CERAMIC-METAL SYSTEMS 14-635:426 **COURSE OUTLINE- SPRING 2006**

Instructor: Victor A Greenhut McLarenCCR 102 ☎ +732.445.3870 greenhut@alumina.rutgers.edu

Course Objectives:

The objectives of this course are to provide students with the following competencies:

a. practical understanding of principles and theories for ceramic-metal bonding and adherence.
b. knowledge of processing, structure, properties and performance for commercially important ceramic- metal bonding/metallization/compositing technologies with practical engineering constraints.
c. ability to select a manufacturing method based on advantages/disadvantages of ceramic-metal system technologies including costs (economics), performance, environmental concerns, manufacturability, and sustainability – with consideration (limited) of health, safety, social and political issues.
d. understanding the relationships between processing, structure, properties and performance { SP^3} for metals (via an introduction to physical metallurgy for Ceramic Engineers) as well as ceramic-metal systems. [Senior/Junior elective course – assumes students possess ceramic engineering competencies].
e. understanding how properly engineered combinations of ceramics and metals can take effective advantage of the properties of each class of materials in joined components, metallization, ceramic/glass coatings and metal matrix composites (cemented carbides, cermets and MMC's).
f. ability to improve ceramic-metal joining/metallization parameters by R&D experiments, production observation/ and modification and performance testing/failure analysis.
g. Understand relationship to other joining (mechanical, adhesive) and composites (polymer, CMC's)

Course Format:

The course is in an interactive lecture/recitation format. Each week one lecture deals with ceramic-metal systems while a second lecture provides practical Physical Metallurgy (not provided in prior course work). For the ceramic-metal systems content, an overview article is provided, reading materials (print and CD) are available in the SERC Reading Room and are also available from the instructor for personal, legally compliant copying (most valuable sources are out of print). Viewgraph visuals are used and available to students for copying. The metallurgy segment is provided with slides. Copies of these notes and visuals are provided at copying cost. Students are encouraged to purchase through a special instructor-organized arrangement with ASM International the *Metals Handbook: Desk Edition* (at a ½ price-student rate) as a course and life-long learning aid. Samples, examples of actual engineering problems, open-ended problem solving, and application choices are incorporated both to extend knowledge to application and to provide engineering "experience". Extra, voluntary seminar classes are provided in special topic areas related to course materials (usually including: a hands-on failure analysis workshop and a corrosion control workshop).

Assessment of Outcomes:

Student progress is assessed by a midterm and final examination divided approximately equally between ceramic-metal systems and metallurgy. Progress is monitored by recitation questions, spot quizzes (verifying attention to readings) and real-world problem solving/applications via hand-in assignments. Course outcomes are assessed formally through the examinations, recitation interaction and student evaluation forms. Additional assessment questions for course modification are occasionally added to the form. Informal evaluation occurs through contacts with alumni, many of whom (15-25%) find careers significantly incorporating the ceramic-metal systems course. About 7-15 contacts per year occur from prior students who use the instructor as a resource for ceramic-metal joining and metal matrix composites (MMC's).Additionally, about 10-15% confer with the instructor at various Ceramic meetings. All report significant use of the metallurgy component and the utility of the *Metals Handbook: Desk Edition*. This includes recent graduates and graduates from prior decades.

Relationship to Program Objectives:

The course provides contributions to program objectives 1 - 4. With respect to general ABET proficiencies it contributes significantly to (a), (b), (c), (e), and (i) as they pertain to ceramic-metal systems and to metallurgy. Items (f), (g) and (h) are stressed through real world examples and examples in which other knowledge may contribute to solving engineering problems in ceramic-metal systems. The nature of multi-disciplinary teams (item d) in electronic and structural applications areas is discussed briefly. As a vital part of ceramic-metal systems technologies, the relationships between processing, structure, properties and performance { SP3 } are stressed in choosing amongst bonding/metallization methods, optimizing production variables and selecting a physical relationship between ceramic and metal components (microstructure and/or macrostructure).

SPRING 2006 SCHEDULE (tentative)

A= Ceramic-Metal -Thursdays **B**= Metallurgy – **M**ondays

WEEK 1: 19 / 23 January

A« Course Introduction
Introduction to Adherence Mechanisms- "Ceramics, Ceramic Metal Systems", Sect. 1 - 2.2.2.
Cermets (Tinklepaugh & Crandall), pages 1- 50

B« Nature & Properties of Pure Metals Metallurgy Notes, Sect. D.

WEEK 2: 26 / 30 January

A« Wetting & Adhesion - Review Above Readings
Glass-to-Metal Sealing (Kohl), pages 501-509
"Surface Tension Measurements and the Sessile Drop Technique (Weinstein)

B« Strength & Deformation of Metals, Metallurgy Notes, Sect. F

WEEK 3- 02 / 06 February

A« Mechanisms of Adhesion "Ceramics, Ceramic Metal Systems", Sect. 2.
"The Adherence of Enamels" (O'Bannon)
Joining Ceramics and Graphite (NASA), Chapter 4
"Role of Adherence Oxides in the Development of Chemical Bonding" (Borom & Pask)

B« Strengthening by Work Hardening & Annealing, Metallurgy Notes, Sect. G.

WEEK4- 09 / 13 February

A« Stresses in Ceramic-Metal Systems - "Ceramics, Ceramic Metal Systems", Sect. 3.
Glass-to-Metal Sealing (Kohl), all Chapter 13 *Joining Ceramics and Graphite* (NASA), pages 1-17

B« Alloying and Casting (Phase Diagrams), Metallurgy Notes, Sect. E.

WEEK 5- 16 / 20 February

A« Glass-Metal Joining - "Ceramics, Ceramic-Metal Systems", Sect 2« pages 59-65
Glass-to-Metal Sealing (Kohl), all Chapter 13
"The Adherence of Enamels" (O'Bannon)

B« Mechanical Forming, Metallurgy Notes, Sect. H

WEEK 6- 23 / 27 February

A« Porcelain Enameling Manuals- *Preparation, Operations, Spraying and Dipping*

B« Alloy Strengthening (Non-Ferrous) Metallurgy Notes, Sect. T

WEEK 7 - 02 / 06 March

A« Porcelain Enameling Manuals- *Preparation, Operations, Spraying and Dipping*

B« Steel Metallurgy I Metallurgy Notes, Sect. J

MIDTERM (Date - TBD) - Covers Material through Week 7 - **(Date - TBD) MIDTERM**

WEEK 8 - 09 March

A« Porcelain Enamel Structure and Defects *Photomicrographic Analysis of Porcelain Enamel Defects*

----------SEMESTER BREAK---------- 11 - 19 March ---------- SEMESTER BREAK----------

20 March

B« Steel Metallurgy II Metallurgy Notes Sect« J

WEEK 9- 23 / 27 March

A« Ceramic-Metal Joining "Ceramics Ceramic Metal Systems", Sect. 3, pages 65-67
Ceramic-to-Metal Sealing (Kohl), all Chap. 14, pg .470-518
Joining Ceramic and Graphite (NASA), entire monograph

B« Steel Metallurgy III Metallurgy Notes, Sect. P.

WEEK 10¦- 30 March / 03 April

A« Ceramic Metal Sealing and Metallization See WEEK- 9.B« for readings.

B« Toughness and Fracture Metallurgy Notes, Sect. K

WEEK 11- 06 / 10 April

A« Cemented Carbides, WC-Co — "Ceramics, Ceramic Metal Systems, Sect. 5,5.1 pg. 74-75
Tungsten Carbide-Cobalt (WC-Co) Visuals
Cermets(Tinkelpaugh & Crandall), pages 50-149

B « AcerS Annual Meeting- Baltimore, MD – Review a Paper or Attend a Presentation

WEEK 12 – 13 / 17 April

A« Cermets (Non-Oxide and Oxide Systems) — *Cermets* (Tinkelpaugh & Crandall) pages 50-149
"Carbide Cermets" (Byra)

B« Corrosion Control — Metallurgy Notes, Sect. L

WEEK 13- 20 / 24 April

A« Metal Matrix Composites — "Ceramics, Ceramic Metal Systems", Sect. 5.2 pg. 75-76

B« Metal Fatigue — Metallurgy Notes, Sect. M

WEEK 27 April / 01 May

A« Thin Films and Coatings — "Ceramics, Ceramic Metal Systems" Sect 4, pages 67-74

B« The Future of Ceramic-Metal Systems

Optional Group Review Sessions (Exam Preparation) - Before Midterm and Final (By Arrangement)

FINAL EXAM (Full Semester Material)

Scheduled for: NOON – 03:00 PM Wednesday 10 May 2005
(or earlier date By Arrangement and with full participant consensus)

COURSE TEXTS

CERAMIC-METAL SYSTEMS:

Notes:

a. Required ceramic-metal systems text materials are provided at the SERC Reading Room or McLaren CCR
Most material is out of print and very difficult to acquire.
It may be legal to copy for yourself - **strictly for personal use**

b. REFERENCES 10-13 and more are now available for electronic copying (from CD),
courtesy of G. Pfendt, Pres. Porcelain Enamel Institute (2006 Mueller Engineering Ceramics,ACerS Awardee)

1. "Glass-to-Metal Sealing " (Chapter 13) & "Ceramic-to-Metal Sealing" (Chapter 14) *Handbook of Materials and Techniques for Vacuum Devices,* Reinhold Publishing Co. New York (1967, pages 391 - 638.
2. *Cermets*, J.R. Tinklepaugh and W.B. Crandall, Reinhold Publishing Co. New York (1960), Chapter 1-6, to page 149.
3. *Joining Graphite and Ceramics*, NASA, U.S. Gov't. Printing Office, Washington, DC (1968).
4. "Ceramics, Ceramic-Metal Systems" V.A. Greenhut and R.A. Haber, *Ullmann's Encyclopedia of Industrial Chemistry*, A6,¦ ed. VCH Press, Weinheim, Germany (1986), pages 51 - 78**.**
- DISTRIBUTED TO PARTICIPANTS at 1st class -
5. "Roll of Adherence Oxides in the Development of Chemical Bonding at Glass-Metal Interfaces" M.P. Borom and J.A. Pask, J. Am. Ceramic Soc. 49, (1966).
6. Lecture Visuals - "Cemented Carbide (WC-Co) Cutting Tools", R. Peters.
7. Lecture Visuals - CVD Coatings for Cutting Tools", R. Peters
8. "Titanium Carbide Cermets" J. Byra.
9. "The Adherence of Enamels, Glass and Ceramic Coatings to Metals - Review", L.S. O'Bannon, Battelle Laboratories (1962).
10. *Preparation of Sheet Steel for Porcelain Enameling*, PE Bull. P-307, Porcelain Enamel Institute, Washington,DC (1967).
11. *Porcelain Enameling Operations*, E.E. Bryant, Enamels Publishing Co. Cleveland (1964).
12. *Manual of Spraying for Porcelain Enameling*, PE Bull.301(69), Porcelain Enamel Institute, Washington, DC (1969).
13. *Manual of Dipping and Flow Coating for Porcelain Enameling*, PE Bull. 302 (73), Porcelain Enamel Institute,

Washington, DC (1973).
14. *Photomicrographic Analysis of Porcelain Enamel Defects*, L.M Dunning,T.J. Ilkanic and W.S. Lee, Ferro Corp., Cleveland (1969)

METALLURGY:

Note:

Metallurgy notes are provided by Victor A. Greenhut & John D. Wood
through the generosity of the Center for Professional Advancement, East Brunswick, NJ.
These notes are strictly for personal use and may not be sold or transferred to others.

Required:

Metallurgy for Non-Metallugists, V.A. Greenhut and J.D. Wood,
Center for Professional Advancement (CfPA), East Brunswick (1979 - 97).

Recommended: *

Metals Handbook: Desk Edition, 2nd Ed. H.E. Boyer and T.L. Gall, ASM Int. Materials Park (1998).

* Students are encouraged to purchase the Handbook through a special instructor-organized arrangement with ASM International (a special ½ price-student rate, below member price) as a course and life-long learning aid.

Grading Criteria:

The final grade is based upon an hourly Midterm and a Final Examination
(plus spot quizzes and assignments).
Details will be discussed at the first class. **The Final Examination will cover the entire semester**.

Participants are "promised" examination questioning involving the "LEVER LAW" calculations & predicted structure.
An optional, voluntary tutorial session will be provided to review Metallurgical Phase Diagrams as it pertains to application of the "Lever Law" and predicted microstructure(s).
A handout with sample problems and practice exercises will be distributed to all students.
This is material which students are responsible for from prior, required courses.
Optional review sessions will be provided for interested students prior to class coverage and exams.

Additional, Optional Topics & Tutorials:

Additional, optional topics of importance not covered in the regular course will be provided, including:
"Failure Analysis & Prevention + Workshop"
"Corrosion & Corrosion Control + Workshop"
and other student-selected topics.
Attendance is voluntary and non-course participants may attend
These presentations will not be included directly on exams.
A participation record will be kept and a certificate of completion provided to all full participants.