ECE 819: Smart Material Sensors and Actuators
Fall 2019 (Credits: 3)

Access MSU D2L for homework, reading materials, etc.

OVERVIEW:

Smart materials (e.g., piezoelectric materials, shape memory alloys, and electroactive polymers) show strong couplings between the applied electric, magnetic, or thermal field with their mechanical properties (strain, viscosity, etc.). Such couplings provide built-in mechanisms for sensing and actuation. Due to their compact sizes and unique properties, smart material sensors and actuators have broad applications in robotics, structural monitoring and control, aerospace industry, biomedical devices, automotive systems, to name just a few. In particular, they provide promising solutions in emerging areas such as soft robotics, biomanipulation, prosthetics, implantable drug delivery systems, and scanning probe microscopy.

The goal of this course is to expose the students to the general area of smart materials with an emphasis on modeling. Students will learn the potentials of smart sensors and actuators, the challenges associated with their uses, and the approaches to address these challenges. This interdisciplinary course will provide an integrative treatment of smart materials and systems, covering material fundamentals, fabrication methods, application examples, and techniques for modeling, analysis, and control.

This course will emphasize discussion and interaction in class along with extensive reading. Students will have opportunities to identify novel problems related to smart sensors or actuators in their own research areas, and carry out the investigation through course projects. The topic of a course project is flexible, and could be the design of a novel device, development of a prototype, controller design, and model development among other possibilities. Project examples in prior related course offerings can be found at the following links:

(1) Spring 2005 offering
(2) Spring 2008 offering
(3) Fall 2011 offering
(4) Fall 2014 offering
(5) Fall 2017 offering

Aside from the individual-based projects, students will co-teach subjects on new smart materials as groups. This component of the course aims to train students in exploring literature, synthesizing and organizing teaching materials, teaching, and collaborating as a team.

INSTRUCTOR:

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CLASS TIME AND PLACE:

Tu, Th: 1-2:20 pm, 2243 Engineering Building

TEXT BOOK:

- D. J. Leo, Engineering Analysis of Smart Material Systems, John Wiley & Sons, Inc., 2007 (available online via MSU Library)

REFERENCES:

- R. Smith, Smart Material Systems: Model Development, SIAM, 2005
- Archival Journals: Smart Materials and Structures, Journal of Intelligent Material Systems and Structures, IEEE Transactions on Mechatronics, Sensors and Actuators A: Physical.

COURSE OUTLINE:

1	**Introduction to materials and their applications** (Chapter 1)
2	**Fundamentals on mechanics and electrostatics** (Section 2.1)
2.1	Basic mechanics of materials: stress and strain
2.2	Basic electrostatics
3	**Piezoelectric materials and actuators** (Chapter 4 and Section 5.1)
3.1	Introduction to piezoelectric materials
3.2	Piezoelectric materials: constitutive relationships
3.3	Piezoelectric actuators: stack actuators
3.4	Piezoelectric actuators: stack actuators (dynamic actuation and sensing)
3.5	Piezoelectric actuators: bending actuators
3.6	Derivation of constitutive relationships via thermodynamic formulation
4	**Piezo-integrated structures** (Sections 2.4-2.6, Sections 5.2-5.6)
4.1	Variational analysis (static)
4.2	Variational analysis (dynamic)
4.3	Modeling of piezo-actuated structures
4.4	Piezo-based damping and energy harvesting
5	**Shape memory alloys (SMAs)** (Chapter 6)
5.1	Introduction to SMAs
5.2	Modeling of SMAs
6	**Other smart materials (student lecturers)** (reference materials)
6.1	Ionic polymer-metal composites
6.2	Dielectric elastomer actuators
6.3	Shape memory polymers
6.4	Magnetorheoloical and electrorheological fluids
7	**Hysteresis in smart materials** (reference materials)
7.1	Introduction to hysteresis
7.2	Modeling of hysteresis in smart materials
7.3	Compensation of hysteresis in smart materials

GRADING:

The final grade is based on

- Class attendance (5%) - For attendance credit, you earn 5 points if you miss less than (<) five lectures (including all legitimate reasons), and receive zero otherwise.
- Homework (30%)
- Midterm exam (25%)
- Group-based teaching (10%)
- Individual project (30%), comprised of presentation (15%) and written report (15%)