PHYSICAL METALLURGY OF TRANSITION-ELEMENT ALLOYS MSE 647

Department of Materials Science and Engineering Spring 2004

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OFFICE HOURS: Open

TOOLKIT: A web site for this course exists on the UVA Instructional Toolkit (Base home page: http://toolkit.virginia.edu). A number of important course functions are accessed from this web site, located at: https://toolkit.itc.virginia.edu/cgi-local/tk/UVa_SEAS_2004_Spring_MSE647-1

E-mail List An E-mail list can be accessed from the MSE 647 home page. Students should post questions to the professor and other students, using this list and the e-mail address: MSE647-1@toolkit.virginia.edu. On-grounds students are automatically added to this mailing list upon registration for the course. Questions and answers will be archived at the Toolkit site, and are of value to students.

OBJECTIVE: The objectives of this course are to: (1) reinforce fundamental concepts and introduce advanced topics in physical metallurgy, and (2) develop literacy in major alloy systems, with emphasis on microstructural evolution and structure-properties relations. From a foundation in modern physical metallurgy, the student will understand the basis for optimization of the structural metallic alloys that enable modern technology. Topics; including equilibrium phase diagrams, thermodynamics, diffusional and martensitic transformation kinetics, recrystallization, and grain growth; are discussed in conjunction with transition-metal alloys based on iron, nickel and titanium, as well as with thermomechanical processing methods. Approaches to model-simulation of selected topics are introduced. This course complements MSE 632 on light alloy metallurgy.

PREREQUISITES: BS in Materials Science and Engineering, or successful completion of MSE 605 or 606.

CLASS TIME: 1:00-2:15 Monday and Wednesday

CLASS LOCATION: MSE Room 125

GRADING:

3 Quizzes		280 points
1 Homework assignment		40
2 Literature papers		80
Lecture project		100
Final exam		None
	Total	*500 points*

One quiz is a 75-minute in-class exam, 1 quiz is a 6-hour take-home exam, and 1 quiz will be given in-class during the 3-hour final exam period. All exams are open-course notes. Students are not permitted to refer to previous homework assignments or exams at any time during this course. There is no comprehensive final examination.

TEXTS: All course notes are contained in the *Materials* section of the Toolkit homepage. The notes for each lecture should be downloaded using the Adobe Reader associated with the Toolkit. A complete set of course notes provides a useful reference and may be retained as hard copy or .PDF files.

Sections from the following books are not assigned, but are cited in the notes to supplement the lectures.

1. *Steels: Heat Treatment and Processing Principles*, G. Krauss, ASM International, Metals Park, OH, 1990.

2. *Heat Treatment, Structure and Properties of NonFerrous Alloys*, C. Brooks, ASM International, Metals Park, OH, 1982.

3. *Steels: Microstructure and Properties*, R.W.K. Honeycombe and H.K.D.H. Bhadeshia, Arnold/Halsted Press, NY, NY, 1996.

The Krauss and Brooks books will be retained on reserve in the MSE office. These books are not carried by the UVa bookstore, but may be obtained from *ASM International* (1-800-336-5152, ext. 900). Wiley Professional Books by Mail (Somerset, NJ) sells the Honeycombe book. Additional reference books are cited in the Bibliography to the course.

ATTENDANCE: Class participation, including attendance and discussion, are important and expected.

ASSIGNMENTS: Download and read the pertinent notes prior to each lecture. Bring the notes to class to reduce the amount of note-taking, and review the notes after each lecture. Textbook reading is optional.

Literature Papers: Select one paper to analyze from those in the Bibliography, numbered between RP#1 and RP#17, and cited in the notes for each lecture. Your written analysis is due on March 5th. Select one paper from those numbered between RP#18 and RP#34; your analysis is due on April 12th. Specific instructions on the form of the written analysis will be provided.

Lecture Project: Select a topic in physical metallurgy, perhaps pertinent to your research, and develop a class lecture with a detailed notes package. Your project is due on April 26th and specific instructions will be provided.

SYLLABUS

Lecture	Topic
1. Jan 14	Class goals, procedures, and content; Physical metallurgy and structural alloys---future *vs* advanced materials. Phase diagram review.
2. Jan 19	Phase diagram review, continued; Physics and chemistry of transition elements.
	FERROUS ALLOYS: STEELS
	Introduction to steel; Physical metallurgy of iron.
3. Jan 21	Iron, continued; Fe-C phase diagram.
4. Jan 26	Diffusional transformation from austenite to ferrite, pearlite, and cementite: Overview of phenomenology.
5. Jan 28	Diffusional transformation from austenite to ferrite and pearlite: Details of nucleation and growth; Modeling.
6. Feb 2	Alloy element effects on Fe-C phase equilibria and transformation kinetics.
7. Feb 4	Martensite transformation.
8. Feb 9	Martensite (continued); Bainite reaction.
9. Feb 11	Bainite (continued); Hardenability; Isothermal and continuous cooling transformation diagrams.
Feb 13	Optional class: Exam Review.
Feb 16	***Quiz #1*** **In class; Covering Lectures 1-9; 90 points**.
10. Feb 18	Tempering of martensite; Heat treatable alloy steels.

11. Feb 23 Ultra-high strength steels and Case Study 1--AerMet 100; Tool steels and Case Study 2--M2 Tool Steel.

or

Carbon steels; High strength low alloy steels, microalloying and controlled thermomechanical processing.

FERROUS ALLOYS: STAINLESS STEELS

12. Feb 25 Physical metallurgy of stainless steels: General phase equilibria; ferritic stainless steels.

13. Mar 1 Physical metallurgy of martensitic and austenitic stainless steels; carbide precipitation.

14. Mar 3 Physical metallurgy of duplex and high strength precipitation hardened stainless steels.

Spring Recess: March 7th to March 14th

NICKEL-BASED SUPERALLOYS

15. Mar 15 Overview of superalloys in technology; Classes of alloys; Physical metallurgy of Ni-based superalloys: composition and microstructure; Phase diagrams--Ni-Al and strength; γ'.

16. Mar 17 Complex Ni-based superalloys: Ternary phase diagrams; Constitution, structure and reactions of phases--γ, γ', γ'', carbides, TCP.

17. Mar 22 Lecture #16 (continued); Prediction of phase equilibria by PHACOMP.

18. Mar 24 Specific Ni-based superalloys: composition, microstructure, heat treatment and properties.

19. Mar 29 Advanced Ni-based superalloys; Modern processing methods.

20. Mar 31 Catch-up and exam review.

Quiz #2 **Take home due April 7th; Covering Lectures 10-20; 110 points**

TITANIUM ALLOYS

21. Apr 5 Overview of Ti alloys: Applications and Designations; Properties of pure Ti and interstitial solid solutions; Equilibrium phases.

22. Apr 7 Overview of α/β titanium alloys; Case Study 3---Ti-6-22-22.

23. Apr 12 Overview of β/α titanium alloys; Case Study 4---Ti-15-3; Intermetallics.

ADVANCED METALLIC ALLOYS

24. Apr 14 Nanocrystalline metals: Structure and properties.

25. Apr 19 Nanocrystalline metals: Processing by amorphous crystallization and severe plastic deformation.

MODELING AND SIMULATION IN PHYSICAL METALLURGY

26. Apr 21 Phase diagram predicitons by the CALPHAD method.

27. Apr 26 Phase equilibria predictions by CALPHAD (continued); Case Studies: alloys steels, stainless steels, nickel-based superalloys.

Quiz #3 **In-class during the 3-hour final exam period; Covering Lectures 21-27; 80 points.**

Final Exam **None.**

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Reference Books

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"Phase Transformations in Metals and Alloys", D.A. Porter and K.E. Easterling, Van Nostrand Reinhold, London, UK, 1981.

"The Physical Metallurgy of Steels", W.C. Leslie, McGraw-Hill, New York, NY, 1981.

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"Superalloys II", C.T. Sims, N.S. Stoloff and W.C. Hagel, John Wiley and Sons, New York, NY, 1987.

"Physical Metallurgy", Peter Haasen, 3rd edition, Cambridge University Press, Cambridge, UK, 1996.

"Modern Physical Metallurgy and Materials Engineering", R.E. Smallman and R.J. Bishop, Butterworth/Heinemann, Oxford, 1999.

"Physical Metallurgy Handbook", A.K. Sinha, McGraw Hill, New York, 2003.

"Titanium", G. Lutjering and J.C. Williams, Springer-Verlag, Berlin, 2003.

"Ultrafine Grain Materials II", Y.T. Zhu, T.G. Langdon, R.S. Mishra, S.L. Semiatin, M.J. Saran, and T.C. Lowe, Minerals, Metals and Materials Society, AIME, Warrendale, PA, 2002.

"Processing and Properties of Structural Nanomaterials", L.L. Shaw, C. Suryanarayana and R.S. Mishra, Minerals, Metals and Materials Society, AIME, Warrendale, PA, 2003.

Literature Review Papers

1. N. Ridley, "The Pearlite Reaction", pp. 201-236 in Phase Transformations in Ferrous Alloys, A.R. Marder and J.I. Goldstein, eds., TMS-AIME, Warrendale, PA (1985).

2. R.W.K. Honeycombe, "Transformation from Austenite in Alloy Steels", Metall. Trans. A, Vol. 7A, pp. 915-936 (1976).

3. J.S. Kirkaldy, B.A. Thomson and E.A. Baganis, "Prediction of Multicomponent Equilibrium and Transformation Diagrams for Low Alloy Steels", pp. 81-125 in Hardenability Concepts with Applications to Steel, D.V. Doane and J.S. Kirkaldy, eds., TMS-AIME, Warrendale, PA (1979).

4. K. Hashiguchi, J.S. Kirkaldy, T. Fukuzumi and V. Pavaskar, "Prediction of the Equilibrium, Paraequilibrium and No-Partition Local Equilibrium Phase Diagrams for Multicomponent Fe-C Base Alloys", CALPHAD, Vol. 8, No. 2, pp. 173-186 (1984).

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8. J.W. Christian, "Military Transformations: An Introductory Survey", pp. 73-91 in Perspectives in Ferrous Metallurgy, T. Bell, ed., Pergamon Press, Oxford, UK (1985).

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