Department of Materials Science and Engineering  
University of Maryland  

ENMA 420, Intermediate Ceramics (Elective) – 3 Credits

Class Schedule: 2145 CHE; Tuesday, Thursday 2:00-3:15 pm

Instructor: Dr. Isabel K. Lloyd


Catalog/Course Description: To introduce basic concepts such as crystal chemistry, defect chemistry and ternary phase equilibria which can also be used to illustrate the various types of advanced ceramics (superconductors; superionic conductors; dielectrics including ferroelectrics; optical materials; high temperature structural materials; etc.) and allow an understanding of their behaviors.

Prerequisites: ENMA 300 or permission of the department.

Course Goals: The primary objective of this class is to explore how crystal structure and defect structure influence the behavior and application of advanced ceramic materials. While a wide variety of materials will be discussed, the focus will be on materials with potential in energy and bioengineering based applications. Properties explored will include phase equilibrium, electrical behavior and mechanical behavior. Students satisfactorily completing the class will:
1. Review and analyze the literature related to a specific advanced ceramic material and its applications.
2. Be able to choose an appropriate model system for single crystals, polycrystalline ceramics, and ceramic glasses using bonding, crystal structure, electronegativity, stoichiometry, packing density, defect chemistry, etc. and then use this model system to predict behavior trends in a material for which there is little information available.
3. Understand ternary phase equilibria as well as binary phase equilibria, and be able to use known phase diagrams to help design processes and to avoid major problems with respect to compatibility, melting, etc.
4. Have a basic understanding of point defect in compounds including the ability to predict the effect of impurities and atmosphere on electrical behavior and mass transport behaviors like sintering and ionic diffusion.

Student Outcomes Covered by the Course:
ABET A: Ability to apply mathematics, science and engineering principles;
ABET B: Ability to design and conduct experiments, analyze and interpret data.
ABET C: Ability to design a system, component, or process to meet desired needs;
ABET E: Ability to identify, formulate and solve engineering problems;
Topics Covered:
I. Introduction: What are ceramic materials? What kinds of properties would you expect ceramic materials to have?

II. Structure
   A. 3-D: Crystal Structure: Basic ceramic structures including: the rocksalt structure; the fluorite structure; the perovskite structure; the zincblende and wurtzite structures; and ceramic glasses will be reviewed. Then the structure of materials currently under investigation for advanced applications will be explored. Discussion of structures will include atomic bonding, symmetry and packing density in addition to the location of the atoms so that the expected behavior (electronic, transport and mechanical) can be predicted and compared with real materials for various structure types. The effects of structural variations on crystal structure and behavior will also be explored.
   
   B. 2-D: Surfaces and Interfaces: Grain boundaries, phase boundaries and external surfaces are defects with respect to atomic arrangement and they often have chemistries which differ from the bulk. The nature of such interfaces will be discussed briefly. Their expected behaviors will be explored in comparison with generalized bulk behavior. The emphasis will be on grain boundaries in bulk polycrystalline materials, and surfaces and interfaces in nanomaterials.
   
   C. 0-D: Point Defects: Since ceramic materials are compounds, often with mixed ionic and covalent bonding, their point defect chemistry is relatively complex. Ionic defects (anion vacancies and interstitials, cation vacancies and interstitials, and substitutional and interstitial impurities), electronic defects (electrons and holes), and their interactions must be considered. Intrinsic (Schottky defects, Frenkel defects, electronic defects) and extrinsic defects will be discussed. Kroger-Vink notation will be introduced and utilized to write point defect reactions and predict their effects on behavior. Specific examples of how point defects are important to behavior, such as in stabilized zirconia oxygen detectors, will be given.

III. Phase Equilibria
   Basic unary and binary phase equilibria are covered in ENMA 300, Introduction to Materials and Their Applications and ENMA 471, Kinetics. This section goes beyond these classes to examine phase equilibria in ternary systems with and without solid solution. Both equilibrium and nonequilibrium cases will be considered. Liquidus projections, vertical sections and isothermal sections will be discussed. The relationships between phase equilibria, processing and microstructure will be considered. The emphasis will be on learning to interpret and use phase diagrams to design processes approaches and avoid problems during application at elevated temperatures.