University of Puerto Rico
Mayagüez Campus
College of Engineering
Department of Engineering Science & Materials
Master of Science in Materials Science and Engineering

Course Syllabus

1. General Information:

Alpha-numeric codification: **CIIM 6030**
Course Title: **Ceramic Materials**
Number of credits: **3**
Contact Period: **3 hours of lecture per week**

2. Course Description:

English: Comprehensive study of ceramic materials including their crystalline structure, electronic and ionic defects and subsequent transport phenomena, microstructure, mechanical properties, processing and characterization techniques. Study of related topics such as glass formation and applications of ceramic materials.

Spanish: Estudio comprehensivo de materiales cerámicos incluyendo su estructura cristalina, defectos electrónicos e iónicos y fenómenos de transporte derivados, microestructura, propiedades mecánicas, procesamiento y técnicas de caracterización. Estudio de temas relacionados como la formación de vidrios y aplicaciones de materiales cerámicos.

3. Pre-requisite and other requirements:

Authorization of the Director of the Department

4. Course Objectives:

After completing the course, the student should be able to:

- Differentiate between crystal and glass structures of ceramics
- Describe the relationship between the structure and properties of ceramic materials
- Evaluate the effect of crystalline defects on mechanical and physical properties of ceramics
- Evaluate mass, charge and site balances in defect reactions
- Describe transport processes in ceramic materials
- Estimate mechanical properties based on the structure of ceramic materials
- Compare bulk, micro and nanoceramic materials.
- Select processing systems of ceramic materials
- Assess the relationship among ceramics processing, structure, and their mechanical properties.
- Describe properties of nanostructured ceramic materials and devise some potential applications.

5. Instructional Strategies:

☒ conference ☐ discussion ☐ computation ☐ laboratory

☐ seminar with formal presentation ☐ seminar without formal presentation ☐ workshop

☐ art workshop ☐ practice ☐ trip ☐ thesis ☐ special problems ☐ tutoring

☐ research ☐ other, please specify: _____

6. Minimum or Required Resources Available:

Textbook: "Ceramic Materials: Science and Engineering," C. B. Carter, Springer-Verlag (2012),ISBN-10: 1461435226, ISBN-13: 978-1461435228

7. Course time frame and thematic outline

Outline	Objectives	Hours
1. Introduction to Ceramics - Discussion of the course syllabus and class organization - Ceramic properties - Types & applications	- Identify the basic differences between traditional and advanced ceramics. - Enumerate modern applications of ceramic materials and their requirements.	1
2. Crystal Structure - Packing sequences - Madelung' constant & Pauling's rules - Traditional FCC/HCP structures - Derivate structures - Covalent ceramics - Silicates: Structures and properties - Introduction to glasses	- Describe how bonding nature affects the structure and material properties. - List and describe the most common types of ceramic crystal structures. - Determine crystal structure given a system parameters such as Madelung's Constant and Pauling's Rules. - Identify the types of silicate, borate, oxide, and glass structures and their properties. - Explain the glass formation phenomena.	4
3. Defects - Point defects - Thermodynamics of defects - Defect concentration and behavior - Defect chemical reactions - Kröger-Vink notation - Brouwer diagrams - Electronic disorders - Defect association and precipitation - Interface/defect interactions - Line and surface defects	- Compare and describe the formation of defects and defect clusters. - Demonstrate the thermodynamic behavior behind defect systems. - Use the Kröger-Vink notation to describe the defect reactions. - Prepare and interpret Brouwer diagrams of systems with multiple defect systems. - Assess the effect of defects in transport and electric properties. - Describe defects and stacking faults that deviate from ideal crystal structures.	9
4. 1st Partial Exam	- Evaluates topics 1 through 3	1
5. Transport Processes - Diffusion kinetics - Atomistic diffusion processes - Types of diffusion coefficients - Electronic and ionic conductivity - Mobility and diffusivities - Electrochemical potential	- Describe the thermodynamics and kinetics behind transport processes. - Predict the transport properties in systems for predominant defect and crystal structure. - Characterize the relationship between mobility and diffusivity. - Characterize the relationship between mobility and electric conductivity.	6
6. Microstructure - Capillarity - Wetting and dihedral angles - Grain growth - Coarsening	- Discuss the effects of interfacial energy in the growth of systems. - Describe the concept of wetting angle and its relationship to nucleation. - Predict the growth of grain boundaries and particles based on processing parameters.	5

7. Mechanical Properties - Crack tip stress - Fracture toughness - Strength of ceramics - Toughening mechanisms - Weibull distribution	- Predict the mechanical properties of a system, based on microstructural properties. - Describe the classical modes of failure. - Explain the toughening and strengthening mechanisms for ceramic materials. - Analyze ceramic failure using the Weibull distribution. - Discuss alternatives for improving mechanical properties of a system based on prior information.	6
8. 2nd Partial Exam	- Evaluation of topics 5 through 7	1
9. Processing - Sintering - Glass and glass-ceramics - Composite materials - Formation & ordering - Oxide glasses - Borates & borosilicates	- Describe the processing methods for various types of ceramics. - Discuss possible processing pathways to tailor ceramic properties. - Apply the mixing rules to describe the behavior of composite materials. - Explain the phenomena of percolation. - Explain the glass formation phenomena - Describe the various types of borates, oxides, and glasses processing	5
10. Applications of Ceramics - Electrical properties - Optical properties - Magnetic properties - Thermal properties	- Explain the conduction mechanisms in ceramics. - Describe the electron mobility and the effect of temperature. - Analyze semiconducting ceramics - Enumerate the main requirements for ceramics insulators - Discuss the dielectric and ferroelectric concepts to ceramics - Describe special optical properties of specific ceramics - Analyze the refractory index for ceramics - Discuss magnetic materials and their differences - Explain ferromagnetism and ferrimagnetism - Analyze absorption, heat capacity, and thermal conductivity - Explain the cause of thermal expansion - Analyze thermal shock in ceramics	5
Final project	- Present a project on ceramics processing and characterization with focus on topics 9 and 10	2
Total hours (equivalent to contact period):		45

8. Grading System:

☒ Quantifiable (letters) ☐ Not Quantifiable

Standard Curve:
100-90 A; 89-80 B; 79-70 C; 69-60 D; 59-0 F

9. Evaluation Strategies:

	Quantity	Percent
☒ **Partial Exams**	**2**	**40**
☒ **Final Exam**	**1**	**20**
☐ **Short Quizzes**	-	-
☒ **Oral Reports**	**10**	**20**
☐ **Monographies**	--	--
☐ **Portfolio**	--	--
☒ **Projects**	**1**	**20**
☐ **Journals**	--	--
TOTAL:		**100**

10. Bibliography:

Textbook:

- "Ceramic Materials: Science and Engineering," C. Barry Carter and M. Grant Norton. 2nd ed., Springer, New York. (2013), ISBN: 9781461435228

Additional Textbooks:

- "Fundamentals of Ceramics," M. W. Barsoum, Series in Material Sciences and Engineering, Institute of Physics Publ., Bristol and Philadelphia. (2003), ISBN: 9780750309024
- Introduction to Ceramics," W. D. Kingery, H. K. Bowen, and D. R. Uhlmann. 2nd ed., Wiley Series on the Science and Technology of Materials, John Wiley and Sons Publ., New York. (1976), ISBN: 9780471478601

The following additional resources are available at the UPR Mayagüez General Library Databases:

- "An Introduction to Ceramics," R. Pampuch, Lecture Notes in Chemistry Series, Springer International Publ., (2014), ISBN: 9783319104096, eBook ISBN: 9783319104102
- "Ceramic and Polymer Matrix Composites: Properties, Performance, and Applications," E. Dimitriou, M. Petralia. Polymer Science and Technology Series, Nova Science Publ., New York. (2010), ISBN: 9781607418962.
- "Piezoelectric Ceramic Materials: Processing, Properties, Characterization, and Applications," X. Zhu, Materials Science and Technologies Series, Nova Science Publ., New York. (2010), ISBN: 9781616684181.
- "Dielectric Materials: Introduction, Research and Applications," R. N. P. Choudhary, S. K. Patri, Materials Science and Technologies Series, Nova Science Publ., New York. (2009), ISBN: 9781607410393.

These are additional important resources also available at the UPR Mayagüez General Library, which have not been re-edited but can be consulted electronically:

- "Ceramic Interconnect Technology Handbook," F. D. Barlow and A. Elshabini, editors, CRC Press (2007), ISBN: 9780849335570, eBook ISBN: 9781420018967
- "Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites," J. Rösler. Springer Verlag (2007), Book ISBN: 978-3-540-73448-2
- "Chemical Processing of Ceramics," S. Komarneni and B. Lee, editors, CRC Press (2005), ISBN: 9781574446487, eBook ISBN: 9781420027334.
- "Ceramic Fabrication Technology," R. W. Rice, CRC Press (2002), ISBN: 9780824708535, eBook ISBN: 9780203911020
- "Mechanical Properties of Ceramics and Composites: Grain and Particle Effects," R. W. Rice, CRC Press, (2000), ISBN: 9780824788742, eBook ISBN: 9780203908471
- "Sintering Mechanisms of Convention Nanodensification and Field Assisted Processes" K. V. Benthem, (2013), ISBN: 9783642310096

11. According to Law 51

Students will identify themselves with the Institution and the instructor of the course for purposes of assessment (exams) accommodations. For more information please call the Students with Disabilities Office, which is part of the Dean of Students Office (Office # 4) at (787) 265 - 3864 or (787) 832 - 4040 extensions 2040 or 3864.

12. Academic Integrity:

─The University of Puerto Rico promotes the highest standards of academic and scientific integrity. Article 6.2 of the UPR Students General Bylaws (Board of Trustees Certification 13, 2009-2010) states that academic dishonesty includes, but is not limited to: fraudulent actions; obtaining grades or academic degrees by false or fraudulent simulations; copying the whole or part of the academic work of another person; plagiarizing totally or partially the work of another person; copying all or part of another person answers to the questions of an oral or written exam by taking or getting someone else to take the exam on his/her behalf; as well as enabling and facilitating another person to perform the aforementioned behavior. Any of these behaviors will be subject to disciplinary action in accordance with the disciplinary procedure laid down in the UPR Students General Bylaws.─