# ME 734 Smart Materials and Structures (3 credits)
# Spring 2023

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| **Instructor:** | **Dr. Xiangfa Wu**, 206 Dolve Hall (231-8836), Email: Xiangfa.wu@ndsu.edu<br>Faculty academic website: www.ndsu.edu/faculty/xwu |
| **Lecture Hours:** | **9:30-10:45 AM T& Th** Dolve 202 (Jan 9 – May 12, 2023)<br>(Dead Week: May 1 – May 5)<br>Holidays: Martin Luther King Day: Jan. 16 (Monday); President Day: Feb. 20 (Monday); Spring Break Week: Mar. 13-17 (Monday – Friday); Spring Recess: Apr. 7-10 (Friday – Monday) |

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| **Special Days:** | Jan. 19 (Thursday): | Withdraw to zero credits at 100% refund |
| | Feb. 20 (Monday): | Withdraw to zero credits at 75% refund |
| | Mar. 23 (Thursday): | Withdraw to zero credits at 50% refund (no refunds for withdraw to zero credits after this date) |
| | Apr. 6 (Thursday): | Last day to drop class with "W" record<br>Last day to withdraw to zero credits |

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| **Office Hours:** | **Tuesday & Thursday: 3:30 – 4:30 PM**, Other hours by appointments |
| **Course Credit:** | 3 |

**Bulletin Description:** Fundamental concepts and principles of smart materials (e.g., piezoelectrics, electrostrictives, magnetostrictives, shape memory alloys & polymers, smart/functional polymers, electrorheological & magnetorheological fluids, etc.) and structures and related applications.

**Course Description:** A smart material may be defined as a material that possesses intrinsic sensing, controlling, and actuating capabilities. A smart structure is a combined material system or device that is, intrinsically or extrinsically, capable of sensing, controlling and actuating. The course will describe the fundamental sciences and engineering involved in the design, synthesis, processing, fabrication, operation, and various applications of smart materials and structures.

**Textbook:** No specific textbook is identified. All well-typed lecture notes will be made available to the students

## References:


1) Engineering Analysis of Smart Materials Systems (by Donald J. Leo), John Wiley & Sons (2007).
2) Smart Materials Systems: Model Development (by Ralph C. Smith), SIAM (2005).
3) Smart Structural Theories (by Inderjit Chopra & Jayant Sirohi), Cambridge University Press (2014).
4) Smart Structures and Materials (by Brian Culshaw), Artech House (1996).
5) Smart Structures: Analysis and Design (A. V. Srinivasan & D. Michael McFarland), Cambridge University Press (2001).
6) Shape Memory Materials (by K. Otsuka & C. M. Wayman), Cambridge University Press (1998).
7) Polymeric Sensors and Actuators (Johannes Karl Fink), Wiley (2013).
8) Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications (by Deborah D. L. Chung), World Scientific Press (2010).
9) Properties of Materials: Anisotropy, Symmetry, and Structure (by Robert E. Newnham), Oxford University Press (2005).
10) Energy Storage (by Robert A. Huggins), Springer Press (2010).
11) Multiple journal papers

**Prerequisites:** Graduate standing.

**Course Objectives:** To provide students with a good understanding of the physics and engineering principles and applications of smart materials and structures.

**Course Outcomes:**
At the completion of this course, students will

1. Understand the definitions and significance of smart materials and structures.
2. Learn the basic principles of smart materials and structures, including the stimulus-response effects in smart materials and their design, fabrication, modeling, and performance predictions.
3. Get familiar with and learn how polymeric materials are designed and used for sensors and actuators.
4. Acquire the operational principles of other organic, inorganic and biological functional materials.
5. Gain the knowledge of how to design and prepare smart materials, structures, and devices.
6. Be familiar with the fundamental principles of smart composites, including design, fabrication, modeling, and performance predictions.
7. Grasp the applications and current research topics in smart material systems.

**Course Grading:**
Students are expected to:

1) Complete homework assignments on time,
2) Take tests: midterm and final exam,
3) Complete term paper and presentation.

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| Homework | **40%** |
| Term paper | **20%** |
| Mid-term exam | **20%** |
| Final Exam | **20%** |
| Total | **100%** |

Final course grades will be assigned according to the following scale:

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| **A** | 90% or greater |
| **B** | 80% to less than 90% |
| **C** | 70% to less than 80% |
| **D** | 60% to less than 70% |
| **F** | Less than 60% |

**No scaling will be applied in this course**

**Homework**: Classical homework problems will be assigned during lectures and posted on the course website. It is essential for the students to do homework problems to learn how to apply the fundamental concepts and principles learned in this class.

**Term Paper**: Each student is required to conduct a critical review on a selected topic related to smart materials and structures (based on open literature). The student is required to write a term paper of approximately 10-15 pages and give a presentation on the selected topic. Preferred term-paper topics are those relevant to new technologies in the sub-fields of new sensor materials, actuator materials, functional materials (e.g., alloys, polymers, composites, etc.), control issues, smart composites, biomimetic materials, multifunctional materials, and related synthesis, fabrication, design and modeling issues. Students are encouraged to discuss with the instructor regarding the term-paper topic. The following requirements should be followed:

1. The term paper should include a concise, informative title, author's name, and contact information.
2. Content of the paper may consist of Introduction, Problem Statement/Formulation, Critical Discussions and Prospects, Conclusions, Acknowledgment (if needed), and References (>15).
3. The term-paper problem should be closely related to the class content and should be a ***Critical Review***. Trivial review and routine collection/reduction of field literature and data without critical comments and rational suggestions and prospects should be avoided. Student is encouraged to discuss his/her term-paper topic with the instructor before starting writing.

4. Format of the paper should follow those used in *ASME Journal of Engineering Materials & Technology* (http://asmedigitalcollection.asme.org/index.aspx), or *Journal of Applied Physics* (http://jap.aip.org/). The following requirements are enforced: Single column and single spaced; Font type: times new roman; Font size: 10 or 11 (Size 11 is preferred); Page size: letter 8.5×11 inches; Page margins: top & bottom: 1 inch, inside & outside: 1 inch; Page number: located at the right bottom; Header & Footer: optional; Figures & Illustrations: with sufficient resolution. The paper should not be longer than 15 pages (including formulas; diagrams, and references).

5. Typed hardcopy of the paper should be turned in on **Thursday of the Dead Week (May 4$^{th}$, 2023)**. An electronic copy of the paper in the format of MS-Word (preferred) or PDF should be sent as email attachment to the instructor at the time when the hardcopy is turned in.

**Academic Honesty Statement**: All work in this course must be completed in a manner consistent with NDSU University Senate Policy, Section 335. Code of Academic Responsibility and Conduct (available on the Web at http://www.dsu.nodak.edu/policy/335.htm). Violation of this code will result in a penalty or penalties to be determined by the instructor to fit the gravity of the offense and the circumstances of the particular case. The instructor may: (1) fail the student for the particular assignment or test, (2) give the student a failing grade in the course, or (3) recommend that the student drop the course.

**Attendance**: Students should realize that there are materials covered in class which are not discussed in the textbook. The student is responsible for **ALL** material presented in class whether or not s/he is present in class. If a student misses a class, it is the student's responsibility to obtain notes from a classmate. Full credit can be received for work turned in late due to an excused absence. It is the student's responsibility to contact the instructor in such a case. If the student is going to miss a test for a good reason, s/he should provide the instructor a written **DOCUMENT** with authority's (or administrative) signature and contact information BEFORE the test in order to arrange for a make-up exam.

*Veterans and student soldiers with special circumstances or who are activated are encouraged to notify the instructor in advance*

**Disabilities**: Any student with disability who needs accommodations is encouraged to talk to the instructor as soon as possible to make appropriate arrangements for these accommodations.

**Course Outline (Tentative):**

| Topics | Topics |
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| **1** | Introduction to Smart Materials & Structures (SMS): Historical developments and potential applications |
| **2** | Biomimetic Principles and Ideas of Smart Materials & Systems<br><br>Bionic principles of smart materials<br>Nano biomimetic materials<br>Biomimetic materials and smart materials development |
| **3** | Smart Polymers & Applications (by **Dr. Oksana Zholobko**)<br><br>Basic concepts of polymers<br>Types of smart polymers (e.g., stimuli-responsive, shape memory, self-healing polymers, and smart polymer hydrogels, etc.)<br>Applications of smart polymers (e.g., biomedical, industrial, sensing, etc.) |
| **4** | Piezoelectric Materials & Systems<br><br>Piezoelectricity & electromechanical constitutive laws<br>Piezoceramic actuators<br>Piezoelectric sensors<br>Structures with induced-strain actuation<br>Passive & semi-active damping system<br>Active structural control<br>Energy harvesting system |
| | **Midterm Exam** |
| **5** | Shape Memory Alloys (SMA) & Polymers<br><br>Fundamentals of SMA behavior<br>Constitutive models<br>Behavior of structures embedded with SMAs<br>Shape memory polymers: Synthesis, performance, and applications |
| **6** | Electroactive Polymeric Materials<br><br>Dielectric elastomer<br>Conducting polymer actuators<br>Ionomeric polymer transducers |
| **7** | Magnetostrictives & Electrostrictives<br><br>Magnetism & Magnetostriction<br>Magnetostrictive models<br>Magnetostrictive actuators & sensors<br>Magnetic SMAs<br>Electrostrictives |
| **8** | Electrorheological (ER) & Magnetorheological (MR) Fluids<br><br>Behaviors of ER & MR Fluids<br>Models of ER/MR Fluid behavior & device performance<br>ER/MR fluid dampers |
| **Extra** | Polymeric sensors & actuators<br>Nanostructured smart materials<br>Nanofibers of smart materials & applications |
| | **Final Exam/Presentation** |