

# ME 5390 – Special Topics in Materials in Extreme Environments

A. Bronson

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**Course Description:** An overview of materials exposed to extreme environments primarily chemical and electromagnetic extremes are discussed with first describing the fundamentals of reactionary thermodynamics, heterogenous kinetics, and phase equilibria. Then the application of fundamental concepts is described as considered with metal and ceramic surfaces exposed to reactive fluids (e.g., carburizing/sulfizing gases and molten metals/salts), extreme temperatures and electromagnetic fields. Experimental techniques used to evaluate reactions are also discussed within each topic to assess material usage in the industrial sector.

**Textbook:** The course will introduce several topics covered in numerous monographs and journal publications, which will be noted in class.

**References:** Y. K. Rao: Stoichiometry and Thermodynamics of Metallurgical Processes, Cambridge University Press, 1985.  
O. Levenspiel: Chemical Reaction Engineering, Wiley, 1999.  
P. Kofstad: High Temperature Corrosion, Elsevier Applied Science, 1988.  
J. Maier: Physical Chemistry of Ionic Materials, Wiley, 2004  
Y. A. Chang and W. A. Oates: Materials Thermodynamics, Wiley, 2010.

**Topics Covered:** Chemical Extremes coupled with temperature gradients and electromagnetic fields associated with synthesis/processing and material performance will be introduced.

1. Fluid/Metal Reactions (Oxidation and Hot Corrosion)
2. Fluid/Ceramic Reactions (e.g., Silicide and Boride Ceramics)
3. Phase Stability in Metals and Ceramics
4. Intermetallic Reactions (e.g., Ti Aluminides)
5. Plasma-Surface (or Plasma-Material) Interactions

**Assessment of Course:** 1. Mid-term examination (40% of final grade)  
2. Fundamental engineering report will amount to 60% of final grade. An electronic version, pdf, of an outline for report is due on March 18 and a full report (again, in pdf sent via email attachment) for submission on April 20. Examples of possible topics will be given at a later date.

## Organization of Topics

Fundamentals	Topics	Applications
Reactionary Thermodynamics -- Fluid/Solid Reactions -- Solution Thermodynamics	Fluid/Solid Reactions -- Gas or Liquid Corrosion -- High Temperature Reactions	Energy Related -- Coal Conversion -- Chemical/Oil Industries -- Fuel Cell Usage
Heterogeneous Kinetics -- Analysis of Rate Equations -- Reaction Sequence	Solid/Solid Reaction -- Metal/Ceramic Reactions -- Phase Stability -- Intermetallic Phases	Electronic Materials -- Sensors (e.g., ZrO <sub>2</sub> -based) -- Electroceramics -- Silicon and Boride systems
Phase Equilibria -- Phase Diagrams -- Microstructures	Plasma-Surface Reactions -- Nonequilibrium Plasmas -- Thermal Plasmas	Transport Related Industries -- Turbine Materials -- Hypersonic Vehicles