

MATSE 417: ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS

Course Designation: Formerly designated CERSE 430; this is a required course in Ceramic Science and Engineering, Electronic and Photonic Materials. It is being considered as a core course for Metals Science and Engineering. It is an elective course in other options.

Catalog Description: Electrical conductivity, dielectric properties, piezoelectric and ferroelectric phenomena; magnetic properties of ceramics.

Course Description: This course is designed to provide students with a fundamental understanding of the different responses a material can make to applied electrical or magnetic fields. Important properties are introduced and correlated with a knowledge of material chemistry, crystal structure, and microstructure to provide an understanding of the mechanisms responsible for controlling the observed properties, as well as the ways in which properties can be engineered.

Prerequisites: MATSE 400, MATSE 402, PHYS 214

Textbook: **(Required)** Electroceramics: Materials Properties, and Applications, by A. J. Moulson and J. Herbert
(Optional) Lectures on the Electrical Properties of Materials, by L. Solymar and D. Walsh

Course Objectives: The objectives of the course shall be to enable students to:

1. To understand the fundamental mechanisms which can occur as electric or magnetic fields are applied to materials.
2. To understand how physical properties are related to these underlying physical phenomena, as well as crystal structure and microstructure.
3. To understand the operating principles of commercially important electroceramics.
4. To appreciate the engineering significance of these ideas and how they relate to industrial products: past, present, and future.
5. To tie together concepts introduced in physics, chemistry, crystal chemistry, kinetics, and processing courses.

Topics Covered:

1. Metallic conductors: scattering, conductivity
2. Energy bands: Kronig-Penney model
3. Semiconductors: conductivity, intrinsic and extrinsic materials, contact, and junctions
4. Semiconducting Ceramics: Defect chemistry, thermistors
5. Ionic conductors: Ion mobility, stabilized ZrO_2 , $\beta-Al_2O_3$
6. Linear dielectrics: Polarizability, dielectric constant and loss, breakdown, electronic packaging
7. Non-linear dielectrics: Ferroelectricity, spontaneous polarization, domains and hysteresis, capacitors, piezoelectrics, and pyroelectrics
8. Magnetic ceramics: superexchange, domains and walls, soft/hard/memory magnets
9. Superconducting ceramics

Class Schedule: 3 credit course offered annually meeting 3 times per week for 50 minutes

Course Outcomes:

1. Students should understand the basic mechanisms governing electrical conductivity in metals, insulators, and semiconductors, including band conduction, electron hopping, and ionic conductivity. They should also be able to calculate the resulting conductivities as a function of temperature.
2. Students should understand the mechanisms that contribute to polarizability in linear and nonlinear dielectrics, and should appreciate the impact on the frequency and temperature dependence of the dielectric constant and loss.
3. Students should understand the origins of magnetic moments in atoms, as well as the means by which magnetic moments couple in ceramic magnets.

4. Students should understand the origin of domain structures in ferroelectric and ferromagnetic materials in terms of the underlying crystallography, and be able to describe the consequences on low and high field electrical and magnetic properties.
5. Students should be able to use the governing equations for thermistors, varistors, capacitors, carrier concentrations and mobilities, defect chemistry concentrations as a function of temperature and the ambient gas pressures, piezoelectricity, pyroelectricity, and magnetic materials.
6. Students should understand how compositions are chosen and modified for a wide variety of electroceramic applications. They should be able to make informed decisions on appropriate materials for specific applications.
7. Students should have integrated phenomena from quantum mechanics, electrostatics, crystal chemistry, processing, and kinetics.

Assessment Tools:

1. Three midterms and a final exam.
2. Problem sets, which allow student collaboration.

Professional Component: This class attempts to teach students to integrate knowledge from several of their other courses, so that they can begin to see connections between course material. By approaching electrical and magnetic properties from an understanding of the fundamental mechanisms which govern polarization, conductivity, and magnetism, etc., students are also equipped to appreciate and contribute to the design of components with specific engineering criteria.

Prepared by: Susan Trolier-McKinstry, February 2002

MAP TO DEPARTMENTAL OUTCOMES (For further detail, see coursebook)											
a	b	c	d	e	f	g	h	i	j	k	l
1	2	1	3	1	3	3	2	2	2	1	1

MAP TO DEPARTMENTAL OBJECTIVES (For further detail, see coursebook)						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1,2,3,5	1,2,3,4,5	1,2,3	3,4,5		2	5