INTERDISCIPLINARY
MATERIALS SCIENCE
VANDERBILT UNIVERSITY

# Interdisciplinary Materials Science Handbook

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# OVERVIEW

## Program Description

The graduate program in Materials Science is designed to provide advanced competence in interdisciplinary materials-related fields of study through didactic coursework and directed research activities. The following regulations describe the requirements for M.S. and Ph.D. degrees in Materials Science and policies for student advising, guidance and performance review. This information is intended to supplement and expand upon the regulations of the Vanderbilt Graduate School and the School of Engineering. However, specific research paths, expectations, and other requirements may be imposed by and are at the discretion of the research advisor. The acronym IMS (Interdisciplinary Materials Science) is used to identify the program and in the course catalog to identify courses specific to the program.

## Admission Criteria

- Satisfactory completion of appropriate coursework in an undergraduate science or engineering program
- The verbal, quantitative and analytic portions of the Graduate Record Examination (GRE) are optional and are not required for admission.
- Students for whom English is not the primary language must take the Test of English as a Foreign Language (TOEFL) examination or other exams accepted by the graduate school.
- The selection committee may consider additional information such as a personal statement, letters of recommendation, caliber of previous schools, etc.

# STUDENT GUIDANCE

## Temporary Advisor

The director of the IMS program will act as a temporary advisor for students entering the IMS program without an advisor (most matriculates). Students will sign up for classes based on the recommendations of the director and program administrator. In cases where the student has already identified an advisor, course selection will be made in cooperation between the advisor and program administrator.

## Thesis Advisor

By the end of the first academic year, the student will identify two thesis/project advisors. The selection is by mutual consent of the advisors and student. Each advisor must be associated with the IMS Program or be willing to join IMS and each must have primary appointments in different departments or can offer research expertise in significantly different areas. In the case of the latter, acceptance of such an arrangement is at the discretion of the director. One advisor will serve as the principal, while the other as a co-advisor. In both cases it is expected and desired that both play an active role in the dissertation research of the student bringing different expertise to bear, as well as ensuring that the student is supported financially as an RA or TA. While identifying an advisor is the primary responsibility of the student, assistance in placing a student into a funded group or in rare cases in changing groups will be provided by the director and administrator.

## Advisory Committee

By the end of the first academic year the student, with the advice of the IMS director and/or thesis advisors will select additional members of the faculty to serve on the advisory committee. The advisory committee will oversee administration of the preliminary examination and consists of at least five (including the two co-advisors) faculty members, representing three departments. At least three must be members of the Graduate Faculty, and at least three must be affiliated with the IMS Program at Vanderbilt. Students may select one of these members to be external to Vanderbilt if this person is actively involved in their dissertation research and/or upon the advice of the student's advisors. Approval of the external member is at the discretion of the research advisor and director. A CV along with a short statement as to the reason for the inclusion of this external committee member must be provided to the director for final approval.

## Ph.D. Committee

The IMS program requires a committee of at least five members to oversee all Ph.D. qualifying examinations, dissertation research and final examinations, with these members proposed to and appointed by the Graduate School. The requirement for this committee is the same as the advisory committee, where a committee consists of five faculty members, representing at least three departments and at least three members from the IMS Program faculty. The student's advisor will nominate this committee and forward the nomination to the Director of the IMS program. One external member may again be allowed based on the guidelines outlined for the Advisory Committee above.

### TA vs. RA

Normally students are admitted with a teaching assistantship (TA) in their first year, which means they work for the materials program as a grader, lab instructor or in some other teaching role. The salary and responsibilities are set by the program. This is the mechanism the program uses to fund students before they join a research group. A TA appointment, however, is not indefinite. Students are expected to find a research advisor who agrees to provide the student's salary, tuition and overhead costs as a research assistant (RA) in return for conducting research within a research group. The salary and expectations of an RA are determined by the faculty advisor.

# DEGREE REQUIREMENTS

## Ph.D. Degree Requirements

The IMS Ph.D. degree requires a total of 72 hours with a minimum of 24 hours of formal coursework, of which 15 hours will be from the IMS core. Students must complete each course with a grade of B or higher. The IMS core courses must be taken in the first semester in which the course is available. The course consists of five fundamental areas. The Materials Fundamentals course is required of all IMS graduate students. From the remaining four areas, a student must select one from three different areas. Within each selection, the student has options as to which course fulfills that requirement as shown.

The core consists of:

1. Materials Fundamentals
   - MSE 6310 Atomic Arrangements in Solids
2. Research Rotations
   - MSE 6391/92 Research Rotations

Three courses from three of the four areas below:

3. Solid State Materials

   **One** of the following:
   - EECE 6301 Solid-State Materials
   - EECE 6306 Solid-State Effects and Devices I
   - ME 8364 Nanophotonic Materials
   - PHYS 5640 Physics of Condensed Matter

4. Statistical Mechanics & Thermodynamics

   **One** of the following:

   - CHBE 6110 Advanced Chemical Engineering Thermodynamics
   - CHEM 5350 Statistical Thermodynamics
   - ME 8320 Statistical Thermodynamics
   - PHYS 5200 Statistical Physics
   - PHYS 8040 Statistical Mechanics

5. Quantum

   **One** of the following:

   - CHEM 5320 Quantum Chemistry
   - PHYS 5651 Advanced Quantum Mechanics
   - PHYS 8030 Quantum Mechanics
   - PHYS 8152 Quantum Mechanics of Solids

6. Chemistry

   **One** of the following:

   - CHEM 5040 Nanoparticles
   - CHEM 5340 Applications of Group Theory
   - CHEM 5410 Molecular Modeling Methods
   - CHEM 5420 Computational Structural Biology
   - CHEM 5610 Chemistry of Inorganic Materials
   - CHEM 5620 Chemistry of Biological Materials
   - CHEM 5630 Macromolecular Chemistry
   - ME 8391 ST-Spectroscopy

The remainder of the 72 hours can be taken as dissertation research, coursework, or transfer credit (if applicable). Performance in dissertation research does not affect the student's GPA. However, it is critical to note that until 72 hours is reached that a full 9-credit hours are taken each semester. This may be all in research, all in courses and seminar, or some combination thereof.

## M.S. Degree Requirements

The interdisciplinary M.S. degree requires a minimum of 24 semester hours (beyond the Baccalaureate) of formal coursework as outlined above for the Ph.D. Degree, plus a thesis

signed by two faculty members. At least 6 additional semester hours in graduate research must also be completed. The thesis is expected to be defended in a public setting with questions from the committee and public attendees as in a Ph.D. defense. No qualifying exam is required. The semester hours will include at least three of the four core program courses.

# Research Rotations

## Overview

First year students will participate in a series of three research rotations. Each research rotation will last 10 weeks with the expectation that approximately 9 hours per week should be devoted to working with the research group. Since the semesters are almost 15 weeks in length, the second rotation would span the end of the fall and the beginning of the spring semesters. A report summarizing the research conducted during the rotation will be submitted upon completion of each 10-week rotation to the IMS director and shared with the faculty member who advised the research rotation. The report should be written as if the work were to be submitted to an appropriate conference related to the field of study.

## Report Requirements

**Format**. The report should be 1 to 3 single-spaced pages in length (including figures and tables) formatted as: title, author list (you as first author along with any students that helped with your training and your advisors), author affiliations, date, and short abstract (~200 words). Use 11- or 12-point size in a Roman font.

**Content**. Typical sections include:

- Introduction --- What is the genesis of your topic and the purpose of the research? How will this research advance science and technology; what potential benefit could it have for society? What scientific question are you trying to answer? Place your work in the context of what has already been done. Include a few key literature references with a bibliography list at the end of the report.
- Methods and Theory --- Not all reports will include both methods and theory. What experimental or computational methods did you use? If you worked in two laboratories, clearly indicate what you did in each one. Describe the procedures, strengths and limitations of the techniques.

- Results and Discussion --- This section should summarize any experimental data or modeling results. Figures with captions should be described using text in this section. Contrary to typical article submissions, please provide clear attribution or delineation of work between you and your collaborators. What part of the work was performed by others in the research group?
- Conclusions, Acknowledgements and References --- The conclusions section should not be merely a restatement or summary of results. Instead, think about what claims you can make about your work that were not known before it was performed. How does your work change the way technology will be developed?

**Style**. Make sure the report tells a compelling story. Every good scientific article clearly explains in the introduction a scientific question to be answered in the article and places the question into context of what the community already knows. The methods or theory section then describes how the effort attempts to address the question posed in the introduction. Finally, the results and discussion provide the answer to your question with a logical development of ideas. Because every story is different, feel free to modify the structure of your report to best tell the story.

# Exams

## Ph.D. Preliminary Exam

To proceed with study for the M.S. or Ph.D. degree in the IMS program, a student must demonstrate proficiency in the fundamentals of materials science, proficiency in the corresponding fields involved in the candidate's dissertation research and demonstrate the potential for conducting high-quality original research by fulfilling the following two requirements.

1. Students must earn a grade of B or better in each of the four core courses taken. Students who fail to receive at least a B in any of the core courses will be required to repeat each course in which a B was not earned. If a student fails to receive a B (or better) in a course that is being repeated, that student will be terminated from the program. For purposes of repeating coursework, any course enrollment maintained by the student past the University-stated add/drop date for that semester will be considered

an attempt. Exemptions for exceptional circumstances (e.g. unforeseen illness) will be considered by the IMS Director on a case by case basis.

2. Students must pass an exam administered by the Advisory Committee that consists of a) submission of an area paper to the Advisory Committee at least one week prior to the oral component, b) oral presentation in a program seminar format of the work contained in the paper, and c) defense of the work presented and examination. The format and extent of the area paper are at the discretion of the advisors, but the expectation is that the paper will describe original research efforts conducted so far and should be written as if the work were to be submitted for publication in a refereed journal or as a conference proceeding. The presentation should be between 15-20 minutes in length, provide an introductory slide highlighting what coursework the student has completed and timeline for completion of any core classes not taken to date. The presentation will be based on the research included in the area paper, but the examination is not limited to those fields of study or technology. Students should be prepared to address questions related to a) the core course work already completed, b) any other materials-related course work already completed, c) work conducted during research rotations, or d) research conducted in the student's research group. The examination can encompass areas both directly and indirectly related to the paper.

The test should be administered after the student's second academic semester and before the last day of classes of their third academic semester. Failure to sit for the exam before the end of their third semester will result in an automatic "U" for that semester. Extensions beyond the end of the third semester will be considered on a case-by-case basis, but in all cases must be completed prior to the start of the fourth semester. For students who have transferred from another graduate institution, scheduling of the exam will be established on an individual basis, but the test must be taken within 12 months of beginning studies at Vanderbilt. If a student fails any component of the exam, the Advisory Committee can grant the student a second chance at their discretion. If a second chance is granted, the second test, which will have the same format, must be retaken within 3 months. A second failure will result in termination from the Ph.D. program.

## Qualifying Exam

The Qualifying Examination will be given in accordance with the regulations of the Graduate School and administered by the Ph.D. committee. The exam will consist of a written dissertation proposal, an oral presentation of the proposal and defense of the proposal. The oral segment may include an examination of concepts both directly and indirectly related to the dissertation proposal. Students should complete the Qualifying Examination after 24 graduate hours and within 42 months of beginning graduate study in the IMS. The examination can be taken a maximum of two times. *For students with any other prior graduate work, the timeline for Ph.D. qualifying exam can be established on an individual basis.*

In the oral qualifying examination, the student should

- demonstrate competency with fundamentals in the areas that required remedial action as a result of the preliminary examination
- demonstrate in-depth knowledge of subject matter related to the dissertation project
- present a written proposal containing a reasonable research plan and some demonstration of original work in the area of the dissertation to the Ph.D. committee two weeks prior to the examination, inclusive of a proposed timeline for completion and defense of the dissertation research.

The formal request for appointment to the qualifying examination committee must be received by the Graduate School at least two weeks prior to the date of the examination. Forms for this request are available in the program office.

## Final Public Oral Examination

The final examination is a public oral defense of the student's thesis presented before the Ph.D. committee and the public in accordance with the Graduate School requirements. The student must pass the oral and the dissertation must be approved by the committee. These two requirements do not have to be concurrent. The student can take the oral examination a maximum of two times. The dissertation is considered approved once it has been signed by all committee members.

In general, the final oral examination will be conducted in two parts. The first consists of a public presentation of the thesis followed by questions from the gallery. The second will be in the form

of a question period attended by the Ph.D. committee and invited faculty only, which may include one faculty member external to Vanderbilt who is directly participating in the student's dissertation research. As indicated previously, any external members must be approved by the advisors and director prior to setting a date for the oral exam. While participation of faculty is preferred to take place in person, virtual attendance can be acceptable under some conditions. Approval for such conditions will be made on a case-by-case basis by the IMS director or if deemed necessary by the University leadership. It is anticipated that the five-member committee chosen for the Oral examination will be used for the final defense. If changes are made after the Oral exam, approval of all changes must be obtained from the IMS Director along with a brief statement concerning why the change(s) was (were) made.

The student shall submit, no later than two weeks before the end of the final exam period of the term in which the student expects to graduate, two approved copies of the thesis to the Graduate School office, one to the program office and one to each of the thesis advisors. Approval requires at least five signatures on the thesis title page of members of the Ph.D. committee. The candidate shall also furnish an abstract of the thesis, not to exceed 250 words in length, to the Graduate School office. Both hard and soft copies of the documents may be accepted depending on graduate school guidance and advisor preference. Signatures may be electronic.

# Other regulations and information

## Transfer Students

All questions pertaining to transfer students are to be decided in accordance with the policies published in the current edition of The Bulletin of Vanderbilt University.

## Registration

Students are required to register for 9 credit hours in the fall and spring semesters, even if all course and semester hour requirements have been met, unless an approved leave of absence has been secured from the Dean of the Graduate School. Responsibility to maintain this registration rests with the students; student status in the Graduate School ceases with failure to register.

## Student Performance

All graduate students must maintain at least a 3.0 overall average. A student is considered on probation following a semester in which the grade average falls below 3.0. If the 3.0 average is not regained at the end of the probationary semester the student will be withdrawn from the Ph.D. program. S/U grades are given every semester for all research courses (7999, 8999, 9999). Following a second, but non-consecutive U grade the student will be placed on probation for a semester, and the student must present a performance improvement plan to the IMS director and thesis advisors concerning how they will improve upon the deficiencies leading to the U grades such that their work can be brought back to a level where an S is obtained. This plan must be submitted in writing, with signatures stating their approval by both advisors and the IMS director. If a student receives two consecutive U grades for their research, or if they accumulate three U grades this will result in dismissal from the program.

## Time Limits

All requirements for the Ph.D. degree must be completed within four years of passing the preliminary examination and within two years of passing the qualifying examination. Extensions to these requirements will be considered on a case-by-case basis by the IMS director.

## Financial Aid

In the first year, financial aid is provided to all IMS students in the form of a teaching assistantship (TA), which includes a salary, tuition, health insurance and fees. TAs should expect to spend 20 hours per week on teaching duties. By the end of the second semester, students are expected to have identified a research advisor who can continue financial support in the form of an RA or a TA in a department or program outside of IMS. Students who fail to secure funding after one year may be withdrawn from the program. Continuation of support and the level of support depends on the students satisfactorily fulfilling all assigned responsibilities, registering for all advised course work, making satisfactory progress toward the degree, and the availability of financial resources. Students will not be supported for more than 6 years.

## Seminar Attendance

All IMS graduate students are required to attend all VINSE colloquia. Attendance is taken, with two unexcused absences resulting in a U for the semester.

### Professional Development

During the first semester, all incoming students are required to attend the professional development seminar series. This is not a registered course, but cover topics ranging from what is expected of a successful graduate student, how to give a presentation, and managing the advisor/advisee relationship. Students are expected to attend all professional development presentations, unless given an excused absence.

### Office Space

First year students will be assigned offices in Olin Hall by Mechanical Engineering where they can maintain office hours while teaching. All IMS students will move to office space within their selected research group once the group is determined.

### Additional Employment

All students receiving aid agree to hold no other employment during the period for which aid is given. Students cannot accept extra jobs for pay within or outside the University unless prior approval is given by the Ph.D. advisor and the IMS Director. Supplemental funding may be allowed for university work related to training, but it must have prior approval.

# Suggested Timeline

### First Year

- Complete at least three of the required four core courses (*Schedules may allow students to complete all courses in three semesters; however, allowing for scheduling problems, completion over 4 semesters is permitted)*
- Complete three research group rotations
- Join a research group by May and begin research as soon as possible
- Participate in all required seminars and graduate student meetings

### Second Year

- Complete core coursework
- Complete elective coursework
- Complete the preliminary examination requirement by December (third academic semester)

- Participate in all required seminars and graduate student meetings

### Third Year

- Continue research as a major, primary effort
- Participate in all required seminars and graduate student meetings
- Select and appoint Ph.D. committee, in consultation with thesis advisor

### Fourth Year

- Participate in all required seminars and graduate student meetings
- Complete required 72 credit hours
- Complete the Ph.D. qualifying examination prior to May

# Elective Courses

## Outline of Elective Course Requirements

All students are required to take 9 credit hours of elective courses. These can be selected from any courses within the School of Engineering or Science-related Graduate classes within Arts & Sciences. Additional courses taken from within a single core focus area (e.g. taking CHEM 5610 and 5040) will qualify as an elective course. Below we highlight courses currently listed within many focus areas to serve as a guide to students in selecting their electives. Students are under no obligation to choose courses from the below lists and the availability of these courses is subject to change without notice depending on the prerogatives of the listing department.

### Bio

- BME 5200 Principles and Applications of BioMEMs
- BME 5500 Nanobiotechnology
- BME 7310 Advanced Computational Modeling and Analysis in Biomedical Engineering
- BME 8901 Special Topics: Advanced Fundamental Biomaterials
- BSCI 5252 Cellular Neurobiology
- EECE 5892 Optical Tweezers in Biology and Medicine

### Computational

- BME 7310 Advanced Computational Modeling and Analysis in Biomedical Engineering
- CHBE 5410 Molecular Modeling Methods
- CHBE 5830 Molecular Simulation

- CHEM 5420 Computational Structural Biology
- ME 8365 Micro-Nano Energy Transport
- PHYS 5237 Computational Physics

## Energy

- ME 5265 Direct Energy Conversion
- ME 8365 Micro-Nano Energy Transport
- ME 8391 ST-Energy Conversion

## Fundamental

- CHBE 5840 Synthesis and Applications of 2D Nanomaterials
- CHBE 5850 Semiconductor Materials Processing
- CHBE 5870 Polymer Science and Engineering
- CHEM 5150 Electrochemistry
- EECE 6307 Solid State Effects in Devices II
- IMS 5320 Nanoscale Science and Engineering
- MSE 6343 Electron Microscopy
- ME 8323 MEMS/NEMS
- ME 8391 ST-Spectroscopy
- PHYS 8159 Experimental Nanoscale Fabrication and Characterization
- PHYS 8164 Many-Particle Quantum Theory

## Optics

- BME 7140 Fundamental of Optics
- EECE 5288 Optoelectronics
- EECE 5892 Optical Tweezers in Biology and Medicine
- EECE 6303 Nanophotonic Devices
- ME 8364 Nanophotonic Materials
- PHYS 8158 Interactions of Photons with Atoms, Molecules and Solids

## Radiation Effects

- EECE 5604 Radiation Effects
- EECE 6307 Solid State Effects in Devices II

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