Ceramic Engineering 203
THERMAL PROCESSES IN CERAMICS

Semester: Fall 2011
Course: Cer203 (Reference number: 70144)

Course Meeting: T-Th, 8:00-9:15 AM. McNutt 212

Late arrival by the professor: In the event no prior notice is given, students are required to wait 15 minutes before departing. The instructor will make every attempt to reschedule lectures or find a substitute teacher for those days on which he is traveling.

Instructor: Richard K. Brow
322 McNutt Hall/341-6812/brow@mst.edu

Office Hours: 8:00AM-9:30, M-W-F; and any other time that can be arranged- e-mail requests are the best way to set up a meeting.

Course Description: This course covers the basic principles and mechanisms of defect chemistry, diffusion, solid state reactions, sintering and grain growth and how they are used in the design and production of ceramics.

Textbook: Ceramic Materials Science and Engineering, C. Barry Carter and M. Grant Norton, Springer Science and Business Media, LLC, New York, 2007.

Course Materials: Powerpoint slides, homework problems, old exams and other course materials will be posted on Blackboard. HW and test grades will also be posted.

Attendance Policy: Please review the Missouri S&T attendance and drop policy under Student Academic Regulations at http://registrar.mst.edu/academicregs/index.html. This policy applies to Cer 203. Because there will be many in-class exercises and your participation is desired, you are encouraged to attend class. A strong correlation exists between attendance and good grades.

Classroom Etiquette: Cell phones and PDA devices are to be turned off prior to the beginning of class. Conducting personal business should be done outside of the classroom, on your own time, where it does not interfere with the learning environment of your fellow students. Unless the class is working on an exercise, or you are interacting with the instructor, you are asked to refrain from talking after the beginning of class.

Grading Policy:

A: 90 – 100	D: 60 – 69
B: 80 – 89	F: < 60
C: 70 – 79	

Grade Components (Tentative):

- Four Hourly examinations (100 pts each)
- Comprehensive Final Examination (200 pts)
- Homework Assignments (150 pts)

Hourly examinations will be graded in a timely fashion. Please review the graded exam for accuracy. If you feel an error has been made in grading your exam, a formal written appeal must be made within one week of the return of your exam. No

appeals will be considered after this time. Your examination must be attached to the appeal letter.

Homework assignments must be handed at the beginning of the class period on the date due. For each day late, 25% of the value of the assignment will be deducted from the assignment grade. No homework assignments will be accepted if submitted more than two school days after the due date.

If you have any questions about the status of your grade throughout the semester, please contact the instructor.

Course Outcomes

(a) Ability to understand and apply defect chemistry principles in ceramic materials within a broad temperature range
(b) Ability to apply the principles of diffusion on mass and electrical transport of ceramics
(c) Ability to apply kinetic analysis and modeling to solid state reactions in ceramics
(d) Ability to understand the relationship between thermal processes and sintering/grain growth in ceramics
(e) Ability to integrate the defects in solids fundamentals of defects chemistry, diffusion and sintering
(f) Ability to apply the basic principles and mechanisms of defect chemistry, diffusion, solid state reaction, sintering and grain growth in the design and production of ceramics

Academic Alert System: (http://academicalert.mst.edu)

I will utilize the online Academic Alert System. The purpose of the Academic Alert System is to improve the overall academic success of students by improving communication among students, instructors and advisors; reducing the time required for students to be informed of their academic status; and informing students of actions necessary by them in order to meet the academic requirements in their courses.
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Academic Dishonesty: (http://registrar.mst.edu/academicregs/index.html)

Page 30 of the Student Academic Regulations handbook describes the student standard of conduct relative to the System's Collected Rules and Regulations section 200.010, and offers descriptions of academic dishonesty including cheating, plagiarism or sabotage.

Classroom Egress Maps: (http://registrar.mst.edu/links/egress.html)

This link shows the location of the classroom emergency exits. Please familiarize yourself with them. For 212 McNutt, please turn right after exiting the classroom and leave the building through the doors straight ahead.

Disability Support Services: (http://dss.mst.edu)

If you have a documented disability and anticipate needing accommodations in this course, you are strongly encouraged to meet with me early in the semester. You will need to request that the Disability Services staff send a letter to me verifying your disability and specifying the accommodation you will need before I can arrange your accommodation.

If you have any questions about the information listed above, please contact the Office of Undergraduate Studies at 573-341-7276.

Tentative Lecture Schedule – CER 203, Electrical Properties of Ceramics, Fall 2011

# Lectures	Topic
2	**Introduction**
	Traditional and Advanced Ceramics Structure: crystalline and amorphous; polycrystalline Composition-microstructure-property relationships Main ceramic fabrication methods Ceramic microstructures Applications of ceramics
8	**Defects in Solids**
	Point defects *Intrinsic/extrinsic; concentration of defects; Kroger-Vink notation; solute incorporation, electrons and holes; oxidation/reduction; non-stoichiometry* Electronic vs. ionic compensation Point defects in ZrO_2 Oxygen sensors Line and planar defects
1	**First Hourly Examination**
7	**Diffusion: Mass and Electrical Transport**
	The Arrhenius equation and its manipulation Diffusion as a thermally activated process The concept of a rate controlling process Mechanisms of diffusion Types of diffusion coefficients Diffusion in cubic stabilized ZrO_2 Electrical conductivity *Mobility and diffusivity; Nernst-Einstein equation; ionic and electronic conductivity* The electrochemical potential *Nernst equation and ionic conductors; oxygen sensors based on ZrO_2; ambipolar diffusion; diffusional creep as an ambipolar diffusion*
1	**Second Hourly Examination**
5	***Solid State Reactions***
	Kinetics of heterogeneous reactions *Reaction rate; equilibrium constant; decomposition of $MgCO_3$* Interdiffusion between solids *Rate of product formation; Kirkendall effect* Reactant transport in particulate systems *Reaction between powder particles; Jander equation and Carter equation* Application to powder processing and ceramic fabrication
1	***Third Hourly Examination***
8	***Sintering and Grain Growth***
	Overview of changes occurring during sintering

Grain growth in ceramics

Elementary features, driving force, normal and abnormal grain growth
Grain growth in dense ceramics: deviation of the quadratic growth law
Grain growth in porous ceramics: pore mobility and boundary mobility; Redaction of normal grain growth and the prevention of abnormal grain growth: use of dopants, fine second phase particles, monodisperse powders

Solid state sintering

Driving force; models; stages and mechanisms; Initial stage neck growth equations for evaporation/condensation and lattice diffusion; summary of initial stage sintering equations; Outline of the intermediate and final stage models
Advantages and limitations of the sintering models

Magnesia-doped alumina (pp. 413-421)

Sintering practice: isothermal and constant heating rate sintering; effects of temperature, atmosphere, particle size and packing

Liquid phase sintering; hot pressing and hot isostatic pressing (pp 421-430)

Firing of silicate systems: Porcelain

1 ***Fourth Hourly Examination***

1 ***Final Comprehensive Examination***