MSE 4002: Ceramic Materials, Processing, Properties, and Applications

Credit hours and contact hours: 3-0-0-3

Instructor: Robert Speyer

Textbook: No textbook used. Instructor notes used.

Specific course information

Catalog description: Properties, processing, and applications of the industrially and technically important ceramic materials. Traditional and oxide ceramics in addition to glass and nonoxide ceramics.

Prerequisites: MSE 3002 – Structural Transformation -Metals, Ceramics & Polymers

Course: Selected Elective

Specific goals for the course

Outcomes of instruction:

Outcome 1: The student will develop a working knowledge of classical ceramics.

1.1 The student will be able to derive ionic structures based on filling of close-packed anions.
1.2 The student will understand the elements and minerals of the earth's crust, and be able to describe natural minerals based on a silica backbone.
1.3 The student will demonstrate an understanding of the structures and properties of clays, as well as processing of triaxial porcelain bodies.
1.4 The student will demonstrate an understanding of adhesion and color in glaze and enamel coatings.
1.5 The student will demonstrate an understanding of fabrication of cement, and cement setting chemistry, including superplasticizer and pozzalonic additives.
1.6The student will demonstrate an understanding of microstructure/property relations of ceramic refractories and the industrial processes they serve.

Outcome 2: The student will gain an understanding of glass network theory and apply it to processing and properties.

2.1 The student will be able to correlate a high degree of covalency to glass-forming tendency and use this to explain Zachariasen's rules.
2.2 The student will use random network theory to explain shifts in the properties of glasses with modifier and intermediate additions.

2.3 The student will understand important viscosity demarcations, as well as the meaning of the glass transformation temperature.
2.4 The student will understand the fundamentals of brittle fracture, and how glass can be strengthened.
2.5 The student will understand liquid immiscibility, and from this, the fabrication methods and products associated with phase separated glass and glass-ceramics.
2.6 The student will demonstrate an understanding of the optical properties of glass, including dispersion, anti-reflective coatings, and ligand theory of color formation.

Outcome 3: The student will understand the fundamentals of powder processing and sintering of high-performance ceramics.

3.1 The student will demonstrate an understanding of powder characterization methods such as sedimentation, coulter counters, BET analysis, and density/pycnometry.
3.2 The student will understand the relative benefits of various particle beneficiation methods as well as particle packing theory.
3.3 The student will understand defloculation theory and the optimization of ceramic aqueous suspensions.
3.4 The student will understand the methods and optimization of powder consolidation: casting, pressing (uniaxial and cold isostatic), extrusion, and injection molding.
3.5 The student will understand thermolysis, sintering, and grain growth, and associated optimization.
3.6 The student will understand processing, properties, and applications of advanced ceramics such as alumina, zirconia, silicon carbide and nitride.

Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

Topics covered:

1. Classical Ceramics
   a) Crystal structures of ionic compounds
   b) Mineralogy and crystal structure of largely covalent compounds
   c) Clays and triaxial porcelains
   d) Glazes and enamels
   e) Plasters, cements, and concretes
   f) Refractories

2. Glass
   a) The glass network
   b) Zachariasen's rules, network formers, intermediates and modifiers
   c) Composition-property relations
   d) Commercially important glass compositions
   e) Temperature-related behavior
   f) Strengthening of glass
   g) Phase-separated glass and glass-ceramics
   h) Optical properties

3. Ceramic Processing
   a) Powder characterization
   b) Powder packing and beneficiation
   c) Ceramic suspensions
   d) Ceramic forming
   e) Thermal processing
   f)
4. High-performance Ceramics
   a) Alumina
   b) Zirconia
   c) Silicon nitride and silicon carbide

Correlation between Outcomes of Instruction and Student Outcomes:

Outcomes of Instruction	**Student Outcomes**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1.1 The student will be able to derive ionic structures based on filling of close-packed anions.	X						
1.2 The student will understand the elements and minerals of the earth's crust, and be able to describe natural minerals based on a silica backbone.	X						
1.3 The student will demonstrate an understanding of the structures and properties of clays, as well as processing of triaxial porcelain bodies.	X	X			X		
1.4 The student will demonstrate an understanding of adhesion and color in glaze and enamel coatings.	X	X			X		
1.5 The student will demonstrate an understanding of fabrication of cement, and cement setting chemistry, including superplasticizer and pozzalonic additives.	X	X			X		

1.6 The student will demonstrate an understanding of microstructure/property relations of ceramic refractories and the industrial processes they serve.	X				X		
2.1 The student will be able to correlate a high degree of covalency to glass-forming tendency and use this to explain Zachariasen's rules.	X				X		
2.2 The student will use random network theory to explain shifts in the properties of glasses with modifier and intermediate additions.	X				X		
2.3 The student will understand important viscosity demarcations, as well as the meaning of the glass transformation temperature.	X				X		
2.4 The student will understand the fundamentals of brittle fracture, and how glass can be strengthened.	X	X			X	X	
2.5 The student will understand liquid immiscibility, and from this, the fabrication methods and products associated with phase separated glass and glass-ceramics.	X	X			X		
2.6 The student will demonstrate an understanding of the optical properties of glass, including dispersion, anti-reflective coatings, and ligand theory of color formation.	X	X			X		
3.1 The student will demonstrate an understanding of powder characterization methods such as sedimentation, coulter counters, BET analysis, and density/pycnometry.	X	X			X	X	
3.2 The student will understand the relative benefits of various particle beneficiation methods as well as particle packing theory.	X	X			X	X	
3.3 The student will understand defloculation theory and the optimization of ceramic aqueous suspensions.	X	X			X	X	
3.4 The student will understand the methods and optimization of powder consolidation: casting, pressing (uniaxial and cold isostatic), extrusion, and injection molding.	X	X			X	X	
3.5 The student will understand thermolysis, sintering, and grain growth, and associated optimization.	X	X			X	X	
3.6 The student will understand processing, properties, and applications of advanced ceramics such as alumina, zirconia, silicon carbide and nitride.	X	X			X	X	

School of Materials Science and Engineering Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(3) An ability to communicate effectively with a range of audiences.
(4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.