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Book Reviews

Composite Materials

A. Kelly, G. C. Smith, P. J. E. Forsyth, A. J. Kennedy

Pp 154 (Iliffe Books, 1966) 37s 6d

At this stage in the development of materials science, new books on broad aspects of the subject are to be welcomed. The science and technology of materials are passing through a formative stage, which is largely concerned with bringing together hitherto isolated topics in a consolidated whole. The subject of composite materials is typical of this development. The expression "composite materials" is itself relatively new, and there are few books on the subject available for the student or the research worker, although there is no shortage of books on individual composite materials like concrete or glass-fibre resin systems.

To some extent, the title of the latest book by Kelly, Smith, Forsyth, and Kennedy is misleading. It is almost solely concerned with metal systems, and only makes passing reference to other composites. Subject to this limitation, it represents a valuable contribution to the subject, as would be expected from four authors of such standing.

The book is based on a series of lectures delivered at the Institution of Metallurgists Refresher Course held in November 1965. Dr Kelly introduces the subject with a chapter on the theory of strengthening of metals. This is a broad review of the subject, beginning with the theoretical strength of metals and then dealing with the major variables such as the effect of grain size, solution and precipitation strengthening, the effect of elevated temperatures, work hardening of metals containing disperse phases, and fibre reinforcement. It constitutes a masterly summary of the state of knowledge today, although the arguments are put forward at a very brisk rate, presumably owing to limitations of space. Readers without a specialised metallurgical background, like the reviewer, would have benefited from a more leisurely treatment. Furthermore, a small section devoted to possible geometrical arrangements, and the problem of packing disperse phases of different geometries, would have been useful.

The following chapter on dispersion strengthened materials by Mr G. C. Smith is a very well-rounded review of this important subject, supplemented by a long list of references to recent work. The section on techniques for producing dispersed phase alloys is admirable, and will enable the general reader to compare techniques used in the metals field with those used with other materials. It is followed by sections on the dispersed phase, deformation and fracture behaviour, low-temperature properties, high-temperature properties, and the joining and uses of these materials.

Mr P. J. E. Forsyth of the RAE Farnborough contributes the next chapter on fibre-strengthened materials. This is a subject which has generated a great deal of enthusiasm in recent years, although there are now signs that a more sober reappraisal is taking place. We still see the possibilities, but the difficulties in the way of commercial development are not overlooked. The author has adopted a balanced approach and has tempered enthusiasm with realism. The section deals mainly with the theory of reinforcement (this is a very clear treatment), discontinuous fibres, orientation effects, methods of producing fibre-composite materials, the production and availability of fibres, and the properties of some experimental composites. It represents an excellent summary of an important and growing field. We are reminded on page 100 *et seq* that the significance of the bond between the whisker and the matrix is not fully understood. It appears that more work on this

particular problem is long overdue.

The final chapter, on the potential of composite materials, is written by Dr A. J. Kennedy, until recently Professor of Materials at Cranfield, and now the Director of the British Non-Ferrous Metals Research Association. After a brief introduction (it should be noted that the caption to fig. 4b is inaccurate), there is a very useful section on the design aspects of filament-reinforced materials. Dr Kennedy then deals with the engineering behaviour of composite structures at moderate and at high temperatures, and with a number of special applications of composites, mostly in rocketry.

The book constitutes a valuable review of one of the most active areas in the field of composite materials. Not only will it be useful to metallurgists, both in universities and in industry, but it will also be welcomed by materials scientists who are concerned with research and development in other fields.

L. HOLLIDAY

Recrystallisation, Grain Growth and Textures

H. Margolin (editor)

Pp xvi + 617 (American Society for Metals, Metals Park, Ohio; Chapman and Hall, London; 1966) £9 12s

This volume contains thirteen invited papers delivered at an ASM seminar in October 1965, together with fourteen submitted "discussions", which are in fact small papers reporting additional experiments and reviews. Most of the contributors are scientists whose names are closely associated with recrystallisation, and therefore this volume is an important contribution to the field. As would be expected, most of the contributions are in the form of review articles, though there is included an important quantity of new experimental results and new theoretical treatments.

The volume is well structured – the first article by S. J. Basinski and Z. S. Basinski summarises the present state of understanding of the nature of cold-worked metal, whose recovery and recrystallisation form the bulk of the book. J. C. M. Li, in an excellent article on recovery processes, deals with the kinetics of dislocation annihilation, particularly in deformed ionic crystals, and the effect of this recovery on subsequent recrystallisation. He also gives a timely review of the important concept of subgrain coalescence occurring by subgrain rotation. Further evidence for this process in deformed metals is presented in a discussion to this paper. The various suggested models for the mechanism of nucleation of new grains in primary recrystallisation are reviewed by R. W. Cahn, who also considers the recrystallisation of deformed alloys with structures other than pure single-phase metals.

A contribution on grain coalescence, the chance meeting of grains with a low-energy interface, by J. P. Nielson is less impressive in that, although he reports some evidence for this, no real assessment is given of the importance of this phenomenon. An important table which lists the probabilities of the formation of low-energy grain boundaries is given, without saying how it was determined, and the important concept of subgrain rotation is dismissed as merely being "too much to expect" – despite the calculations by Li on this process. An additional calculation by Shewman, for the equivalent process for large-angle boundaries, is given in this article on the energy and structure of grain boundaries – this is an excellent review of general interest to many fields as well as that of this conference.

Vandermeer and Gordon present a review of the latest ideas on grain-boundary migration, including a full discussion of the complex effects of adsorbed impurities. The use of quantitative metallography in recrystallisation studies is presented by J. E. Hilliard, whose contribution should become a standard handbook for future studies using this technique.

Most of the remainder of the book is devoted to articles and discussion on the development of deformation and annealing textures in deformed metals. This subject is aptly described as "one of the most complex in nature", though it is also of considerable commercial importance. It appears that there is as yet little, real, quantitative understanding of this phenomenon and it is sad to discover that the old "oriented nuclei versus growth selection" argument concerning the origin of annealing textures is not yet resolved. This work will be of importance to anyone working in this area but, unlike other

sections of the book, cannot be recommended as an introduction to the subject.

This criticism does not apply to the final articles on crystallisation of amorphous alloys and on the morphology of polymers, which are clear introductions to these new fields of investigation, and they should be of interest to many materials scientists. The last article on recrystallisation in rapidly heated silicon/iron is of value both for the experimental results and from the description of laser heating of thin metal samples.

In general, the volume will be essential reading for all present and potential research workers in the field of recrystallisation; in addition, many of the articles will be of value to both undergraduate and more senior students of metallurgy and materials science. The micrographs are well reproduced and there is a useful index.

R. D. DOHERTY

The Refractory Carbides

E. K. Storms

Pp xiii + 285 (Academic Press, 1967) £5

This excellent volume presents a summary and critical review of the preparation, phase diagrams and thermochemical data, including vaporisation processes, of the carbides of the nine transition elements of Groups IVA, VA and VIA, plus those of thorium, uranium and plutonium. Lattice parameters, structures, hardness and chemical reactivity are also treated, the last two in rather less detail.

The detailed assessments for each of the twelve systems, in general excellent, are followed by a less successful general discussion of each property for all the carbides considered. Dr Storms combines a critical eye for possible explanations of inconsistencies in data with a polite and kindly style. He is at great pains to emphasise the difficulty in removing the last traces of oxygen and nitrogen from these refractory carbides, and the disproportionately large effect these can have on the properties and phase diagram. Detailed purification procedures are quoted for many compounds, but in the general discussion it is inexplicably suggested that in the presence of free graphite, an increased CO pressure will lead to a "purer and more nearly stoichiometric carbide". Although in some circumstances an increase in the CO pressure can lead to an oxycarbide containing less oxygen (as in the U(C,O) + UO_2 diaphasic region), this cannot be so when the carbon activity is fixed at unity. For then the CO pressure will be proportional to the oxygen activity of the solid, and an increased CO pressure must correspond to a higher oxygen content.

The phase diagrams for most of the systems discussed are very complicated, involving phases with wide homogeneity ranges, and many research workers will welcome the critical reviews for these increasingly important systems. Much recent work, some still unpublished, particularly on the Mo/C, W/C, and U/C systems, has been incorporated. Solid state chemists are slowly realising that for many systems, particularly those involving transition metals, the Law of Definite Proportions is often obeyed only by accident. However, a reluctance to drop the corresponding terminology has led Dr Storms to some possibly misleading statements, particularly in dealing with the Mo/C and W/C systems. The Mo/C system is described as having two phases Mo_2C and MoC_{1-x}, each having two crystal forms; later those for Mo_2C are described as allotropes. However, the phase diagram shows one region where α and β Mo_2C coexist, and another where α and β MoC_{1-x} coexist. It does not seem proper to describe this behaviour merely as a change of crystal form, however closely the structures of the α and β compounds are related, and certainly not as allotropy. A term to signify structures which are interchanged by a small change in *composition* rather than temperature would perhaps be useful – a similar problem arises at various points in the rare earth and heavier actinide oxide systems.

Each section on the lattice parameter and structure contains, in addition to a review of the literature data, the calculated powder pattern including relative intensities, for CuKα radiation, for each phase. While this is useful and welcome for the more complicated phases like Cr_3C_2 and ThC_2, it seems hardly necessary for the many face-centred-cubic phases encountered.

The sections on thermochemical properties are uniformly excellent and include many reassessments of all existing data; workers in the

atomic energy field will realise how much effort this involves for the uranium carbides alone. The vaporisation behaviour is particularly clearly treated, and where possible includes information on the congruently vaporising composition as a function of temperature and the variation of the activities of the components across a homogeneity range.

In the final comparison of the properties of the carbides, the discussion of the thermochemical data is again strongest, while that on the structure and bonding is rather disappointing. While no pretence at any complete theoretical treatment is attempted, a discussion mainly of M-M and M-C bond strengths, without for example any reference to the metallic behaviour which is such a feature of many of these compounds, seems hardly worth while.

This book can be strongly recommended to research workers for providing a really up-to-date critical review (with more than 600 references) of the relevant data on these carbide systems. How long it will remain so is of course another question.

M. H. RAND