with the previously observed slip systems in sapphire – increasing Burger's vector or decreasing slip-plane spacing leading to an increase in the minimum temperature of observation. The reason why the new slip system has not previously been observed in single crystals is that a specimen orientation is required which will prevent basal slip, which would otherwise occur readily at 1200° C. The only reported work on specimens of such an orientation [3] was with large single crystals at relatively low stresses ($\leqslant$ 10 kg/mm^2) and strain rates, and, in this case, plasticity was not observed below 1600° C.

The observation of a non-basal slip system implies that the Taylor-von Mises criterion for plastic deformation of a polycrystalline aggregate can be satisfied by alumina at elevated temperatures. A good deal of experimental work has been carried out on polycrystalline alumina at temperatures above 1200° C [4-7], but only at low strain rates, where the experimental data can be explained in terms of Nabarro-Herring creep [8, 9], and where non-basal slip would not be expected to occur.

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Note The observed {10$\bar{1}$1} slip bands can be distinguished from {10$\bar{1}$1} twins, produced by the authors in <0001> whiskers, as the two types of deformation behave quite differently under polarised light.

Book Reviews

Refractory Metals and Alloys III: Applied Aspects

AIME Metallurgical Society Conferences Volume 30

R. I. Jaffee (editor)

Pp xli + 996 (Gordon and Breach, 1966) £21 16s, paperback in two volumes at £3 16s and £4 6s

As the editor observes, the time (1963) was ripe for a conference devoted to manufacturing technology and the problems of application of the refractory metals (niobium, tantalum, molybdenum, and tungsten) and their alloys. With the incentive provided by the needs of the aerospace industry, basic studies of the general physical metallurgy of these materials had already been pursued with considerable enthusiasm during the previous ten-year period. These studies formed the substance of the first two AIME conferences on refractory metals held in 1960 and 1962, and they are a necessary prelude to a conference on applied aspects.

Most of the papers published in this volume deal with specific applications or with production difficulties associated with such applications, and the problems of using these materials under service conditions. It is interesting that a majority of the applications discussed are for advanced aerospace systems – solid propellant rockets, re-entry vehicles, and liquid-metal containment for space power systems – rather than for the more urgent needs of the air-breathing gas-turbine. The editor implies that the latter can expect no assistance from the refractory quartet, and it is presumably on the consistent failure of attempts to develop satisfactory oxidation-resistant coating systems that he bases his implication, for it would appear from reading this book that most of the other problems associated with the use of these materials have been solved.

This is a well-organised volume, as AIME conferences usually are, and the papers are grouped under the following sub-titles: Extrusion; Forging and Forming Operations; Tubing Technology; Brazing Alloy Development and Techniques; Consolidation into Shapes by

Powder Metallurgy and Other Techniques; Welding Technology and Evaluation; Shear Spinning and Metal Removal; Corrosion by Liquid Metals; Nuclear, Liquid-Metal, and Related Applications; Coatings, Coating Techniques and Evaluation; Behaviour under Thermal and Mechanical Stresses and Special Environments; and Applications. This list will, in itself, give an idea of the scope of the Conference.

There are nearly a hundred papers, and it is to the credit of the editor and authors that most of them are concise and contain only essential information. This forms a fine contrast with the speculative analysis often found in conference volumes.

It is of interest to read of the application to refractory metals of such fabrication methods as hot, isostatic pressing (gas-pressure bonding), vapour deposition, ductile-core tube drawing, flow turning, and chemical machining (although one is surprised to find no reference to hydrostatic extrusion). Looking back to the early days of refractory metals technology, one is reminded of frustrating attempts to fabricate small and impure samples of refractory alloys with inadequate equipment, and one realises now the value of accepting the properties of a new class of materials for what they are and developing new methods of coping with them. This has often meant solving a problem in the continuum mechanics of fabrication instead of metallurgically tailoring the materials to fit the old manufacturing methods.

This is a necessary addition to the refractory metals literature. B. HARRIS

Application of Fracture Toughness Parameters to Structural Metals

AIME Metallurgical Society Conferences Volume 31

H. D. Greenberg (editor)

Pp x + 406 (Gordon and Breach, 1966) £10, paperback £4 4s

This volume contains ten papers presented at the 1964 Fall Meeting of the Metallurgical Society of AIME.

Schnadt* tells an apocryphal story of the days when doors first came into use. People were continually striking their heads against the top of the door frame, and the alarmed Authorities decided to determine empirically the safe height for doorways, by observing the passage of all kinds of people through doorways of various heights. The investigators observed a sound, statistical correlation between the safe height of a door and the age and weight of people passing through. Sceptics, who felt that there ought to be a correlation between the height of people and the safe height of doorways, were ignored. For many years, the evaluation of fracture properties has been carried out on a similar basis; and there must be more than one laboratory where the well-tried "vice-and-hammer" test and the firing of a 0.22 bullet at a component held in a vice are regarded as the only necessary means of judging a material's suitability for use under conditions broadly considered as shock-loading. The development of the concept of fracture toughness and the theory of fracture mechanics in general may, in time, lead to a far more realistic use of the potential of various materials often considered to be brittle. One hardly expects chromium alloys, at the present stage of their development, to find much favour with the believers in over-design.

This book should be welcomed by those dealing with potentially brittle materials who want to understand the fracture-mechanics approach to evaluation, selection, and application. It is essentially a practical book and does not attempt to treat the theoretical aspects of fracture mechanics in anything but an applied manner. Its value for manufacturer, designer, and user lies in the range of materials studied and the wealth of data presented. One hopes that the ideas discussed will stimulate a more widespread adoption of this approach.

The opening paper by Parker sets the scene by introducing the relevant parts of the theory of fracture mechanics. After discussing the physical nature of fracture processes and the effects of structure and external conditions, he progresses through the Griffith theory to the concept of fracture toughness. He shows sensitivity of this parameter to geometrical, structural, and environmental variables. In the second paper, Brothers and Yukawa discuss the advantages and limitations of fracture test methods, including those of the conventional transition-temperature type and others employing fracture-

*"Nuclear Containment Buildings and Pressure Vessels" (Butterworths, 1960), p. 540.

mechanics criteria. Katz and Abbott introduce the notion of the critical thickness concept for design purposes. They illustrate the paper with case-histories that demonstrate the importance of the fact that fracture toughness increases with increasing thickness to a critical point after which it falls off with further increases in thickness.

Four papers follow in which the concepts of fracture mechanics and methods of fracture toughness evaluation are considered with relation to specific materials and products – steel pressure vessels, titanium alloy plate and forgings, welds in maraging steels, and aluminium alloy sheet. The remaining three papers analyse the behaviour of low-carbon, high-strength alloy steels, ultra-high-strength steels, and heavily work-hardened stainless steel, with extensive reference to microstructural and fractographic studies.

B. HARRIS

La Diffusion dans les Solides

Y. Adda, J. Philibert

Volume I pp 692, Volume II pp 624 (Presses Universitaires de France, 1966) F 212 (for the two volumes together)

This extensive, two-volume work will be welcomed as a valuable reference book by many of the large number of scientists concerned with the migration of atoms in crystalline materials, and with the various aspects of the physics of the solid state which are closely related to the presence and movement of crystal defects.

The authors, who are well known for their original contributions to the study of diffusion in solids, have aimed at making individual chapters as self-contained as possible, to facilitate the use of the book for reference purposes. Each chapter is provided with a full bibliography and, where necessary, appendices containing the details of relevant mathematical analyses.

The first two chapters are designed as introductory summaries of the principal concepts involved in atomic diffusion in solids, and the various types of crystal defect by means of which atomic displacements may occur. The remaining nine chapters of Volume I then deal in further detail with particular basic aspects of diffusion phenomena, including phenomenological and atomic theories, a survey of experimental methods, and the interpretation of diffusion processes in pure metals and both single- and poly-phase alloys. Throughout this volume, the emphasis is on theory and measurement relating to diffusion over macroscopic distances, and the applications are mainly confined to metallic systems. Only very brief references are made to the direct measurement of atomic jump probabilities, by internal friction and magnetic resonance studies for example; though the first of these is treated in a separate chapter in Volume II.

In general, the second volume is devoted to discussions of more specialised diffusion topics, such as surface and grain-boundary diffusion, and diffusion under the influence of pressure, temperature gradients, and electric fields. There is also the chapter on inelastic phenomena and two on diffusion in ionic crystals and oxides. The book concludes with a selection of tables of relevant mathematical functions and a very comprehensive and up-to-date set of tables of experimental diffusion data. These contribute considerably to the usefulness of the book.

The authors are to be congratulated on the thoroughness with which the topics selected for detailed discussion have been treated, but it is almost inevitable that individual readers will regret the omission of specific diffusion or atomic displacement problems as principal topics. In particular, it is perhaps unfortunate that atomic diffusion in semiconducting materials has not been included, especially in view of the power and elegance of electrical methods available for experimental investigation and the importance of diffusion processes in the preparation of semiconducting devices. Awareness on the part of the authors of such omissions is pointed out in the preface, where it is explained that the book is addressed particularly to metallurgists. Those primarily concerned with diffusion processes in the metallurgical context will certainly find much relevant and clear discussion, particularly in the sections on chemical diffusion and poly-phase systems. The background of basic theory is very thoroughly covered, making the book equally valuable to those more interested in the fundamental physical importance of atomic diffusion in relation to the physics of solids.

D. H. TOMLIN

Type II Superconductors*

Reports on Progress in Physics, Volume XXIX, Part II, p. 445

B. B. Goodman

(The Institute of Physics and The Physical Society, London, 1966)

This volume is bound in two parts, each priced at 105s.

Interest in superconductivity has blossomed since the early 1950's, owing, in part, to the invention of the Collin's liquefier, which has made liquid helium readily available. It is also due to the tremendous stimulus received by the remarkable theoretical work of Ginzburg, Landau, Abrikosov, and Gor'kov (GLAG) in the USSR and of Bardeen, Cooper, and Schrieffer (BCS) in the USA. Practical interest has developed from the discovery of certain alloys and compounds ("hard" superconductors) which are able to carry current densities $\sim 10^6$ A/cm^2 in fields of about 10^5 Oe. Superconductivity is no longer a rare phenomenon: about one-third of all metallic elements, and some thousand alloys and compounds are known to be superconductors.

The earliest known fact about superconductors was that they have, in the superconducting state, zero electrical resistance. It was later discovered that magnetic flux is excluded from bulk superconductors (the Meissner effect). The BCS theory predicted the presence of an energy gap in the excitation spectrum of electrons, and this energy gap has been measured experimentally for many superconductors. Paradoxically, it is now known that there are superconductors which do not show a complete Meissner effect, that some superconductors may have electrical resistance while still in the superconducting state, and that an energy gap is not essential to superconductivity. These facts have, not unnaturally, led to much confusion. The superconductors which show an incomplete Meissner effect (type II superconductors) are also those which can, in certain circumstances, have a finite resistivity. Professor Goodman's review article does much to clarify the situation regarding the peculiarities of these materials.

Beginning with an excellent and concise historical introduction, the author goes on to develop the Ginzburg-Landau equations, and to introduce the concepts of penetration depth, range of coherence, and upper critical field. Landau's treatment of a quantised fluxoid in a multiply connected superconductor is then related to Abrikosov's concept of flux quanta in the mixed state. Almost half of the article, and herein lies its real meat, is devoted to the reversible behaviour of type II materials. The self-energy of flux lines, the behaviour in magnetic fields (the incomplete Meissner effect), and evidence for flux quantisation are discussed. Of particular interest are the latest results, as yet unpublished, of neutron diffraction in the mixed state. The thermodynamics of the mixed state are treated in detail, and this treatment makes use of the temperature variation of κ_1, κ_2, and κ_3 as calculated by Maki. Having mentioned that there is some doubt about the variation of κ_2, the author unfortunately does not point out, as can be shown quite simply, that κ_2/κ_1 cannot be <1, in contradiction to Maki's prediction.

Also covered in this section are the surface superconducting sheath, and paramagnetic limitations on the upper critical field. In connexion with the latter, Professor Goodman remarks that the actual upper critical field may be somewhat lower than either the predicted paramagnetic limit or the transition field predicted in the absence of paramagnetic effects. This is borne out by the recent measurements of $H_{c2}(O)$ for V_3Ga of 210 kOe, compared with a calculated paramagnetic limit of 270 kOe and an estimated H_{c2} of 350 kOe.

The final section of the article is concerned with the irreversible behaviour of type II superconductors. In view of its practical importance, this section is all too short. It begins with a rigorous derivation of the force acting on one flux line in an inhomogeneous flux distribution and concludes with a consideration of flux creep, flux flow (explaining how a resistance can be induced in the superconducting state), and flux jumping. A discussion of the interaction between flux lines and microstructural defects would have been particularly relevant here, but the author chooses to ignore this vital subject.

The review is comprehensive and authoritative, as is to be expected from one who has, for many years, been an oustanding research worker in this field. It is to be thoroughly recommended to all who are concerned with type II superconductors, though its comprehension demands a fair competence in mathematical methods.

D. DEW-HUGHES

*This article can be purchased as a separate pamphlet at 10s 6d.

Deformation and Strength of Materials

P. Feltham

Pp 135 (Butterworths, 1966) 25s

Dr Feltham has set out to do what many who teach materials science must have been tempted to do – to fill the gap in the range of suitable textbooks created by the birth of this cross-linked curriculum topic. In the field covered by this text, the mechanical behaviour of materials, the problem is to write a book, or construct a course, in which a macroscopic treatment of deformation is reconciled with an atomistic treatment. An author must first consider the various régimes of response to stress – those of elastic, viscoelastic, plastic, and fracture behaviour – from the phenomenological or continuum point of view. This much can often be done satisfactorily no matter what the author's background or experience. But the next step is to analyse the same set of responses in terms of atomic or molecular models of behaviour, and it is at this stage that the hostile may point a critical finger, accuse the author of being merely a metallurgist, ceramist, or what-have-you, and demand by what authority he calls himself a materials scientist. Without almost equal acquaintance with the separate behaviour of ceramics, polymers, and metals, the most convincing examples in the book will always be drawn from the author's own field, and the label on his hat will be clear to his readers. The book will be a metallurgical text (for example) with asides. We must ask whether Dr Feltham's book falls short in this manner, and the answer is that it does, for the text implicitly concerns itself more with metals than with any other material. But most other books of this kind fail in the same way; and we can presumably excuse the first generation of writers and teachers because it is the first, build on their efforts, and continue trying to make sense of the teaching of a subject which many critics today insist is no subject at all. Curiously enough, the same voices do not make the same complaint about the "subject" called engineering.

There are few specific criticisms that might be made. One feels that too little attention is given to fatigue and toughness (a most important materials and mechanics problem), while the section on liquids might well have been omitted. An odd inclusion is the antique notion of Brinell hardness, which is given an inordinately lengthy treatment. One might ask why, in a text of this kind, the author did not begin with a useful modification, the pyramid indentation hardness, and relate it to the plastic punching problem and to tensile strain-hardening.

At 25s, this book is good value, particularly as the alternatives are very comprehensive texts costing between £5 and £7. But to benefit properly from it, the student needs guidance, possibly in the form of amplification of some topics which are too much abridged, and directed reading of research papers to counter a somewhat esoteric treatment of other topics.

B. HARRIS