Michigan Tech

Office of the Provost and
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Office Memo

TO: Richard Koubek, President

FROM: Jacqueline E. Huntoon, Provost & Senior Vice President for Academic Affairs

DATE: April 22, 2021

SUBJECT: Senate Proposal 66-21

Attached is Senate proposal 66-21, "A New Graduate Certificate: Frontiers in Materials Physics," and a memo stating the Senate passed this proposal at their April 21, 2021 meeting. I have reviewed this memo and recommend approving this proposal.

I concur__X__ do not concur_______ with this recommendation.

Richard Koubek, President

Date: 4/26/21

Michigan Tech

University Senate

DATE:	April 22, 2021
TO:	Richard Koubek, President
FROM:	Samuel Sweitz University Senate President
SUBJECT:	Proposal 66-21
COPIES:	Jacqueline E. Huntoon, Provost & Senior VP for Academic Affairs

At its meeting on April 21, 2021, the University Senate approved Proposal 66-21, "A New Graduate Certificate: Frontiers in Materials Physics". Feel free to contact me if you have any questions.

The University Senate of Michigan Technological University
Proposal 66-21

A New Graduate Certificate: Frontiers in Materials Physics

Submitted by: Department of Physics

Co-sponsored by:
Department of Materials Science and Engineering
Department of Electrical and Computer Engineering

1. **Version Date: March 29, 2021**

2. **Proposer Contacts:** Jae Yong Suh (jsuh@mtu.edu), Miguel Levy (mlevy@mtu.edu), Claudio Mazzoleni (cmazzoleni@mtu.edu), Bryan Suits (suits@mtu.edu), Ranjit Pati (patir@mtu.edu), Yoke Khin Yap (ykyap@mtu.edu), and Ravi Pandey (pandey@mtu.edu)

3. **Interdisciplinary Program:** Final approvals from the collaborating departments and college were obtained in the Deans' Council meetings before forwarding to the Provost's office and the senate. Advising and administrative duties will be housed entirely in the Physics department.

4. **General Description and Characteristics**

General Description: This Graduate Certificate in "**Frontiers in Materials Physics**" is intended to allow students to establish key physics concepts to drive frontier experimental materials research. The objectives are to:

a) Prepare graduate students with a strong foundation in materials / solid-state physics that will allow them to explore new frontiers in low-dimensional quantum materials, energy materials, electronic and optical materials at the nanometer scale, atmospheric particles, and emerging new materials in the future.

b) Prepare graduate students on the basics of materials fabrication, materials characterization and applications.

c) Enhance the credibility of graduate students with the theoretical background and experimental skills needed for their career in advanced materials.

Catalog Description: The graduate certificate in "**Frontiers in Materials Physics**" aims at developing the foundational knowledge and techniques in the areas of: 1) low-dimensional materials, 2) quantum and topological materials 3) energy materials, 4) atmospheric particles and nanomaterials. Students may also explore applications for spectroscopy, photovoltaics, optoelectronic devices, and environmental optics.

Graduate Learning Outcome (GLO) Assessment

GLO 1: Students earning this certificate will be able to explain the key concepts of frontier materials including one or more of the following topics: quantum confinement effects, crystal structures, energy band structures, electrical and/or optical properties.

GLO 2: Students earning this certificate will be able to explain one or more of the following topics: materials synthesis, materials characterization, device fabrication, applications of materials.

5. **Title of Program:** "Graduate Certificate in Frontiers in Materials Physics"

6. **Rationale**

Experimental Materials physics is an indispensable field for advanced electronic, photonic, energy devices, and future quantum computation and communication. This growing area is expected to meet many academic and industrial needs.

7. **Discussion of Related Programs**

Our proposed certificate is unique for the diverse topics focus on materials physics and engineering. Several other universities are offering related certificate programs, with the focus on the engineering aspect and are different in course requirements,

Michigan State University – https://www.chems.msu.edu/academics/continuing-ed-mse
University of Michigan – https://micde.umich.edu/certificate/
Stanford University – https://online.stanford.edu/programs/nanoscale-materials-science-graduate-certificate
Columbia University (Fully online) – https://www.cvn.columbia.edu/program/columbia-university-materials-science-certification-certificate
Boise Sate Unviersity – https://www.boisestate.edu/coen-materials/academic-programs/certificate-programs/

From the information in these links, some of these external programs are being offered online:

Michigan State: Online (3 semester credits required, just one single course)
U of Michigan: Not specified (9 credits required)
Stanford University: Partly online (2 courses out of 6 courses are available online)
Columbia University: Online (12 credits required)
Boise State University: Not specified (12 credits required)

8. **Projected Enrollments**

Table 1 shows estimated minimum targets assuming a more aggressive marketing approach is deployed. The enrollment cap depends on the number of sections that can be allocated to each course. The certificate can be offered online in the future when online versions of the required and elective courses become available.

Table 1. Estimated minimum enrollment by year.

Academic Year	On Campus
2021-2022	2
2022-2023	2
2023-2024	3
2024-2025	3
2025-2026	4

9. Curriculum Design

This certificate consists of two required courses and other elective courses. A minimum of 9 total credits is required. Only three credits may be at the 4000 level. The required and elective course list with the course descriptions are given below. It is expected that students will work with the program advisor to select courses that fit their interests and prerequisite skills.

Required Courses - 4 credits
PH 4510 - Introduction to Solid State Physics (2-credits)
PH 5530 - Selected Topics in Nanoscale Science and Technology (2-credits)

Elective Courses - take any such that the total for the certificate is at least 9 credits
PH 5510 – Theory of Solids (3 credits)
PH 5520 - Materials Physics (3 credits)
PH 5151/MSE 5151 - Quantum Field Theory for Photonics and Materials (3 credits)
EE 5430 - Electronic Materials (3 credits)
EE 5490 - Solar Photovoltaic Science and Engineering (3 credits)
EE 5471 - Microfabrication Laboratory (2 credits)
EE 5460 - Solid-State Devices (3 credits)
MSE 5130 - Crystallography & Diffraction (3 credits)
MSE 5550 - Transmission Electron Microscopy (3 credits)
MSE 5580 - Introduction to Scanning Probe Microscopy (2 credits)

Only 1 credit of the following can be counted for the certificate:
PH 4292/MSE 4292 - Light and Photonic Materials (3 credits)
MSE 4530 – Scanning Electron Microscopy and X-ray Microanalysis (3 credits)

Course Descriptions

PH4510 - Introduction to Solid State Physics

Crystal structures, X-ray diffraction, phonons, free electron theory of metals, rudiments of band theory, an overview of semiconductors, and other topics in solid-state physics.

PH 5530 - Selected Topics in Nanoscale Science and Technology

Presentation and discussion of selected topics in nanoscale science and engineering. Topics include growth, properties, applications, and societal implication of nanoscale materials. Evaluation: attendance and assignment.
Credits: 2.0
Lec-Rec-Lab: (2-0-0)

PH 5510 - Theory of Solids
Free electron theory, Bloch's theorem, electronic band structure theory, Fermi surfaces, electron transport in metals and semiconductors. Lattice vibrations and phonons, other topics as time permits.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)

PH 5520 - Materials Physics
Materials classification and structures; phase diagrams; lattice imperfections; quasiparticles; boundaries and interfaces; mechanical, electronic, optical, magnetic and superconducting properties of materials.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)

PH 5151/MSE 5151 – Quantum Field Theory for Photonics and Materials
This course will review the basics of quantum mechanics and second quantization, and cover quantum field theoretical methods, including Wick's theorem and Feynman diagram techniques, for absolute zero and non-zero temperatures (Matsubara frequencies) and their application in photonics, properties of materials and condensed matter physics.
Credits: 2.0
Lec-Rec-Lab: (2-0-0)

PH 4292/MSE4292 – Light and Photonic Materials
Material properties controlling lightwave propagation in optical crystals and optical waveguides. Photonic crystals and photonic devices based on electrical, magnetic, and strain effects.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)

EE 5430 - Electronic Materials
A study of the physical principles, operational characteristics, models, and basic applications of selected solid-state devices.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)
Semesters Offered: Fall

EE 5490 - Solar Photovoltaic Science and Engineering

Solar photovoltaic materials, the device physics of photovoltaic cells and practical applications of solar electric systems engineering.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)

EE 5471 - Microfabrication Laboratory
A hands-on laboratory experience in which the students fabricate devices with micro-and nano- scale dimensions. Lecture component covers safety training, background on microfabrication processes and systems, and facility tours to observe additional systems.
Credits: 2.0
Lec-Rec-Lab: (1-0-3)

EE 5460 - Solid State Devices
A study of the physical principles, operational characteristics and models and basic applications of solid state devices such as p-n junctions, metal- semiconductor junctions and transistors.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)

MSE 5130 - Crystallography & Diffraction
Crystallographic concepts and diffraction analyses in materials science.
Credits: 3.0
Lec-Rec-Lab: (2-0-3)

MSE 5550 - Transmission Electron Microscopy
Practical aspects of materials characterization by transmission electron microscopy.
Credits: 3.0
Lec-Rec-Lab: (2-0-3)

MSE 5580 - Introduction to Scanning Probe Microscopy
Students will learn the basics of design and fundamental physics behind the scanning probe microscopy techniques. The lectures will also discuss the analysis of the solid surfaces regarding roughness, topography, composition, heterogeneity, and adhesion properties using atomic force microscopy (AFM). Artifacts associated with inappropriate conditions in atomic AFM imaging will be discussed as well. Training in the operation of the AFM instrument and exploration of its capability during the laboratory sessions will complement the lectures.
Credits: 2.0
Lec-Rec-Lab: (1-0-3)

MSE 4530 – Scanning Electron Microscopy and X-ray Microanalysis
Topics include electron beam and image formation, beam- specimen interactions, and x-ray microanalysis. Course content is relevant to students of the physical sciences, engineering, and related disciplines. Includes a laboratory experience that provides hands-on practical training sufficient to enable independent use of the SEM.

Credits: 3.0
Lec-Rec-Lab: (2-0-3)

10. New Course Descriptions
None

11. Model Schedule Demonstrating Completion Time
The minimum completion time is two semesters. A typical schedule is shown below.

Fall Semester	***Spring Semester***
PH4510 (2 Cr)	PH5530 (2 Cr)
MSE5580 (2 Cr)	PH5520 (3 Cr)

12. Library and Other Learning Resources
No additional library or other learning resources are required.

13. Description of available/needed equipment
No additional equipment is needed.

14. Program Costs
No additional program costs are anticipated.

15. Accreditation Requirements
None

16. Planned Implementation Date
This program has an anticipated start in Fall 2021. The certificate program will be extended into an online program as soon as it is established and practical to do so.

Additional Information for New Programs:

1. **Program-Specific Policies, Regulations and Rules.**
This program will follow Senate Policy 411.1 for Graduate Certificates. No additional program-specific policies apply besides the curricular requirements described above.

2. Scheduling Plans
On-campus sections will not require changes in class schedule, while online sections can be implemented asynchronously.

3. Space
No additional space requirements are necessary for this certificate.

4. Faculty Resumes
The associated faculty who have taught or can teach related courses are listed in the web sites of the Department of Physics, the Department of Electrical and Computer Engineering, and

the Department of Materials Science and Engineering. Examples of faculty webpages are embedded with the faculty names.

PH4510, PH5530, PH5520: Yoke Khin Yap (Physics)
PH5510: Ranjit Pati (Physics)
PH 4292/MSE 4292 and PH 5151/MSE 5151 Miguel Levy (Physics and MSE)

Approval Process
Department approval: January 22, 2021
College of Sciences and Arts: February 15, 2021
Graduate Faculty Council: March 2, 2021
Provost's Office and Deans' Council: March 15, 2021
Approval by the Senate:
Approval by the President: