Montana University System
Collaborative Materials Science Ph.D.

Student Guidebook

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1. Introduction

1.1. Objective

This guidebook describes the academic degree requirements, policies and practices for graduate students in the Montana University System Materials Science Ph.D. Program (MatSci Ph.D. Program). The general program degree requirements are presented, along with the milestones, rules and policies, and standards of performance and integrity expected of graduate students.

The graduate student is responsible for understanding and adhering to the policies and procedures outlined in this guidebook as well as the policies in effect at the university in which the student is enrolled. Inconsistencies may arise between the contents of this guidebook and the specific policies of the University of Montana, Montana State University, and Montana Tech. In such instances, the policies of the university in which the student is enrolled take precedence.

1.2. Program Overview

The University of Montana (UM), Montana State University (MSU), and Montana Tech (MTech) participate in the Materials Science Ph.D. program. The program is a collaborative effort of the three campuses, and involves multiple departments, faculty, courses, and research infrastructure.

Research specialties are focused in four areas:

1. biomaterials
2. electronic, photonic, and magnetic materials
3. materials for energy storage, conversion, and conservation
4. materials synthesis, processing, and fabrication

The curriculum integrates a broad range of physical science and engineering disciplines with an even broader range of applications: from health and medicine to nanotechnology to energy, environment, and natural resources. Courses are coordinated and shared by the three campuses, taking advantage of on-line instructional technologies where appropriate. Each student must complete original, independent research culminating in a dissertation. The program offers optional, employer-based internships, in which the student tackles a current problem important to the employer.

Program requirements include the qualifying exam, the candidacy exam, the dissertation, participation in the program's annual summer symposium, annual meetings with a student's advisory committee, and an optional internship. These requirements and their timing are summarized in Table I and described in greater detail in the sections that follow.

Table I. Typical Schedule for MatSci Ph.D. Program of Study

Year 1 Fall Term	**Year 1 Spring Term**
MTSI 500 Survey of Materials Science &	MTSI 500 Survey of Materials Science &
MTSI 501 Advanced Materials Science I	MTSI 502 Advanced Materials Science II
MTSI 511 Thermodynamics of Materials	MTSI 512 Kinetics and Phase
MTSI 551 Materials Characterization I (2)	MTSI 552 Materials Characterization II (3)
Total Credits: 10	*Total credits: 10*
Choose Research Advisor by the end of Year 1 Spring Term	
Summer: Qualifying Exam & Summer Symposium	
Year 2 Fall Term	**Year 2 Spring Term**
Electives (6-9)	Electives (6-9)
Research (0-6)	Research (0-6)
Total Credits: 9-12	*Total Credits: 9-12*
Late Spring: Candidacy proposal and oral exam; June/July: Summer Symposium	
Summer: If needed, repeat Qualifying	*Sept-Dec: Assemble dissertation*
Year 3 Fall Term	**Year 3 Spring Term**
Electives (0-6)	Electives (0-6)
Research (3-9)	Research (6-9)
Total Credits: 9-12	*Total Credits: 9-12*
June/July: Summer Symposium	
Year 4 *et seq.*	
Research (6-9 credits each semester)	
Every Year in June/July: Summer Symposium	
Final Term: Submission and Oral Defense of Ph.D. Dissertation	

2. Admissions

To be eligible for admission to the Ph.D. program, the student must have earned a B.S. degree or equivalent in materials science, materials engineering, physics, chemistry, metallurgy, or a related science or engineering field. The student's academic record must provide evidence of a strong background in the fundamentals of science and/or engineering principles. A student with such a background who has not passed certain undergraduate courses that are prerequisites for their required or elective graduate courses must remedy this gap as expeditiously as possible, either by taking the prerequisite undergraduate course or through independent study and "credit by examination."

The program Admissions Committee includes membership from all three campuses. The Admissions Committee member from each campus is designated as the MatSci Ph.D. program admissions representative on that campus.

Students may apply to the MatSci Ph.D. program through the graduate admissions office of any one of the three campuses, ideally the campus where they prefer to enroll:

Admission information can be accessed through the following links:

Montana State University: http://www.montana.edu/wwwdg/apply.html

Montana Tech: http://www.mtech.edu/academics/gradschool/

The University of Montana: http://www.umt.edu/grad/default.php

The Ph.D. Program Admissions Committee reviews the applicants, including the match between the applicant's interest and preferred campus. Admissions recommendations will consider the applicant's quality, the availability of financial support, and the availability of willing mentor(s)/advisor(s). The admitted students will be extraordinary applicants with interests spanning the research themes of program and an appropriate distribution of enrollment across the three institutions. The Program's recommendation on each applicant is forwarded for action to the graduate admissions office on the campus where the student is recommended or waitlisted for admission. In the case of students not recommended for admission, the recommendation is returned to the graduate admissions office of the campus where the student applied.

Once the program's admission recommendation is made, the remainder of the admissions process follows the normal graduate admissions process on the campus where the student is admitted, waitlisted, or applied. Admissions offers are made by the campus where the student will matriculate, in the same manner and by the same official as for other graduate students at that campus.

3. Doctor of Philosophy Degree

The Montana University System Materials Science Ph.D. Program is designed to be flexible but still provide students with an exceptionally broad and strong understanding of the theory, experimental techniques, current challenges, and socioeconomic impacts of materials science and engineering. All students in the program – regardless of specialty – will understand how classes of materials derive their properties from the atomic to the macroscopic level and be familiar with the growing set of materials fabrication, assembly, processing and characterization tools and techniques. Further, students will be aware of and committed to the professional and ethical standards of the field. Students are also expected to become aware of the economic, societal, and broader impacts of materials and materials research. Through their dissertation research, students will demonstrate that they can conceive, plan, design, conduct, analyze, defend, publish, and communicate original and creative research that advances understanding in an area important to materials science.

3.1. Research Advisor, Research Topic, and Committee Selection

Incoming students are classified as "unplaced." During the initial year, unplaced students are expected to meet MatSci faculty, discuss mutual research interests, and learn about available projects. As part of MTSI 500 Survey of Material Science and Engineering, each campus will host a one-day forum/exposition each academic year to provide students with the opportunity to meet the MatSci faculty, learn about their research interests, and discuss potential research projects. The format may include seminars, tours, equipment demonstrations, etc.

Once a student and advisor agree to work together on a specific research project, they must notify the MatSci Ph.D. Program Leadership Council of their decision, and the student will be classified as "placed". Consequently, that specific research project will not be advertised or available to the unplaced students. Before the mid-semester break in the first semester of the second year, all unplaced students specify their project preferences and are then placed by agreement of the MatSci Ph.D. Program faculty and the Leadership Council.

Not later than the first semester of the second year, the student will form a faculty advisory committee with at least five members, of which at least one is from a non-home campus, and another is the Graduate School Representative. The advisor and committee monitors the student's progress, helps the student tailor elective course choices to his/her interests, and provides feedback and guidance to keep the student on track to completing all program requirements in a timely manner. Students meet with their committees annually during every year they remain in the program following their candidacy exam. An additional "outside examiner" from outside the Montana University System may be added to the Advisory Committee prior to the time the dissertation is submitted. The outside examiner reviews the dissertation, participates in the oral defense, and makes a formal recommendation to the Committee about the quality and originality of the dissertation. Selection and appointment of the outside examiner follows the standard practice on the campus where the student is enrolled.

3.2. Credit Requirement

The MUS MatSci Ph.D. requires a minimum of 60 semester credits beyond the bachelor's degree. Of the 60 credits, at least 18 credits must be obtained for dissertation research, and at least 32 credits must be earned for coursework. Up to 24 semester-credits from a master's degree may be accepted toward the minimum degree requirements, but they must be applicable to the MatSci curriculum, and their acceptance is subject to the review and approval of the student's committee and the MatSci program's Leadership Council. No more than 9 credits may be from 400-level courses. To ensure that students benefit from the collaborative, three-campus nature of the program, at least 9 credits must be earned from courses offered away from the home campus. Full-time students are expected to complete the 20-credit core curriculum and pass the qualifying examination within the first year.

In addition to the core curriculum, each student must earn at least 12 credits of electives within or related to the chosen specialty. Typically, this coursework is completed by the end of the student's second year. Additional elective courses intended to provide a student with specialized expertise and/or skills relevant to their dissertation research may be recommended by the individual student's advisor and committee.

3.3. Core Course Requirements

3.3.1. MTSC 500 – Survey of Materials Science and Engineering (2 credits: 1 credit/semester)

A two-semester, seminar-format overview of Materials Science, with some units focusing on the specialty/niche areas of the MatSci Ph.D. program and introducing students to the faculty and research on the three campuses. Other professional-development content, such as research ethics, is included. Primarily distance/-participation with different sessions organized and hosted at the three campuses. One face-to-face session at each campus each semester brings students and faculty together.

3.3.2. Advanced Materials Science I and II

3.3.2.1. Semester 1: MTSI 501 – Bonding, Structure and Defects (4 credits)

How do structure and bonding at a microscopic level lead to macroscopic material properties? Topics include treatment of ionic and covalent bonding; quantum mechanical foundation of the cohesion and properties of solids and the evolution of band structure; three dimensional crystallography including point groups, stereographic projections, Bravais lattices, space groups and representative crystal structures; and study of the electronic and mechanical properties of materials and the effects of point, line, and planar defects in crystalline solids.

3.3.2.2. Semester 2: MTSI 502 – Function and Application (3 credits)

How are materials designed and synthesized to achieve specific applications? A team taught course broken up into three 12-lecture segments. Each segment will cover a specific topic where potential topics may include ceramics, polymers, magnetic materials, biomaterials, glasses, etc. This course will be taught in such a way that material discussed in Semester 1 is put into practice, introducing students to principles of "rational material design."

3.3.2.3. MTSI 511 – Thermodynamics of Materials (3 credits)

(3 credits) Advanced thermodynamic principles in the context of materials science; solution thermodynamics, multi-phase mixing, entropy, and equilibria; state functions and free

energies; statistical thermodynamics, including ensembles, lattices, and phase transitions.

3.3.2.4. MTSI 512 – Kinetics and Phase Transformations (3 credits)

The mechanisms controlling the rates of structural/chemical changes and reactions in materials. The course examines quantitative diffusion theory and practical applications. The course considers nucleation and growth as a mechanism for phase transformations. The course then looks at examples of the application of phase transformations in materials processing.

3.3.2.5. MTSI 551/552 – Advanced Materials Characterization Techniques I & II (5 credits: 2 credits 1st semester; 3 credits 2nd semester)

A two-semester laboratory-based survey providing experience with the common qualitative and quantitative characterization and analytical tools used in materials science and engineering. Techniques include scattering, diffraction, microscopy (optical, electron, tunneling, etc.), optical, thermal, mass spectrometry, NMR, and other techniques. An important emphasis of this course sequence will be teaching students how to select the characterization/analysis tools appropriate to the research project, use the instruments effectively, and analyze and evaluate the data that result from the different types of measurements. Relevant data from actual materials systems (acquired from instrumentation at any one of the three campuses) will serve as the platform for discussing the basis (theory) of the instrument and assessing instrumental capabilities and limitations. Specific instrumentation and methods featured each semester are selected to complement the topics in Advanced Materials Science I/II.

3.4. Waiver of a Core Course

Students can petition to waive any core course if the student has taken an equivalent course at another accredited university and achieved a grade of B or better at the graduate level. The student must provide proof in the form of transcripts and a syllabus of that course. A petition should be submitted to the graduate program chair via the graduate advisor who reviews requests for waivers or substitutions of the core courses. The student must take an approved technical elective in the place of the waived core course. Students will be responsible for material from waived courses during the qualifying exam.

3.5. Technical Electives

Elective courses are available to allow students to deepen their understanding and research skills in the program's focus areas in biomaterials; materials for energy storage, conversion, and conservation; electronic, magnetic, and photonic materials; and materials synthesis, processing, and fabrication. Courses in mathematics,

statistics, and numerical modeling are recommended for students with special interests in theory and simulation.

Many graduate-level electives applicable to the MatSci Ph.D. program exist at all three campuses. Some electives were developed specifically for the MatSci Ph.D. program, others are graduate courses from other related graduate programs at the three campuses. As examples, applicable electives are offered in the following departments:

Montana State University: Chemistry, Biological Sciences, Physics, Chemical and Biological Engineering, Earth Sciences, Electrical and Computer Engineering, Mechanical and Industrial Engineering, Mathematics, and Computer Science.

Montana Tech: Biological Sciences, Chemistry, Environmental Engineering, General Engineering, Geological Engineering, and Metallurgical and Materials Engineering.

University of Montana: Chemistry, Biology, Mathematics, School of Pharmacy.

3.6. Summer Symposium

Every student is expected to attend and participate in the doctoral program's annual summer symposium. Every student who has advanced to candidacy is required to present either a poster or a talk.

3.7. Deficiency Course Requirements for non-Materials Students

Students who do not possess an undergraduate materials science degree may be required to complete additional coursework in order to remediate deficiencies before they enroll in certain graduate level courses. Deficiencies will be identified by the Admissions Committee and will be stated on the student's admission letter. Deficiencies in the courses listed hereunder must be remedied in addition to the required graduate coursework. Students who do not enter the program in possession of an undergraduate materials science degree are required to complete additional coursework to remediate deficiencies before they may enroll in certain graduate level courses. Deficiencies identified by the Admissions Committee will be stated on the student's admission letter. Deficiencies in the following courses (or equivalent coursework, as determined by the Admissions committee) including course prerequisites, must be remedied in addition to the graduate coursework.

Mathematics, Chemistry and Physics:

M 274 – Introduction to Differential Equations

CHMY 373 – Physical Chemistry (kinetics and thermodynamics)

PHSX 322 – Electronics for Scientists

Materials Science:

EMAT 251 – Materials Structure and Properties

EMAT 351 – Fundamentals of Materials

4. Qualifying Exam

Every student must take and pass a comprehensive, written qualifying examination at the end of the first year. Qualifying exams will be offered at a specified time during the summer and prior to the start of fall classes. The outcome of the exam will be "pass," "conditional pass," or "fail." A conditional pass indicates that a student has significant deficiencies in one of the areas tested. This student would be required to take and pass (B or better) designated course(s) in the following year to "pass" the qualifying exam. Students who fail on the first attempt may retake the exam at the next scheduled date. Students who fail twice are released from the Ph.D. program. By passing the qualifying exam, the students demonstrate that they understand materials and their properties from the atomic to the macroscopic levels and have familiarity with the growing set of materials fabrication, assembly, processing, characterization, and modeling tools and techniques.

5. Candidacy Examination

After passing the qualifying exam and typically before the start of a student's third year, the student will take a candidacy exam. By passing the candidacy exam, the student demonstrates that he/she can both: conceive, plan, and design an original and creative research project on a topic important to advancing understanding in MatSci; and communicate effectively both orally and in writing.

The candidacy exam will consist of two parts: (1) a written proposal describing the student's intended dissertation research; and (2) an oral defense of the proposal to the student's doctoral committee. The defense will include an open seminar followed by a closed interview/examination by the Committee that can cover a broad range of topics related to the proposed dissertation research.

The outcome of the candidacy exam will be either (1) full pass; (2) conditional pass; or (3) fail. Full pass enables the student to advance to candidacy with no further program requirements remaining other than the dissertation and annual meetings with the committee. A conditional pass will be awarded if the committee feels that the student is lacking knowledge in a specific area that is vital to the proposed research.

The committee may recommend specific requirements for the student to fulfill in order to successfully advance to candidacy. These requirements may include taking (and passing) an additional course; preparing an appendix or response to questions that arose

about the proposed research's viability; and/or reconvening with the committee for a second oral examination.

6. Dissertation

A written dissertation must be prepared, submitted, presented, and defended. The dissertation must be based on original and independent research conducted by the student under the guidance of the graduate supervisory committee. The dissertation must demonstrate the candidate's ability to address a major intellectual problem and to propose meaningful questions and hypothesis through the mastery of research methods, theory, and tools of the discipline.

An oral, public defense of the dissertation is required and is scheduled for a minimum of 2 hours. A copy of the dissertation is given to the department and copies are placed in the three participating campus libraries.

6.1. Graduate Faculty Supervisory Committee

With input from the student, the MatSci Leadership Council will recommend the committee composition for each student. The committee will have at least five members, including at least one faculty member from a collaborating campus and one member appointed by the graduate dean of the campus where the student is enrolled. The committee chair (the student's advisor) must be a member of the graduate faculty that is approved to chair dissertation committee in the Materials Science program. A majority of the faculty committee must be MatSci faculty, however, academic professionals, research scientists, industrial professionals and other non-MatSci faculty may serve on doctoral supervisory committees with approval of the graduate director and the Graduate College of the home institution. Students should contact their graduate advisor for instructions for approval and assignment of such individuals to the committee.

7. Registration Requirements and Financial Support

Financial support is reserved for students enrolled for 6 or more credits in an academic term and full-time students receiving financial support are expected to register for at least 6 credit hours per semester. In general, students will be eligible for no more than 12 semesters of financial support.

The Ph.D. program offers a standard total financial support package to students in the program. There may be variability based on whether the student has attained candidate status, but not based on the home institution or type of support. In accordance with BOR 940.31, Ph.D. students will be identified as GTA/GRA and be charged the instate tuition rate. The tuition may be covered by each campus with some combination of waivers, grant funds, and other funds (institutional fellowships,

endowment income, industrial funding, etc). Fees are the responsibility of the student and follow the policies and rates of the home institution.

Students in the program are eligible for financial support during the summer, without being enrolled, provided they were enrolled and eligible for financial support the previous spring term, have not yet completed the degree, and are working on their research.

7.1. Optional Off-Campus Activities in Support of the Student's Research

Students have the option to participate in a collaborative research activity at affiliated University Research Center, national laboratory, or industrial site. Students may complete one or more collaborative projects hosted by industrial partners, national laboratories, or Centers of Excellence, typically involving a project of at least 4 months duration (one semester). However, the dates of the residency at the host location need not align with the start and end dates of an academic semester.

Such projects will be reviewed by the student's committee, which will determine—in consultation with the student and the sponsor/host—whether the project is suitable as the dissertation project or as a component of the dissertation. These opportunities are primarily considered a means to augment the student's graduate education and research and, therefore, as stand-alone projects are unlikely to have the intellectual and scientific depth expected of a doctoral dissertation.

- Intellectual property and proprietary issues associated with such projects will be addressed by the host organization, the student, and the student's campus, and will follow the process and policies on that campus related to intellectual property and proprietary work.
- Compensation from the project sponsor/host paid directly to the student will be counted as part of the student's financial support "package."
- The project must be summarized in a written report. This report may be the entire dissertation, a chapter in the dissertation, or a separate report.