ISD (MFG) 599 FND: Foundations in Smart Additive Manufacturing (W21)

Instructional Team

- Prof. Chinedum Okwudire: Course coordinator & module 1 instructor (okwudire@umich.edu)
- Prof. Daniel Cooper: Module 2 instructor (drcooper@umich.edu)
- Prof. Kazu Saitou: Module 3 instructor (kazu@umich.edu)
- Prof. Kevin Field: Module 4 instructor (kgfield@umich.edu)
- Prof. Kira Barton: Module 5 instructor (bartonkl@umich.edu)

GSI: Ms. Heejin Kim, (heejink@umich.edu)

Lectures: Mondays and Wednesdays, 11:30-1, Remote via Zoom (recorded for later viewing)

Office Hours: Office hours for each instructor and the GSI will be posted on Canvas.

Course Website: https://umich.instructure.com/

Text Book(s): Gibson, I., Rosen, D. W., & Stucker, B. (2015). Additive Manufacturing Technologies 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. (2nd Edition). New York: Springer. Free download available through U-M library: https://www.springer.com/gp/book/9781493944552#otherversion=9781493921126

Pre-requisites: None

Software: Basic CAD, CURA, MATLAB, ANSYS Discovery Live/SpaceClaim

All software used in this course will be either available for free or through CAEN for U-M students. Tutorials and GSI support will be provided to familiarize students with any software required for lab assignments.

Learning goals: Students will gain foundational knowledge and skills in smart additive manufacturing. Specifically, they will learn about: (1) AM workflow, processes and applications; (2) design and verification; (3) material characterization and processing; (4) monitoring, diagnostics and control; and (5) lifecycle economic and environmental considerations, all with emphasis on practice. The connections of these topics to smart manufacturing technologies will be specifically highlighted. Hands-on labs[1] and industrial case studies will be used to reinforce the course material.

Lectures: Attendance to synchronous lectures or viewing of lecture videos asynchronously is expected of all students. All lecture notes will be posted on Canvas. Lecture styles and formats may vary slightly from module to module.

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[1] All W21 labs will be remote-learning-compatible. **Students will each be loaned a desktop 3D printer for the labs.**

Course Modules: This course has five interconnected modules:

Module 1 – AM Workflow, Processes and Applications: Students will: (1) Understand what additive manufacturing (AM) is, the standard workflow for creating parts using AM, the various processes available for AM, how smart manufacturing enables and benefits from AM, as well as current and future industrial applications of AM; and (2) Gain hands-on experience of the AM workflow including part design, pre-processing, printing and post processing on polymer and metal AM machines.

Module 2 – Lifecycle Economic and Environmental Costing for AM: Students will learn to: (1) Evaluate the appropriateness of using an AM process to produce a given part by considering key manufacturing performance metrics; (2) Analyze the lifecycle economic costs and environmental impacts of using AM processes; (3) Understand the current opportunities and barriers to scaling up AM to production parts; and (4) Understand how to apply Technoeconomic Analysis and Life Cycle Assessment to target technical advances that will increase the competitiveness of AM technologies.

Module 3 – Design and Verification for AM: Students will gain knowledge for rationally incorporating AM in existing and clean-sheet product designs through the principles of part consolidation, process selection, and design for manufacture, and be exposed to advanced CAD/CAM tools for AM, including topology optimization and 3D-printer-specific automated model correction.

Module 4 – Materials Fundamentals for AM: Students will: (1) Gain an understanding of processing - microstructure - property relationships; (2) Gain an understanding of AM specificity of the different materials class (polymers, ceramics, metals) in terms of specific physical properties constraining processing and final physical and metallurgical properties and structural properties constraining microstructures; (3) Learn and apply characterization/metrology techniques and quantification within the AM flow and optimization.

Module 5 – Monitoring, Diagnostics and Control for AM: Students will: (1) Understand opportunities for *in situ* monitoring, become familiar with both *in situ* and *ex situ* techniques for monitoring and validating 3D printed components. They will learn how these measurements are used to verify functionality, as well as evaluate process parameter selection for a given device structure and material class. Concepts of control will be touched upon briefly; and (2) Gain hands-on experience of example monitoring methods for different AM processes. Data extracted from these measurement devices will be analyzed to evaluate process performance, part functionality, and determine basic control decisions.

Labs: Course will have a total of five labs – one for each module. Each lab may entail some homework before the lab, on-machine time and a template-based individual report which will be graded. In W21, the on-machine portion of the lab will be performed by students at their preferred locations using desktop 3D printers that will be loaned to them. *Students must return the 3D printers and other accessories in proper working condition at the end of the semester in order to receive their final grade for this course*

Assignments and Quizzes: Module instructors may assign graded assignments and quizzes covering the contents of each of their modules.

Exams: This course will have no exams.

Grading:

Labs, HW assignments and quizzes	20% per module

Note: The detailed breakdown of grades for each module will be provided by each module instructor at the beginning of their respective modules.

Final letter grade: A+ (>95), A (>90), A- (>85), B+ (>80), B (>75), B- (>70), C+ (>65)

University Policies and Resources

Diversity, Equity, and Inclusion

We consider this classroom to be a place where you will be treated with respect, and we welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. We are dedicated to helping each of you achieve all that you can in this class. We may, either in lecture or smaller interactions, accidentally use language that creates offense or discomfort. Should we do this, we invite you to contact us and help us understand and avoid making the same mistake again. If you do not feel comfortable contacting us in person, anonymous feedback is also fine. Please also contact us (in person, e-mail, or anonymously) if other members of the teaching staff or fellow students are detracting from our class climate.

Lecture Recording Policies

Course lectures will be audio/video recorded and made available to other students in this course. As part of your participation in this course, you may be recorded. If you do not wish to be recorded, please contact the course coordinator (okwudire@umich.edu) during the first week of class to discuss alternative arrangements. Students may NOT record or distribute any class activity without written permission from the course coordinator, except as necessary as part of

approved accommodations for students with disabilities. Any approved recordings may only be used for the student's own private use.

Accommodations for Students with Disabilities

The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Requests for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office at 734-763-3000 or ssdoffice@umich.edu.

For more information about the SSD office and the services they provide, please visit their website: https://ssd.umich.edu (Links to an external site.)

University of Michigan College of Engineering Honor Code

All students are presumed to be decent and honorable, and all students are bound by the College of Engineering Honor Code. You may not seek to gain an unfair advantage over your fellow students; you may not consult, look at, or possess the unpublished work of another without their permission; and you must appropriately acknowledge your use of another's work. Any violation of the honor policies will be reported to the Honor Council.

For more information about the Standards of Conduct, Honor Code, and Statement of Student Rights and Responsibilities, please consult the following resource:

https://bulletin.engin.umich.edu/rules/ (Links to an external site.)

University of Michigan Policy & Procedures on Student Sexual & Gender-Based Misconduct & Other Forms of Interpersonal Violence

The University of Michigan supports its educational mission by fostering a community based on civility, dignity, diversity, inclusivity, education, equality, freedom, honesty, and safety. Consistent with these values, the University is committed to providing a safe and non-discriminatory learning, living, and working environment for all members of the University community. The University does not discriminate on the basis of sex or gender in any of its education or employment programs and activities.

Please consult the following website for policy details and related support resources:

https://studentsexualmisconductpolicy.umich.edu/content/policy-statement

Course-Specific Policies

- You are allowed to discuss labs and assignments with other students. However, your reports must be based on your own work and you must indicate anyone with whom you discussed your labs and assignments report. You are not allowed to share your computer codes or reports with other students. You are also not allowed to possess, look at, use or in any way derive advantage from the existence of computer codes, lab reports or solutions prepared in prior years from former students' work. Violation of this policy will be treated as a breach of the College of Engineering's Honor Code and will be filed with the Honor's Council.
- All electronic communications with the instructors and/or GSI on course-related material should happen via the course Slack channel. **Do NOT email your questions**. If you have a question, please check the Discussions tab to see if your question has already been answered. If not, post a question and the instructor or GSI will respond to it within 24 hours. However, you may contact the instructors via email on matters that are personal in nature, and would therefore not be appropriate for public discussions.
- Students may audit this course (with permission from the course coordinator), in which case they may attend lectures but may not participate in any of the graded portions of the course.
- All lab rules and safety protocols must be obeyed during on-machine work and labs.
- Lab reports and assignments must be submitted on time otherwise a late penalty will be incurred.
- Other specific policies will be announced in class and on Canvas as the need arises.

Course Outline: Please see Course Calendar in Canvas