of 2.0 and a major GPA of 2.0. Major courses are defined as those with an M prefix in the curricula listed in the Appendix. If the student anticipates any problems in meeting the requirements for graduation, it is the student's responsibility to meet with the Undergraduate Director well in advance of the end of the last semester.

ELECTIVES

There are four types of electives that the student may select: General, Humanity/Social Science, Technical, and Department Electives.

General Electives are defined as any course, excluding those listed by the School of Engineering as unacceptable. A list of acceptable and unacceptable General Electives is included in the Appendix of this booklet.

Hum/Soc Electives are defined as specific courses that go beyond a math, science or engineering curriculum. The undergraduate curriculum is designed with 18 credits of

Hum/Soc courses. Twelve credits are open for the student to select. There is a fixed list of potential Hum/Soc electives from which the student may select. This list is included in the Appendix of this booklet. Students are advised to discuss these electives with their Academic Advisor.

Technical Electives are designed to provide a course or series of courses that supplement the MSE Program. Courses that can be considered a Technical Elective include most selected science, math, statistics or other engineering courses that add to the students Materials Science and Engineering experience. All Technical Electives must be cleared with your advisor before registering. A list of acceptable Technical Electives is included in the Appendix of this booklet. Graduate courses may also be used as Technical Electives.

Department Electives are most non-core courses offered by the MSE Department. In most cases, a Specialization Elective must be a 300 or 400 level course. Courses outside the Department are also acceptable but must be approved by your advisor and the Undergraduate Director. Graduate courses may also be used as Department Electives.

REGISTRATION

You should register online. You can access the registration form from anywhere in the world regardless of the school you attend. A user-friendly menu will guide you through the process. You will find detailed instructions in the *Schedule of Classes*. Complete the Add/Drop worksheet before calling. Use the worksheet to guide you through your add/drop transactions. The required courses and sequence of courses that a MSE student must follow are shown in the Appendix. *However, A student can deviate from this sequence only by having written permission from the Undergraduate Office.*

The MSE Department requires all sophomores, juniors and seniors to see their assigned Advisors during the spring and fall registration period to avoid being deregistered. The schedule for advising, posted on the Undergraduate Bulletin Board and outside each advisor's office should be checked prior to the registration period. If the student's class schedule conflicts with the advisor's office hours, it is the student's responsibility to contact the advisor and make other arrangements prior to the registration deadline. All deadlines are strictly enforced. No exceptions!

TRANSFER OF COURSES

At times a student may elect to take courses outside of Rutgers. It is important that students realize that they must ensure that these courses match with an existing course at Rutgers. Students should meet with the Undergraduate Director prior to taking any outside courses to determine whether degree credit can be assigned to these courses.

CO-OP INTERNSHIP 635:496/497 (3/3 credits, Pass/No Credit basis only)

The Co-op internship provides the student with the opportunity to practice and/or apply knowledge and skills in various ceramic or materials engineering professional environments. This internship is intended to provide a real-world experience to the student's undergraduate studies by integrating prior course work into a working engineering environment. The credits earned are for the educational benefits of the experience. Typically, the Internship is taken during the summer and the fall semester following a

student's junior year. This will require that the student take one extra semester to graduate. The Department will assist students wishing to participate in the Internship by finding appropriate placement. Students are encouraged to discuss the Co-Op Internship with their Academic Advisors in their sophomore year.

The students must satisfy the following criteria to be eligible to enter a Co-op internship:

1. Complete minimum of 85 credits within a cumulative grade point average of at least 2.5 and cannot currently be on probation.
2. Complete a minimum of 30 credits in the major, with a major cumulative grade point average of at least 2.5.
3. In special cases, a student may take the Co-op Internship starting in the spring semester and continuing the Internship through the summer.
4. The 6 credit Co-op Internship will replace one Specialization or Technical Elective and the General Elective and should be taken in the fall semester. If this causes an overload of credits permission will be granted by the Dean's office.

The grading for this course will be based upon the recommendation of the student's industrial supervisor in consultation with the faculty advisor. Students will be required to make a presentation and provide a report, detailing their experience.

AREAS OF CONCENTRATION

Our students, alumni and the employers of our students have a great influence on our curriculum. Recently this was demonstrated by their desire to create areas of concentration that are critical to today's graduating engineers. In response to our constituencies, we have established seven exciting Areas of Concentration:

1. Biomaterials.
2. Electronic and Optical Materials.
3. Energy Conversion and Storage.
4. Metals.
5. Nanomaterials.
6. Packaging Materials.
7. Polymers.

An Area of Concentration is defined by a student selecting a minimum of three courses (9 credits) from a list of electives in an area provided on the MSE website. Students who complete the sequence of four courses will be awarded a Certificate. Selection of an Area of Concentration should be made after meeting with your Academic Advisor at the end of the spring semester of the sophomore year.

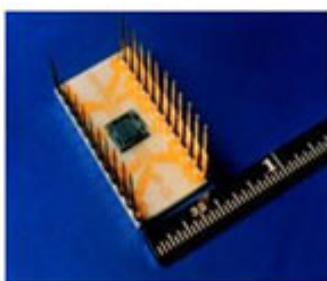
CURRICULUM FOR THE MSE DEPARTMENT

The next few pages provide students with the minimum requirements and the recommended sequence of courses necessary to graduate

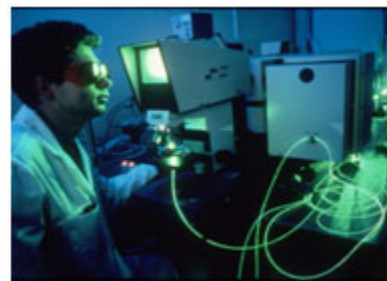
Materials are the essential enabling substances of all engineering technologies



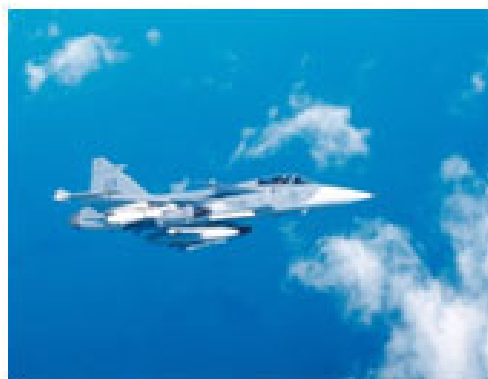
Ballistic Test: Impact resistant armor materials.



Integrated circuit for military applications



Argon laser light transmitted through optical fiber



The Saab JAS-38 in test flight



High efficiency thermal insulation



Full body medical scanners

Questions on any aspect of the curriculum? Check with the Undergraduate Director:

Professor E. K. Akdoğan

[*eka@soe.rutgers.edu*](mailto:eka@soe.rutgers.edu)

Room 114, McLaren Ceramics Building

(848) 445-4513

Materials Science and Engineering Curriculum

Updated 12 November 2020 – GE Core in Red, Major in Black

First Semester

160:159	Chemistry I for Engineers	GE	3
160:171	Intro to Experimentation	GE	1
355:101	Expository Writing	GE	3
640:151	Calculus I Math/Phys	GE	4
750:123	Analytical Physics IA	GE	2
440:100	Engineering Orientation Lec	GE	1
___:___	Hum/SocSci Elective	GE	3
Credits			17

Second Semester

160:160	Chemistry II for Engineers	GE	3
640:152	Calculus II Math/Phys	GE	4
750:124	Analytical Physics IB	GE	2
440:127	Intro Computers for Eng'g	GE	3
440:221	Eng Mechanics:Statics	GE	3
___:___	Hum/SocSci Elective	GE	3
Credits			18

Third Semester

640:251	Multivariable Calculus	GE	4
750:227	Analytical Physics IIA	GE	3
750:229	Analytical Physics IIA Lab	GE	1
960:xxx*	Statistics (*211, 384, 401, 490)	M	3
635:203	Intro to MSE	M	3
635:205	Crystal Chem & Struct	M	3
Credits			17

Fourth Semester

640:244	Differential Equations	GE	4
635:204	Materials Processing	M	3
635:206	Mat. Thermodynamics	M	4
635:212	Physics of Materials	M	3
635:252	Laboratory I	M	2
Credits			16

Fifth Semester

635:305	Materials Microprocessing	M	3
635:307	Kinetics of Mat'l Processing	M	3
635:309	Characterization of Materials	M	3
635:316	EOM Properties of Materials	M	3
635:353	Laboratory II	M	2
___:___	Elective (Dept/Tech)	M	3
Credits			17

Sixth Semester

540: 343	Engineering Economics	GE	3
635:314	Strength of Materials	M	3
635:354	Laboratory III	M	2
635:401	Senior MSE Lab I	M	3
OR (only one of 401/411 is required)			
635:411	MSE Eng Design I	M	3
___:___	Elective (Dept/Tech)	M	3
Credits			14

Seventh Semester

635:402	Senior MSE Lab II	M	3
OR (only one of 402/412 is required)			
635:412	MSE Eng Design I	M	3
635:403	MSE Seminar	M	1
___:___	Elective (Dept/Tech)	M	3
___:___	Elective (Dept/Tech)	M	3
___:___	Elective (Dept/Tech)	M	3
___:___	Hum/SocSci Elective (300+)	GE	3
Credits			16

Eighth Semester

635:404	MSE Seminar	M	1
___:___	Elective (Dept/Tech)	M	3
___:___	Elective (Dept/Tech)	M	3
___:___	Hum/SocSci Elective (300+)	GE	3
___:___	General Elective	GE	3
Credits			13

Total Credits at Graduation: 128

Electives

Aside from the Humanities/Social Science electives, the Materials Science and Engineering (MSE) program contains eight elective slots (4 Department, 3 Technical, and 1 General) that can be used to tailor your degree. You can concentrate in specific areas of MSE, dual major, or prepare for specialized professional training after graduation. Talk to us about your interests and we will help you identify the best possibilities. Contact Professor Akdoğan for advice at eka@soe.rutgers.edu.

Department Electives (4)

Take two from this list...

- 635:312 Glass Engineering
- 635:360 Ceramics Engineering
- 635:361 Materials Science and Engineering of Polymers
- 635:362 Physical Metallurgy

...and two from this list:

- 635:312 Glass Engineering
- 635:320 Introduction to Nanomaterials
- 635:321 Structural, Mechanical & Chemical Applications of Nanostructures & Nanomaterials
- 635:322 Photonic, Electronic & Magnetic Applications of Nanostructures & Nanomaterials
- 635:360 Ceramics Engineering
- 635:361 Materials Science & Engineering of Polymers
- 635:362 Physical Metallurgy
- 635:405 Solar Cell Design & Processing
- 635:407 Mechanical Properties of Materials
- 635:410 Biological Applications of Nanostructures & Nanomaterials
- 635:413 Materials Science & Engineering: Venture Analysis
- 635:416 Physical & Chemical Properties of Glass
- 635:440 Electrochemical Materials and Devices
- 635:505 Advanced Optical Materials

Technical Electives (3)

Your three technical electives may be selected from the Department Electives list or from the list below. If you wish to take a course not on this list (e.g., graduate courses or courses in other fields), apply to Professor Akdoğan (eka@soe.rutgers.edu) in writing explaining your rationale.

- 01:119: Biological Sciences: only 119:100-103, 131, 140, and 148
- 01:146: Cell Biology & Neurosciences: all except 146:302
- 01:160: Chemistry: all 160:3xx and 4xx
- 01:198: Computer Sciences: all except 198:105, 107, 110 and 170

- 01:447: Genetics & Microbiology: all except 447:302
- 01:460: Geological Sciences: all except 460:206
- 01:640: Mathematics: 640:250 and all 640:3xx and 4xx except 640:336, 338, 339, and 436
- 01:694: Molecular Biology & Biochemistry: all
- 01:750: Physics: 750:228/230 and all 750:3xx and 4xx
- 01:960: Statistics: all
- 11:115: Biochemistry: all 115:3xx and 4xx
- 11:126: Biotechnology: all
- 11:127: Bio-resource Engineering: all
- 11:375: Environmental Sciences: all
- 11:400: Food Sciences: only 400:201, 304, 401, and 411
- 11:628: Marine Sciences: all
- 11:670: Meteorology: all
- 14:125: Biomedical Engineering: all 125:2xx and 3xx
- 14:155: Chemical & Biochemical Engineering: all
- 14:180: Civil & Environmental Engineering: all
- 14:332: Electrical & Computer Engineering: all except 301
- 14:440: Packaging
- 14:540: Industrial Engineering: 540:201/202 and all 540:3xx and 4xx
- 14:635: Materials Science and Engineering: all except 407
- 14:650: Mechanical & Aerospace Engineering: all except 650:351

Statistics

One of the following courses must be taken to satisfy the statistics requirement:

- 960:211 Statistics I
- 960:384 Intermediate Statistical Analysis
- 960:401 Basic Statistics for Research
- 960:490 Introduction to Experimental Design

Double Majoring

The MSE curriculum is quite flexible and permits double majoring in certain instances for students with AP credits or transfer credits.

Concentrations

The MSE Department presently has seven areas of concentration in which you may specialize and receive a certificate upon graduation. These are highly relevant areas science and engineering that are favored by graduate schools and employers. See the following page. To receive a certificate in any one of these areas you must take at least three of the courses listed.

The 7 Optional MSE Concentrations

Enhance your MSE experience with a Concentration in one or more specific areas of interest described below.

Concentration	Acceptable Courses (Choose 3)
<p>Electronic & Optical</p> <p>Faculty coordinators: Professors Safari & Birnie</p>	<ul style="list-style-type: none"> • 14:635:322 Photonic, Electronic and Magnetic Applications of Nanostructures and Nanomaterials (3) • 14:635:405 Solar Cell Design and Processing (3) • 14:635:413 Solar Technology Venture Analysis (3) • 14:332:466 Opto-Electronic Devices (3) • 14:635:505 Advanced Optical Materials (3) • 12:750:305 Modern Optics (3) • 12:750:406 Introductory Solid State Physics (3)
Concentration	Acceptable Courses
<p>Energy Conversion & Storage</p> <p>Faculty coordinators: Professors Klein & Amatucci</p>	<ul style="list-style-type: none"> • 11:375:322 (F) Energy Technology and its Environmental Impact (3) • 14:635:405 (F) Solar Cell Design and Processing (3) • 14:332:402 (S) Sustainable Energy: Choosing Among Options (3) • 14:635:440 (S) Electrochemical Devices (3) • 14:332:361 (S) Electronic Devices (pre-requisite is Principles of Electrical Engineering 14:332:222) (3) • 14:332:460 (S) Power Electronics (pre-requisite is Electronic Devices 14:332:361) (3)
Concentration	Acceptable Courses
<p>Nanomaterials</p> <p>Faculty coordinators: Professors O'Carroll & Klein</p>	<ul style="list-style-type: none"> • 14:635:320 Introduction to Nanomaterials (3) • 14:635:410 Biological Applications of Nanomaterials (3) • 16:635:604 Introduction to Nanoscience and Nanotechnology (3) • 16:635:321 Structural, Mechanical, and Chemical Properties of Nanomaterials. (3)
Concentration	Acceptable Courses
<p>Polymers</p> <p>Faculty coordinators: Professors Lehman & Wenzel</p>	<ul style="list-style-type: none"> • 01:160:307 Organic Chemistry I (4) • 14:635:361 Materials Science and Engineering of Polymers • 16:155:551 Polymer Science and Engineering • 14:440:301 Introduction to Packaging • Polymer Engineering or Science Elective (TBD)

Concentration	Acceptable Courses
Packaging Materials	<ul style="list-style-type: none"> • 14:635:312 Glass Engineering • 14:635:361 Polymer Engineering
Faculty coordinators: Professors Lehman & Nosker	<ul style="list-style-type: none"> • 14:635:362 Physical Metallurgy • 14:440:301 Intro to Packaging 3 • 14:440:302 CAD in Packaging 3 • Other Packaging Engineering or Science Elective (TBD)

Concentration	Acceptable Courses
Metals	<ul style="list-style-type: none"> • 14:635:362 Physical Metallurgy • 14:635:206 Thermodynamics of Materials
Faculty coordinators: Professors Akdoğan & Sills	<ul style="list-style-type: none"> • 14:635:307 Kinetics of Materials Processing • 14:635:314 Strength of Materials

Questions on any aspect of the curriculum? Check with the Undergraduate Director:

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eka@soe.rutgers.edu

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DESCRIPTION OF MATERIALS SCIENCE AND ENGINEERING COURSES

14:635:203. INTRODUCTION TO MATERIALS SCIENCE AND ENGINEERING (3)

Pre- or Co-requisite 01:160:160 or 01:160:162

The general field of materials, including its development and present scope, the classification of the industry by major divisions, and discussion of the technology of these industries. The broad principles of materials based on an approach from crystal physics and unit processes.

14:635:204. MATERIALS PROCESSING I (3)

Pre-requisites: 14:635:203

The methods and techniques of producing ceramic raw materials from mined ores are investigated with an emphasis on the fundamental processes of liberation and separation, and the engineering of these materials to suit specific material processes and applications. Types of raw materials and their application, mining methods, and control parameters are considered broadly. Emphasis is placed on modern beneficiation technology. Ceramic raw materials for advanced materials are studied and discussed in the context of their predominantly chemical origin. Important properties of both chemical and mineral raw materials are examined with respect to processing and property requirements. Recovery and utilization of wastes, raw material blending, and the use of previously unusable materials are discussed in the context of the characterization and reformulation concept.

14:635:205 CRYSTAL CHEMISTRY AND STRUCTURE OF MATERIALS (3)

Pre- or Co-requisite: 01:160:160 or 01:160:162

This course introduces concepts of crystal chemistry applied to ceramics, oxides and non-oxides. It develops from bonding, the unit cell, crystallography and symmetry in such a way that the ceramic engineering students have a basis for structure-property relationships.

14:635:206 THERMODYNAMICS FOR MATERIALS (4)

Pre-requisite 01:160:160 or 01:160:162, 01:640:244

The laws of thermodynamics, thermochemistry (isothermal and nonisothermal processes -adiabatic flame temperature), auxiliary functions (Pfaffians, Legendre transform, Helmholtz and Gibbs Free Energies, Maxwell Relations), one component systems (Gibbs Phase Rule, Clausius-Clayperon Equations, Unary Phase Diagram and Equilibria), open systems (Chemical potential concept, Partial and Relative Partial Molar Properties and Integral Molar Properties, Gibbs-Duhem relation), Activity concept and the Behavior of Solutions (Raoult's and Henry's laws, ideal behavior, regular solutions, quasi-regular solutions), thermodynamics of binary phase diagrams (Gibbs free energy curves and construction of phase diagrams) and development of microstructure (eutectic, eutectoid, peritectic, peritectoid etc.), thermodynamics of chemical reactions (Activity quotient, equilibrium constant, gas phase equilibria, gas-solid reactions, condensed phase equilibria, Ellingham Diagrams, Boudouard equilibrium etc.), elements of thermodynamics of surfaces (effect of surface curvature, effect of particle size, effect of particle size on solubility).

14:635:212 PHYSICS OF MATERIALS (3)

Pre-requisites: 01:640:244, 635:203

This course extends the coverage of structure-processing-property relationships and emphasizes properties. It includes an introduction to thermal processes and thermal properties, as well as optical properties.

14:635:253 LABORATORY I (2)

Lab. 3 hrs., Lec. 55 min.

This laboratory course focuses on helping the student develop skills for the planning, execution and reporting of formal experimental results relating to the processing of ceramic materials. Various

topics expose students to ceramic fabrication methods used in industry such as powder processing, porcelain enameling and melt forming.

14:635:353 LABORATORY II (2)

Lab. 3 hrs., Lec. 55 min.

This laboratory course focuses on helping the student develop skills for the planning, execution and reporting of formal experimental results relating to the characterization of selected materials. Various topics expose student to ceramic characterization procedures used in industry such as particle size measurement, phase identification and dilatometry.

14:635:305 MATERIALS MICROPROCESSING (3)

Pre-requisite: 14:635:204, 01:160:160 OR 01:160:162

This course will equip the student with a fundamental understanding of the processing steps, which precede forming. In order to accomplish this, both the processes and additional fundamental not covered in other courses must be discussed. Such fundamental topics include powder processing, rheology and organic and colloidal chemistry. The role of these fundamental processes in forming is stressed by a detailed discussion of casting methods.

14:635:307 KINETICS OF MATERIALS PROCESSES (3)

Pre-requisite: 14:635:205, 206, 01:640:244

This course takes a phenomenological approach to the solid-state reactions involved in materials processing. It includes phase transformations and phase separation. It discusses mechanisms and transport phenomena.

14:635:309 CHARACTERIZATION OF MATERIALS (3)

Pre-requisite 01:160:160 or 01:160:162, 14:635:205

Interactions of electromagnetic radiation, electrons, and ions with matter and their application in x-ray diffraction and x-ray, IR, UV, electron and ion spectroscopies in the analysis of materials. Additional, non-spectroscopic analytical techniques are also covered.

14:635:312 GLASS ENGINEERING (3)

Pre-requisite: 14:635:204, 303

Discussion of basic physical and chemical properties, chemical durability, stress release, annealing and tempering, mechanical strength, raw materials and melting, and methods of manufacture. Design of composition for desired engineered properties.

14:635:314 STRENGTH OF MATERIALS (3)

Pre-requisite: 01:640:244, 144, 01:750: 124

The mechanical behavior of materials is discussed with emphasis on brittle behavior at room temperature and the transition to a limited plasticity regime at high temperatures. The interplay of basic deformation mechanisms with microstructural features and the implication for design and processing of materials are considered.

14:635:320 INTRODUCTION TO NANOMATERIALS (3)

Open to all Science and Engineering Students who have completed 60 credit hours

Nanotechnology involves behavior and control of materials and processes at the atomic and molecular levels. This interdisciplinary course introduces the student to the theoretical basis, synthetic processes and experimental techniques for nanomaterials. This course is the introduction to 3 advanced courses in (1) Photonic, Electronic and Magnetic Applications of Nanomaterials and Nanostructures, (2) Structural, Mechanical and Chemical Applications, and (3) Biological Applications.

14:635:322 PHOTONIC, ELECTRONIC, AND MAGNETIC APPLICATIONS OF NANOSTRUCTURES AND NANOMATERIAL (3)

This course covers electronic applications of nanomaterials such as quantum dots, nanowires, field effect transistors, and nanoelectromechanical systems. Magnetic applications include information storage, giant and colossal magnetoresistance, and superparamagnetism. Photonic applications include nanolasers, photonic band gap devices and dense wavelength multiplexers.

14:635:340 ELECTROCHEMICAL MATERIALS AND DEVICES (3)

This course will give an introduction to basic electrochemistry, principles of electrochemical devices, electroactive materials used in such devices, and case studies of batteries, fuel cells, and sensors. An emphasis is placed on the integration of electrochemical principles and materials science for application in modern electrochemical devices.

14:635:355 LABORATORY III (2)

Lab. 3 hrs., Lec. 55 min.

This laboratory course focuses on helping the student develop skills for the planning, execution and reporting of formal experimental results relating to the measurement of ceramic materials properties. Properties investigated are optical, electrical and mechanical in nature. The measurement method as well as the structure-property relationship found in ceramic materials will be stressed. In addition, principles of electrical engineering relevant to the property measurements will be also be emphasized.

14:635:360 MATERIALS SCIENCE & ENGINEERING OF CERAMICS & GLASSES

The course focuses on the principal materials fields that are satisfied by ceramic materials. The topics covered by this course go well beyond those covered in Introduction to Materials Science and Engineering 14-150:150:203. These topics include traditional areas such as whitewares, enamels, glazes, glass and refractories. In addition a wide range of advanced materials topics include electronic, magnetic, optic, biomedical, catalyst and structural materials. An emphasis will be placed on understanding the interrelationship between chemistry, structure, properties and performance.

14:635:361 MATERIALS SCIENCE & ENGINEERING OF POLYMERS

This course focuses on the principal materials fields that are satisfied by organic polymers. The topics covered by this course go well beyond those covered in Introduction to Materials Science and Engineering 14-150:203. Topics covered in this course include, polymerization, structure, characterization methods, stress/strain behavior, processing methods, and structure-property relationships with an emphasis on mechanical, optical, and transport properties.

14:635:362 PHYSICAL METALLURGY

Pre-requisite: 14:635:206

This course introduces MSE students to the fundamentals relating composition, structure and processing of metals and alloys and their properties. Throughout the course, examples will be given of conventional and specialty alloys usage in today's construction, transportation, energy, and consumer products industries. Materials problems will be discussed to underline the importance of the cross-disciplinary effort needed to integrate materials and component design in today's advanced engineered systems, such as gas-turbine engines, nuclear reactors, space vehicles, and communications systems. The topics of discussion include: Elements of Elasticity and Plasticity Theory, Elements of Dislocation Theory, Strengthening Mechanisms, Recovery and Recrystallization, Solidification in Metals and Alloys, Conventional casting, directional solidification, and rapid solidification processing, Production of metal powders by inert-gas atomization, Diffusional Phase Transformations and Microstructural Development (Eutectic, Eutectoid, Bainitic, Order-disorder transitions and Precipitation Reactions), Displacive Phase Transitions (Martensite), Heat Treatment of Steel and Nonferrous metals. Metallurgy of Brittle and Ductile Fracture (Crack tip plasticity),

Elements of Creep in Metals and Alloys; Elements of Fatigue in Metals and Alloys. Survey on the classification of metals, abundance, and prices. Materials usage in today's advanced engineering systems. Elements of Chemical Metallurgy and Review of Extraction Processes for Ferrous: and Nonferrous Metals: Processing and properties of steels, titanium alloys, and nickel-base alloys, and their applications.

14:635:401, 402 SENIOR MATERIALS SCIENCE & ENGINEERING LABORATORY I, II (3,3)

Conf. 1 hr., lab 6 hrs.

Training in methods of independent research. Students, after consultation, are assigned a problem connected with some phase of materials or materials engineering in their elected field of specialization.

14:635:403, 404 SENIOR MATERIALS SCIENCE & ENGINEERING SEMINAR (1,1)

Current trends and topics of special interest in materials discussed by faculty, students, and representatives from the materials industry.

14:635:405 SOLAR CELLS AND DEVICES (3)

Pre-requisites: 14:750:227, 229

The course will cover principles of photovoltaic solar cells and build from that foundation to discuss how these principles guide solar cell design. Significant time will be devoted to the wide variety of processing methods that are utilized for making different kinds of solar cells. This class is intentionally hands-on oriented with an emphasis on design. In addition to the lecture foundation that stresses the principles, there will be major student design project that will help emphasize the basic current-voltage output responses of solar cells.

14:635:407 Mechanical Properties of Materials (3); MSE Major not eligible for this course. Course offered to all School of Engineering departments as a technical elective.

This course provides an in-depth discussion on the factors governing the macroscopic mechanical response of engineering materials. It does so by establishing relationships between an applied load and the response developed by the materials' microstructure. To understand such mechanical response, it is imperative to develop a thorough understanding of the constitution of solids, and their microstructures that control their mechanical properties. As such, the discussion in this course is based on structure-property relations, and covers multiple length scales spanning seven orders of magnitude, i.e. from nanometers to centimeters. The mechanical properties of materials is one of the core engineering subjects that is of utmost importance in the design and analysis of engineering systems originating from any of the engineering disciplines (electrical, electronics, mechanical, chemical, civil, biomedical etc.). That is so because mechanical failure is the common denominator of all engineering disciplines (in one way or another), which we try to prevent in a give system. In this course, the students will learn the fundamentals of materials science and engineering appertaining to the mechanical properties of engineering materials such as elasticity, plasticity, strength, hardness, ductility, fracture, time dependent deformation and the impact of environmental effects on such properties -concepts that need to be mastered by a competitive professional engineer whose mission is to advance modern society by innovating new engineering technologies.

14:635:410 BIOLOGICAL APPLICATIONS OF NANOSTRUCTURES AND NANOMATERIAL (3)

(Co-listed with 125:582)

This course is interdisciplinary in nature and seeks to involve engineers and scientists in exploring how the multi-scale nature of materials can be tailored to invoke biological response for a wide rang of biomedical materials ranging from metal alloys, ceramics and polymers. A focus on the nanoscale is made to emphasize how this length scale can engage the sciences/technology acumen of both the life science, hard science and engineering disciplines. Topics of interest include materials processing,

interfacial engineering, nano-bio, micro - and nano-machines, and the relationship of this technology to biomedical materials and devices.

14:635:411, 412 CERAMIC AND MATERIALS ENGINEERING DESIGN I, II (3,3)

Pre-requisites: 14:635:204-305-306. Co-requisite: 14:635:411

Fundamentals of equipment and plant design, construction, installation, maintenance, and cost for manufacture of ceramic products. Assignment of a problem in elected field of specialization.

14:635:413 CERAMIC ENGINEERING VENTURE ANALYSIS (3)

Pre-requisite: 01:220:200

Product innovation and development techniques for ceramic materials based on traditional venture—analysis techniques. Aspects of marketing, engineering design, framework structuring, and decision and risk analysis.

14:635:414 ELECTRONIC, OPTICAL, AND MAGNETIC PROPERTIES OF MATERIALS (3)

Pre-requisite: 14:635:205, 355

This course will introduce the concept of electrons in solids. Specifically, it will describe how electrons interact with each other, electromagnetic radiation and the crystal lattice to give the material its inherent electrical, optical and magnetic properties. Semiconductors, metals, insulators, polymers and superconductors will be discussed.

14:635:416 PHYSICAL AND CHEMICAL PROPERTIES OF GLASS (3).

Pre-requisites: 01:160:160 or 01:160:162, 01:750:228

Provide an atomistic understanding of the role of composition on the structure and properties of glasses.

14:635:433 OPTICAL MATERIALS (3)

Fundamentals of optical materials (crystal, glasses, polymers). Relation of structure with optical properties and applications. Spectral characteristics of thin material.

14:635:491, 492 SPECIAL PROBLEMS (BA, BA)

Individual or group study or study projects, under the guidance of a faculty member on special areas of interest in ceramic engineering.

14:635:496, 497 CO-OP INTERNSHIP (3,3)

Pre-requisites: Open to MSE students who have completed their junior year & maintain a GPA of 2.5.

The internship provides the student with the opportunity to practice and/or apply knowledge and skills in various ceramic or materials engineering professional environments. This internship is intended to provide a capstone experience to the student's undergraduate studies by integrating prior course work into a working engineering environment. The credits earned are for the educational benefits of the experience. The student will be provided with real world experience covering the fundamentals of materials, equipment, processing, plant design and product performance.

FACULTY PROFILES IN MATERIALS SCIENCE AND ENGINEERING

<p>E. Koray Akdoğan Undergraduate Program Director</p>	<p><i>Ph.D.; Rutgers University.</i> Computational and experimental chemical and solid state thermodynamics, Landau-Ginzburg-Devonshire theories, High temperature and pressure synchrotron and laboratory x-ray diffractometry (incl. Rietveld Analysis), Physics of Solids, Pulsed Laser Deposition of thin films, Experimental Micro- and nanomechanics, Dislocation Phenomena in Metals & Alloys and nonmetallic epitaxial thin films, Physics and processing of electrical-dielectric-piezoelectric-ferroelectric-electrostrictive bulk materials, thin films and nanoparticles.</p> <p><u>Contact Information:</u> Telephone: 848-445-4513 E-mail: eka@soe.rutgers.edu</p>
<p>Glenn Amatucci</p>	<p><i>Ph.D., Rutgers University.</i> Development and advancement of new energy storage device chemistries enabled by advancements in materials science, nonaqueous and solid state chemistries and understanding of bulk and interfacial operational and failure mechanisms which occur on the nanoscale during the operation of these ionically active materials.</p> <p><u>Contact Information:</u> Telephone: 848-932-6850 x 601 E-mail: gamatucc@soe.rutgers.edu</p>
<p>Dunbar P. Birnie</p>	<p><i>Ph.D., Massachusetts Institute of Technology.</i> Thin films, nanomaterials, processing, energy, spin coating, sol gel science, ferroelectric device fabrication, phase transformation modeling, solid state chemistry, and point defect properties, crystallography and structure determination, phase diagram determination, and advanced nanomaterials for solar energy applications.</p> <p><u>Contact Information:</u> Telephone: 848-445-5605 E-mail: dbirnie@soe.rutgers.edu</p>
<p>Laura Fabris</p>	<p><i>Ph.D., University of Padua (Italy).</i> Synthesis, characterization and application of nanoparticles and their assemblies in optics, electronics, and bio-nanotechnology.</p> <p><u>Contact Information:</u> Telephone: 848-445-5606 E-mail: lfabris@soe.rutgers.edu</p>

<p>Stephen H. Garofalini</p>	<p>Ph.D., Stanford University. Molecular dynamics simulations, surfaces and interfaces, glass, nanomaterials, structure, and kinetics.</p> <p><u>Contact Information:</u> Telephone: 848-445-2216 E-mail: shg@glass.rutgers.edu</p>
<p>Ashutosh Goel</p>	<p>Ph.D., University of Aveiro, Portugal. Bioceramics, Nuclear waste immobilization, Optical fibers, Chemical durability of glasses, Crystallization in oxide glasses, Structure - Property relationships in oxide glasses.</p> <p><u>Contact Information:</u> E-mail: ag1179@soe.rutgers.edu Telephone: 848-445-4512</p>
<p>Richard A. Haber Director, Ceramic, Composite & Optical Materials Center</p>	<p>Ph.D., Rutgers University. Processing and reformulation of silicon carbide, oxides and clay based systems; extrusion, slip casting, glazes, particulate composites, health aspects of particulate minerals, armor processing.</p> <p><u>Contact Information:</u> Telephone: 848-445-4931 E-mail: rhaber1@soe.rutgers.edu</p>
<p>Lisa C. Klein Department Chair</p>	<p>Ph.D., Massachusetts Institute of Technology. Sol-gel processing of glass frits, coatings and monoliths, silicate and phosphate glasses, viscosity, and transformation kinetics.</p> <p><u>Contact Information:</u> Telephone: 848-445-2096 E-mail: licklein@soe.rutgers.edu</p>
<p>Richard L. Lehman</p>	<p>Ph.D., Rutgers University. Glass transition, processing & properties of inorganic and organic glasses, mechanical and chemical properties of polymer blends, immiscible blends, behavior of multiphase composite interfaces & applicability of these systems in structural & biomedical applications, developing manufacturing technologies for commercial soda lime silicate glasses.</p> <p><u>Contact Information:</u> Telephone: 848-445-2317 E-mail: rllehman@soe.rutgers.edu</p>
<p>Adrian Mann Graduate Program Director</p>	<p>Ph.D., Oxford University. Biomaterials, Nanomaterials, early stages of diseases in mineralized tissues are being studied, examples include dental caries and osteoporosis in bone. Near-field scanning optical microscopy and advanced modeling techniques are used to study the deposition, growth,</p>

	<p>chemistry, and mechanics of thin protein films on biomaterials surfaces.</p> <p><u>Contact Information:</u> Telephone: 848-445-8421 E-mail: abmann@soe.rutgers.edu</p>
M. John Matthewson	<p><i>Ph.D., University of Cambridge (UK).</i> Mechanical behavior of optical materials and optical fibers, fatigue, reliability, liquid and solid impact, erosion of optical materials, protective coatings, impact properties of materials, thin films, mechanical properties, failure mechanisms, stress analysis, adhesion.</p> <p><u>Contact Information:</u> Telephone: 848-445-5933 E-mail: mjohnm@fracture.rutgers.edu</p>
Thomas Nosker	<p><i>Ph.D., Rutgers University.</i> Polymer physics, viscoelastic properties of polymers and composites, immiscible polymer blends and composites, polymer processing, polymer packaging, plastics recycling.</p> <p><u>Contact Information:</u> Telephone: 848-445-3631 E-mail: tjnosker@soe.rutgers.edu</p>
Deirdre O'Carroll	<p><i>Ph.D., Tyndall National Institute University College Cork (Ireland).</i> Nanoscale engineering of efficiency and direction of light generating and light harvesting processes in photonic devices which employ organic polymeric semiconductor materials and plasmonic nanostructures.</p> <p><u>Contact information:</u> Telephone: 848-445-1496 E-mail: ocarroll@soe.rutgers.edu</p>
Richard E. Riman	<p><i>Ph.D., Massachusetts Institute of Technology.</i> Hydrothermal synthesis, reactive-sol gel synthesis of nonoxides, mixedness modulated solid state reactivity, mixedness simulation and determination, powder characterization, thermodynamic and kinetic process modeling</p> <p><u>Contact Information:</u> Telephone: 848-445-4946 E-mail: riman@soe.rutgers.edu</p>
Ahmad Safari	<p><i>Ph.D., Pennsylvania State University.</i> Solid freeform fabrication, piezoelectric ceramics, ceramic-polymer composite devices, dielectrics and thermistors, ferroelectric and microwave ceramic, and thin films.</p>

	<p><u>Contact Information:</u> Telephone: 848-445-4367 E-mail: safari@soe.rutgers.edu</p>
Ryan Sills	<p><i>Ph.D., Stanford University.</i> Computational Micromechanics of Deformation, mechanical behavior of engineering materials and composites, development of advanced computational tools for mechanical properties and behavior of materials. Multiscale simulation of plasticity, damage, and fracture in metals and laminated composites, modeling techniques, and failure modes. Prof. Sill's group has a dedicated 1000 core, 4 GPU computing cluster in the School of Engineering for rapid modeling of large systems.</p> <p><u>Contact Information:</u> Telephone: 848-445-4942 E-mail: 848-445-4942</p>
Thomas Tsakalakos	<p><i>Ph.D., Northwestern University.</i> Nanostructured materials, multilayered thin film technology, magneto optic and ferroelectric nanomultilayers, mechanical properties of thin films, phase transformation in solids, spinodal alloys, diffusion in solids.</p> <p><u>Contact Information:</u> Telephone: 848-445-2888, Fax: 848-445-2873 E-mail: tsakalak@soe.rutgers.edu</p>
John Wenzel	<p><i>Ph.D., University of Chicago.</i> Glass technology, glass packaging, optical glasses and fibers, sol-gel processing, and refractories.</p> <p><u>Contact Information:</u> Telephone: 848-445-5092 Email: wenzel@soe.rutgers.edu</p>

LIST OF ACCEPTABLE HUMANITIES/SOCIAL SCIENCE ELECTIVES

NOTE: All updates and amendments from the Dean's Office are implemented in the Degree Navigator (DN). Please refer to the DN for the most up to date listing of acceptable Hum/Soc electives.

School Requirements:

All candidates for the B.S. degree must complete a minimum of 18 credits of Hum/Soc courses including the following:

- 01:355:101
- 14:540:343
- Four free electives chosen from courses listed below
- Free electives must be selected in a manner such that at least two courses are at the 300/400 (upper) level, at least two courses, including one upper level, are from the same subject area; and at least two different subjects are represented. All courses may be from the same subject if a minor is earned.
- Elementary language courses are normally not accepted for Hum/Soc credit. However, four semesters of a language (2 elementary and 2 intermediate) that was not taken in high school and is not the student's native language will count as 1 general, 1 Hum/Soc lower, and 1 Hum/Soc upper elective. The second upper level Hum/Soc elective must come from another subject unless a minor is earned.
- **Questions or appeals regarding course acceptability should be directed to the Associate Dean.**

Rationale for Hum/Soc Electives in the Curriculum:

A good undergraduate education should provide more than the development of technical skills. Properly chosen, Hum/Soc electives can complement your technical courses by helping you to develop an understanding of the problems facing our society, a historical consciousness, a sense of values, a knowledge of other cultures, an appreciation of the fine arts, and an ability to think logically and communicate effectively. Think seriously about your choices and use them to enhance your educational experience. Engineering students may also complete a minor or major in these disciplines. See the Associate Dean for details.

CONCLUDING COMMENTS FROM THE UNDERGRADUATE PROGRAM DIRECTOR

I hope the information presented in this MSE Handbook has helped to answer some of your questions. At the very least, I hope that the information has pointed you in the right direction. I invite your comments and suggestions for future revisions. I encourage each of our students to discuss their course selections with their Academic Advisor or me.

Once more, I, along with the entire MSE faculty wish you every success in all of your activities while you are at Rutgers and beyond.

We are committed to help you succeed and support you in any way we possibly can.



Sincerely,

Dr. E. Koray Akdoğan
Undergraduate Program Director
eka@soe.rutgers.edu