December 15, 2023

**Purdue University**
**School of Materials Engineering**

***MSE 568 Additive Manufacturing of Materials*** **Spring 2024**

**Lecture:** TTh 10:30-11:45 WANG 2599
**Instructor:** Prof. Kevin Trumble, ARMS 2333, 765-494-4114, driscol@purdue.edu
**Teaching Assistants:** Patrick Hearne, phearne@purdue.edu
Bingyuan Zhao, zhao1098@purdue.edu
**Website:** *Brightspace*

**Office Hours:** By phone, Webex (https://purdue.webex.com/meet/driscol), or in-person; arranged by e-mail preferred. Regular office hours will be set once semester starts. The TA(s) will also be available for regular office hours.

**Objective:** Apply the general materials processing approach to additive manufacturing for all the main classes of engineering materials.

**Description:** The course will take an MSE approach to Additive Manufacturing (AM), following the structure of the general materials processing course series taught in the School of Materials Engineering (*MSE 512 Powder Processing*, *MSE 536 Solidification Processing* and *MSE 548 Deposition Processing*); but these courses are not prerequisites. The overarching goal is to learn how microstructure development is controlled by the interaction of physical, chemical, thermal and mechanical phenomena in the shaping of materials by additive processing. All major classes of materials and AM processes will be included. Other objectives are to develop the ability to quantitatively analyze the capabilities and limitations of AM processes relative to established commercial processes; and to critically analyze the AM research literature. The course will also provide opportunities for students to explore AM topic area(s) of their own particular interest.

**Brief Outline:** Materials processing and manufacturing; Unified aspects of Additive Manufacturing (AM); Main AM process classes: vat photopolymerization, extrusion, jet printing, binder jetting, powder bed fusion, directed energy deposition; Comparative processing, including AM process design, selection and applications. Supporting fundamentals underpinning the AM unit processes will include: polymerization, rheology of melts, slurries and pastes, powder characterization and processing, focused-beam energy sources and their interaction with materials, and solidification of alloys. Relationships between microstructure development and resulting properties are stressed throughout. A week-by-week topic outline is provided (see p. 4).

**Prerequisites**: Graduate standing, or MSE 330 or MSE 367.

**Textbooks** (all available through the Purdue Library)

I. Gibson, D. Rosen, B. Stucker and M. Khorasani (**GRSK**), Additive Manufacturing Technologies, 3rd Edition, Springer Nature Switzerland AG (2021). ISBN 978-3-030-56126-0. DOI:10.1007/978-3-030-56127-7. *This book will serve as the main text for the course (pdf and epub versions are available for download).*

D. Bourell, H. Kuhn, W. Frazier, and M. Seifi, editors, (**ASM**), ASM Handbook, Vol. 24, Additive Manufacturing Processes (2020), DOI: 10.31399/asm.hb.v24.9781627082907. *Selected chapters; available at Purdue Library > Databases > ASM Materials Information Online > ASM Handbooks Online > Handbooks by Volume.*

J. Zhang and Y-G Jung, editors (**ZJ**), Additive Manufacturing: Materials, Processes, Quantifications and Applications, Elsevier, Butterworth-Heinemann (2018). DOI: 10.1016/C2016-0-01595-4. *An alternate textbook, also available through Purdue Library, with good overview chapters (1 and 2) and material class-specific AM processing chapters (3-5).*

M. F. Ashby (**A**), Materials Selection in Mechanial Design, 4th edition Elsevier, Butterworth-Heinemann (2010). *Also available through Purdue Library. General processing lectures will follow chapters 13 and 14.*

Granta EduPack (formerly CES Edupack), Ansys. *Interactive software platform accompanying the Ashby Materials texts. Purdue Library > Databases > Granta Edupack; Requires Citrix Receiver.*

Also handy may be any introductory *Engineering Materials* text (e.g., Callister, Ashby, Flinn and Trojan, Smith, etc.) and any introductory *Manufacturing Processes* text (e.g., Schey, Kalpakjian, DeGarmo, Groover). These references will be useful for reviewing related materials and manufacturing fundamentals. Back editions of these books can be obtained for next to nothing, i.e., don't spend $250 on the latest edition(s), as their relevant content does not go out of date. These books can also be readily borrowed from libraries.

**Course Format**
The course is running in a hybrid mode through the Purdue College of Engineering online program. Lectures will be recorded with an in-person (on-campus) class in the WANG 2599 studio-classroom and posted to *Brightspace* the same day. The lecture recordings will be available to all student any time.

**Lecture Format**
The lectures will be presented using partially completed template slides that can be downloaded from the website and used to follow along with note taking.

**Exams**
Two midterm exams (Thursday, February 15 and Tuesday, April 2) and a comprehensive final exam (April 29-May 4 TBA) will be given. The exams will be in-class for the on-campus students and online via *Gradescope* in *Brightspace* for the off-campus students (see p. 3).

**Homework**
Homework sets (5) will be turned in electronically on *Brightspace* and nominally graded as follows: ✓+ (100), ✓(75), ✓– (50). Solutions will be discussed in class.

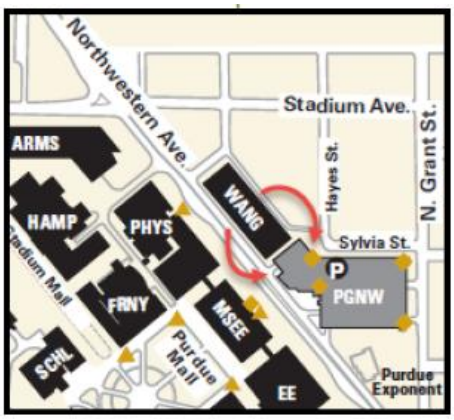
**Presentation Assignment**
A communication assignment (due after the second exam) will involve preparing a recorded presentation (voice recording over slides) on an AM topic of particular interest to the student.

**Assessments and Grading (percentage of final grade):**
Homework problem sets throughout the semester (10%); virtual (recorded) oral presentation (15%); two midterm exams (20% each); and a comprehensive final exam (35%). The final grade scale will be based on class performance, with divisions no higher than the following total scores: A ≥85%, B ≥70%, C ≥60%, D ≥50%. Final grades will include "+" and "–" divisions, divided evenly by score within each letter grade range. Although on-campus and off-campus student will take the same exams, final grades will be assigned relative to the separate distributions.

**Emergency Procedures**

Fire, weather, and civil emergency procedures specific to the WANG 2599 will be reviewed in class. Information on emergency preparedness at Purdue is available on the Purdue homepage and at http://www.purdue.edu/emergency_preparedness/.

For a shelter-in-place siren (tornado, hazardous material release, civil disturbance) stay in WANG 2599 and wait for further instructions. In case of a fire alarm, exit WANG via the stairway and assemble in the Northwestern Avenue parking garage.




In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances. These changes would be posted on the course website on *Brightspace*. In case of an extended disruption in which classes on campus are suspended the course will continue in the online only mode via *Brightspace*.

**Covid-19 Protocols**

See the Protect Purdue central website for Covid-19 updates: https://protect.purdue.edu/. On-campus students can also contact the Purdue Health Center by calling 765-496-INFO (4636) or toll-free at 833-571-1043. If you feel at all sick, it is very important not to come to class. One advantage we have with this course format is that the lecture recordings will be available to all students at any time. So, if you do miss class you can keep up with the lectures remotely. That said, please do attend lecture if you are healthy. If you anticipate an extended absence from the course for any reason (e.g., severe illness, family emergency) please inform Prof. Trumble as soon as possible, to discuss how you can make up any missed work.

**Remote Examinations**

Off-campus students will take the same exams, on the same days, as on-campus students, but administered online through *Gradescope* via *Brightspace* using the following procedure:

A pdf exam file identical to the in-class exam paper (~6 pages) will be downloaded and worked (written out) by the student, either electronically on a tablet or printed and worked on paper and then scanned or photographed, and uploaded as a single electronic file to *Gradescope*. The midterm exams will be 60 minutes and the final exam 120 minutes. Extra time will be allowed for downloading and uploading the exams. Students are on their honor to work the exam by themselves and without any internet resources. The midterm exams will be available in a window from the start of the in-class exams (10:30a-11:59p EST).

**Mental Health Resources**

If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours. Students should also feel welcome to discuss any concerns they have with Prof. Trumble.

**Students with Disabilities**

If you anticipate or experience physical or academic barriers based on disability, you are welcome to discuss options with Prof. Trumble. You are also encouraged to contact the Disability Resource Center at drc@purdue.edu or by phone: 765-494-1247; https://www.purdue.edu/drc/.

**Diversity and Inclusion**
Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. Purdue's nondiscrimination policy can be found at the following website: http://www.purdue.edu/purdue/ea_eou_statement.html. If you see, hear or experience discrimination in any form you are always welcome to discuss it with Prof. Trumble. The College of Engineering also has a website that provides extensive resources for diversity at: https://engineering.purdue.edu/Engr/AboutUs/Diversity/DiversityResources.

**Academic Dishonesty Policy**
Purdue University Regulations, Part 5, Section III-B-2-a describes the formal policies governing academic dishonesty. A guide providing specific examples, tips, and consequences is available at http://www.purdue.edu/odos/osrr/academic-integrity/index.html. You are encouraged to study together and discuss coursework, but any work you turn in for grading is expected to be your own original work. Notes presented in the lectures are subject to copyright. Students in the course are granted permission to copy and exchange these notes with other students in the course, but they cannot be sold, bartered or posted on any website without permission.

**Week-by-Week Topic Outline (approximate)**
1. Introduction, Materials processing and Additive Manufacturing
2. Generic AM kinematics and Cost analysis
3. Polymers, Polymerization and Vat Photopolymerization (VPP)
4. Vat Photopolymerization, polymer rheology and extrusion
5. Material Extrusion (MEX)
6. Material Jetting (MJT) and **Exam 1** (INTRO, VPP and MEX)
7. Surface tension, capillarity and MJT
8. Powder characterization and bulk powder processing
9. Binder Jetting (BJT) and desification (post-processing)
10. SPRING BREAK
11. Focused-beam heating
12. Powder Bed Fusion (PBF) and solidification of alloys
13. **Exam 2** (MJT, BJT) and Powder Bed Fusion
14. Directed Energy Deposition (DED)
15. DED and Hybrid processes
16. Comparative AM processes-properties
17. **Final Exam** (Comprehensive, but with emphasis on material since E2)