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Embrittlement of Engineering Alloys

Edited by C.L. Briant and S.K. Baneerji

(Volume 25 of *Treatise on Materials Science and Technology*, Academic Press, 1983)

In view of the present demand for engineering alloys that can withstand extreme service conditions and aggressive environments, this book comes at a very opportune moment. It presents a comprehensive review of the various process and service conditions that lead to degradation of the mechanical properties of common structural materials. The topics, organized in 11 chapters, cover the influence of alloy composition or processing, effects of elevated temperature service, corrosion in air or aqueous environments, and embrittlement by hydrogen, liquid metals, and irradiation. Each chapter provides considerable information and a literature review to allow the reader to pursue specific interests.

Chapter 1 by Mulford discusses the susceptibility of nickel to embrittlement by trace impurities. Recent data are presented to support the conclusion that embrittlement at temperatures below 900°C is primarily due to equilibrium segregation of sulfur and harmful metallic elements (e.g., Bi, Pb, Te, and Se). The effects of grain boundary precipitation of sulfides, intermetallics, etc., at hot working temperatures (above 900°C), are considered separately. The influence of trace amounts of beneficial elements is also discussed.

Chapter 2 by Briant and Baneerji covers intergranular fracture in ferrous alloys as a result of grain boundary segregation of embrittling elements. The discussions focus on embrittlement of tempered martensite and temper embrittlement of low-alloy ferritic steels. The embrittling elements and process conditions as well as the beneficial effects of other alloying elements are identified. Finally, results from recent investigations to explain embrittlement from theoretical considerations are presented. The kinetics and thermodynamics of segregation, the mechanics of intergranular fracture, and the role of chemical bonding in grain boundary decohesion are discussed.

In Chapter 3, Ritter and Briant describe the effects of second-phase particles on the fracture of engineering alloys. Four classes of structural materials (steels, superalloys, and aluminum and titanium alloys) are discussed. The chapter identifies the second-phase particles involved and provides a mechanistic understanding of the fracture process. The section on steels is primarily devoted to ductile fracture; the role of second-phase particles in brittle cleavage fracture is neglected. The various phases in

superalloys and the conditions for their formation are detailed. The methods of using electron vacancy calculations to predict the formation of the harmful phases in superalloys are also presented.

Chapter 4 by Pope deals with the creep behavior of Cr-Mo and Cr-Mo-V ferritic steels. It would have been helpful if the title had reflected the restriction to these steels. Effects of temperature, strain rate, stress, microstructure, and impurities on creep ductility of ferritic steels are discussed. The existing data are reviewed to identify the factors that promote brittle intergranular fracture.

In Chapter 5, Woodford and Bricknell describe the embrittlement of high-temperature alloys by oxygen. They present several instances of mechanical-property degradation of metals and alloys in oxygen-containing environments and consider the possibilities for prevention by surface coating, formation of an oxide layer, and chemistry modification. The various mechanisms for oxygen embrittlement (e.g., solute segregation, precipitation, gas bubble formation, release of embrittling elements, and the concomitant interacting fracture processes) are also discussed. Finally, environmental effects during mechanical testing in air- or oxygen-containing environments and the implications for data analysis and life-predicting techniques are reviewed.

Chapter 6 by Devine introduces the corrosion and passivation of iron and iron-base alloys. The major electrochemical processes are reviewed and the influence of alloying elements on the corrosion behavior of iron is discussed.

In Chapter 7, stress corrosion cracking of iron-base alloys in aqueous environments is reviewed by Ford. The current mechanistic understanding of subcritical crack propagation is discussed. Finally, the mechanistic aspects of cracking in low-alloy and stainless steels in aqueous environments are described.

Chapter 8 by Nelson deals with hydrogen embrittlement and its influence on the plastic deformation and fracture behavior of alloys. The origin and form of hydrogen, transport of hydrogen, and the possible hydrogen-metal interactions are discussed. This is followed by an extensive and detailed review of hydrogen embrittlement of martensitic, ferritic, and austenitic steels, and nickel-, aluminum-, titanium-, and zirconium-base alloys. The different processes of embrittlement (e.g., dislocation or lattice bond interaction, internal pressure formation, and hydride precipitation) and their influence on deformation behavior are identified for specific alloys. Finally, different methods for reducing susceptibility to hydrogen embrittlement are discussed.

Liquid-metal embrittlement (LME) is covered in Chapter 9 by Kamdar. Data

continues

from numerous investigations on the phenomenon of LME are presented, and possible mechanisms and prerequisites for its occurrence are discussed. The influence of metallurgical, physical, and mechanical parameters on LME are reviewed in terms of the various mechanisms. An extensive summary and bibliography on LME of metals and alloys during soldering or industrial processing are also presented.

Chapter 10 by Hawthorne provides an in-depth review of irradiation embrittlement of common structural steels for service temperatures below 400°C. Irradiation embrittlement of ferritic steels, and the environmental and metallurgical variables which influence the irradiation response of alloys are described. Mechanical-property data and correlations for estimating radiation effects during reactor service are presented. Recent efforts to develop radiation-resistant structural steels and methods for restoring mechanical properties of irradiated materials are detailed.

The last chapter by Solomon describes metallurgical processes that result in weld defects or cracks: hot cracking of weld metal, reheat or stress-relief cracking of heat-affected zones (HAZ), weld sensitization, and cold or hydrogen cracking. A detailed discussion of solute distribution during solidification and its effect on weld structure identifies the factors that influence hot cracking. The influence of alloy composition, trace impurities, and welding conditions on susceptibility to weld defects is described in great detail.

This volume offers comprehensive coverage of topics involved in materials degradation. The scope and relevance of these subjects will provide impetus and guidance to materials scientists, engineers, and designers. The well-illustrated volume with its extensive background information, bibliography, and detailed discussions could serve as a source book for students and researchers in materials science. It should be a valuable addition to reference libraries.

Reviewer: Omesh K. Chopra is a metallurgist in the Materials Science and Technology Division of Argonne National Laboratory.

Materials for Microlithography

Edited by L.F. Thompson, C.G. Willson, and J.M.J. Frechet

(Volume 266 of ACS Symposium Series, American Chemical Society, 1984)

This volume is a collection of papers given in a symposium at the American Chemical Society's Annual Meeting in St. Louis, MO in April 1984.

Conference proceedings often convey a rather fragmented picture of their field. This volume achieves unusual consistency

due partly to three excellent introductory chapters by Everhart (Limits of Lithography), by Broers (Fundamentals), and by Bowden (Resist Materials). The other papers fall into two groups: the first concerns the fundamental radiation chemistry of electron beam, x-ray, or deep UV materials; the second deals directly with resist materials and their applications.

A brief perusal of the papers will show that coverage of the field of microlithographic materials is fairly comprehensive and that the volume title is justified.

Reviewer: Arnost Reiser is chairman of the Department of Imaging Sciences of the Polytechnic Institute of New York, Brooklyn, NY.

New Frontiers in Rare Earth Science and Applications, Volume I

Edited by G. Xu and J. Xiao
(Science Press, Beijing and Academic Press, New York, 1985)

New Frontiers in Rare Earth Science and Application contains the proceedings of the International Conference on Rare Earth Development and Applications held in Beijing, China, September 10-14, 1985. The editors, Drs. Xu and Xiao, are professors at Peking University and Beijing University of Iron and Steel Technology, respectively. Volume I includes approximately 170 extended abstracts of invited and contributed papers by several internationally recognized authorities on the rare earths and by numerous workers from the People's Republic of China.

In addition to plenary lectures, the volume includes a mixture of reports on theoretical, experimental, and applied topics. The People's Republic reportedly has the world's largest reserves of rare earths, and the rapid expansion of interest in rare earth technology suggests that the development of this resource is being actively pursued. Surprisingly large sections are devoted to geochemistry, extraction, and analytical chemistry. Approximately one fourth of the papers are related to bio-inorganic and organometallic chemistry, but only ten papers were presented on the chemistry and physics of solids. Sections on quantum chemistry and spectroscopy, catalysis, and environmental chemistry are also included.

Volume II was not available for review, but abstracts on important topics such as luminescence, hydrogen storage, and magnetism are included in the table of contents. Lengthy sections on applications in steels, alloys, and ceramics also appear in the second volume along with a series of reports on the effects of rare earths in crop production, nitrogen fixation, and other agricultural applications. The abstracts generally provide enough information to be of

technical value, but they are probably most useful as a guide to current directions of rare earth research, particularly in the People's Republic of China.

Reviewer: J.M. Haschke, a member of the research staff at Rockwell International, has been interested in the solid-state chemistry of rare earth and actinide compounds throughout his career.

Glass IV

Edited by M. Tomozawa and R.H. Doremus

(Volume 26 of Treatise on Materials Science and Technology, Academic Press, 1985)

Glass IV is the most recent volume in a series that began with the publication of *Glass I* in 1977. This volume contains five chapters in different areas in glass, science, and technology.

In the first chapter, J.M. Aitken (IBM Corporation) and E.A. Irene (University of North Carolina) review the use of SiO₂ films in semiconductor devices. The aim of the review, according to the authors, is to give materials scientists working outside the electronics industry some insight into the role of glass films in modern micro-electronic devices. They describe the preparation method of the films, physicochemical characterization of the films, and electrical properties of the films.

In the second chapter, G.C. Wicks summarizes the progress in the program on the solidification of nuclear waste in glass. He starts his description with waste disposal strategy and then explains the vitrification process and waste-glass performance.

The third chapter, written by R.E. Loehman, covers almost every field of the science of oxynitride glasses, which attracts much interest because of their mechanical properties. This chapter consists of seven sections: introduction, glass synthesis, compositional system, properties, crystallization, structure, and applications.

Heavy-metal fluoride glasses, good candidates for an optical material that accesses the mid-IR region, are described in the fourth chapter by M.G. Drexhage (Rome Air Development Center). Beginning with the history of fluoride glasses, he covers almost all areas in the science of these glasses.

The final chapter on viscoelastic analysis of stresses in composites was written by G.W. Scherer (Corning Glass Works) and S.M. Rekhson (General Electric Company). This chapter explains and quantifies the influence of relaxation phenomena on the stresses in composites such as seals. The description includes numerical formulae for the analysis and then the comparison with measured results and calculated stress followed for different geometric shapes of the composites.

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