ME/MS 576: Nanomanufacturing and Hierarchical Materials

INSTRUCTOR
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LECTURE
Monday/Wednesday 12:20 to 2:05 PM EPC 208 (reserve a seat via *InClassLfA*)
https://bostonu.zoom.us/j/94799155718
Password: Nano2Macro

PREREQUISITES
ENG ME 304, ME 305, and ME 306 or equivalents.

READINGS
Readings will be provided from the literature. In addition, the following texts are useful (but not required) resources for this course:

- "Micro and Nanomanufacturing" by Mark J. Jackson, Springer International Publishing
- "Biomimetics" by Bharat Bhushan, Springer International Publishing
- "Hybrid and Hierarchical Composite Materials" by Chang-Soo Kim, Charles Randow, and Tomoko Sano, Springer International Publishing
- "Nanotechnology: Understanding Small Systems" By Ben Rogers, Jesse Adams, and Sumita Pennathur, CRC Press

COURSE WEB SITE:
Blackboard

OVERVIEW
Nanoscale materials are often celebrated as having unique properties that exceed their bulk counterparts. However, leveraging such nanoscale materials as components in bulk materials is challenging as it requires (1) making enough material to be relevant on bulk scales and (2) incorporating nanomaterials at a bulk scale in a manner so as to maximize their effect. The structural ordering of these nanomaterials can range from disordered, as in the case of nanocomposites, to highly ordered, as is generally the case in metamaterials. This course is designed to communicate the state-of-the-art, challenges, and opportunities of constructing hierarchical materials with nanoscale constituents.

COURSE GOALS
Obtain fundamental understanding of how emergent properties derive from structure and material
Overview nanoscale effects that can be leveraged in bulk materials
Understand the challenges of scaling nanomanufacturing
Learn applications of conventional semiconductor processing to materials processing
Survey classes of bulk nanostructured materials and their applications
Overview colloidal assembly processes and characteristics of smart materials
Define metamaterials in different contexts and understand associated design principles
Ability to critically read primary literature related to nanomanufacturing

COURSE OUTCOMES

1. Understand how emergent properties derive from structure and material properties
2. Understand state-of-the-art nanomanufacturing approaches and their limitations
3. Understand the applications of hierarchical nanostructured materials
4. Ability to critically read primary literature to determine manufacturing limitations
5. Experience presenting a critical evaluation of literature
6. Prepare a proposal that connects a manufacturing technique, a hierarchical material, and a model application
7. Experience designing hierarchical materials

ASSESSMENT

10%	Participation – attendance and contributions to classroom learning environment
30%	Problem sets – collections of quantitative analysis problems that build on lecture discussion
10%	Media presentation –presentation during lecture on a selected video
20%	Project presentations – three presentations defending proposed topic for final topic
30%	Final project – Written report

PROBLEM SETS

Problem sets will be due one week after they are distributed. There are no restrictions to what may be used as a resource to solve these, but the submitted work must reflect the student's own work.

MEDIA PRESENTATION

~10 minute presentation to be presented at the end of class covering a video that topically aligns with the content of the lecture. The video will be assigned by Prof. Brown approximately one week ahead of the lecture (although suggestions are welcome). The purpose of the presentation is to summarize the media, then evaluate their technical accuracy and implications. Organizationally, this must include

(A) Identification of the key length scales in the material, system, or application of interest
(B) Discussion of the structure and its key features
(C) Overview of how the structure was made
(D) A judgement on the honesty of the video

FINAL PROJECT

The main evaluation from the class is a project based upon an approved topic of the student's choosing. Deliverables for this project include three presentations and a final paper. To aid in the selection of the project, 2/3 will be an "Applications Marketplace" for students to discuss topics and a class theme.

- Presentation 1 (2/8) – Define the problem, define the fundamental challenges and key length scales.
- Presentation 2 (3/3) – Introduce structures that are made to address the challenges and describe how they are constructed with a focus on the limitations of the techniques.
- Presentation 3 (4/28) – Analyze hierarchical materials that have been designed to address the challenge and compare their properties. Be sure to emphasize how these properties differ from materials that do not feature hierarchical structure.

Final paper must be five pages *or less*, have 1" margins, single spaced, and the font must be 12 point Times New Roman. This page limit includes all cover pages, figures, and references. The paper should be broken into six clearly delineated sections

1. Identification of the application area and overview of challenges
2. Identification of key length scales and why they are important
3. Overview of structures and their properties
4. Description of the synthesis/fabrication processes and their limitations
5. Summary and outlook
6. References

SCHEDULE

1/25	Introductions	Length Scales
1/27	Introductions	Nano is Relative
2/1	Introductions	Applications of Nanomanufacturing
2/3		Applications Marketplace and Discussion
2/8		**Presentation 1**
2/10	Nanomanufacturing	Films
2/16	Nanomanufacturing	Lithography
2/17	Nanomanufacturing	Etching
2/22	Nanomanufacturing	Additive Manufacturing
2/24	Nanomanufacturing	Nanoparticles
3/1	Nanomanufacturing	Nanowires
3/3		**Presentation 2**
3/8	Hierarchical Surfaces	Wetting
3/10	Hierarchical Surfaces	Drag & Adhesion
3/15	Hierarchical Surfaces	Devices
3/17	Composites & Colloids	Mixing Laws and Lattices
3/22	Composites & Colloids	Mechanical Metamaterials
3/24	Composites & Colloids	Polymer Matrix Composites
3/29	Composites & Colloids	Composites with Fibers and Plates
4/5	Composites & Colloids	Liquid Matrix Colloids
4/7	Composites & Colloids	Smart Fluids
4/12	Waves	Particles and Waves
4/14	Waves	Optical Metasurfaces
4/21	Waves	Optical Metamaterials
4/26	Waves	Acoustic and Thermal Metamaterials
4/28		**Presentation 3**