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Book Reviews

The Growth of Crystals from the Melt

Selected Topics in Solid State Physics, V

J. C. Brice

Pp x + 192 (North-Holland Publishing Co, 1965) 50*s*

This book is a very welcome addition to the very limited number of books dealing with the growth of single crystals, a subject of which the importance is now receiving wide recognition. The book deals with the theory and practice of crystal growth from pure and doped melts.

The various methods of crystal growth are treated in detail in Chapters 5 to 7 under the headings *Growth in Crucibles*, *Crystal Pulling*, and *Growth without Crucibles*. These chapters are preceded, in Chapter 4, by a discussion of the basic techniques, common to all methods, of heating, temperature measurement, temperature control, crucible design and materials, and atmosphere control. All these chapters give a clear description of the practical techniques and the important criteria in the design of apparatus; they reveal the author's extensive practical experience of crystal growth.

Chapter 3 concerns the macroscopic distributions of impurities obtained with normal-freeze and zone-melting processes. These are treated in considerable detail both for perfectly-stirred and for partially-stirred melts, the latter being discussed in terms of the concept of the effective distribution coefficient. The effect of volatilisation of impurity from the melt is also taken into account. The chapter concludes with a section on chemical inhomogeneities in crystals in which are discussed orientation-dependent distribution coefficients (the facet effect) and impurity striations. Whilst the important concept of constitutional supercooling is fully treated in Chapter 2, the inhomogeneities which arise from it are not described in detail anywhere in the book.

The bulk of the theory of crystal growth from the melt is contained in Chapter 2, entitled *The Kinetics of Growth from the Melt*. It includes the use of free-energy polar diagrams to determine the equilibrium shape of crystals (though the fact that such a consideration is important only for very small crystals is not stated), nucleation phenomena, growth on different types of interfaces, dendritic growth, constitutional supercooling, and the concept of an interface distribution coefficient and its relationship to the equilibrium distribution coefficient. The subject matter covered in this chapter is so extensive that it is more in the nature of a review.

This leaves Chapter 1 – a curious chapter, entitled *Gases, Solids and Liquids*, and containing such topics as the kinetic theory of gases, crystal lattices, melting, intrinsic and grown-in defects; the last named is treated very superficially. The important subject of phase equilibrium is treated very briefly by refer-

ence to the system Ga-Te, with P-X, T-X and P-T sections of the diagram shown but inadequately captioned. A study of this system does not afford the easiest introduction to the mysteries of the phase diagram!

The only important defect of the book lies not with its contents, but the order in which they are presented. By the time the reader has reached the end of Chapter 1 (on page 38) he still has read nothing of crystal growth. He is then thrown into theory at the deep end and it is not until Chapter 4 (page 94) that the basic techniques of crystal growth are described. Your reviewer can only recommend to the reader unfamiliar with the subject that he start at Chapter 4 on first reading the book.

One excellent feature of the book is that it contains numerous tables of values of properties discussed for a wide range of materials. There is also a complete list of the symbols used at the front of the book. Disappointingly, the subject index is most inadequate; it contains only 45 entries.

The author has attained his declared objective which was "to give a simple account of the scientific principles which underlie the various processes associated with growth from the melt" and the book should prove very valuable to every practising crystal grower.

For the price, a buyer could reasonably have expected the publishers to have provided stronger covers.

D. T. J. HURLE

The Sorby Centennial Symposium on the History of Metallurgy

AIME Metallurgical Society Conferences, Volume 27

C. S. Smith (editor)

Pp xxii + 558 (Gordon and Breach, New York, 1966) 156*s*

This book is a record of a number of scientific and historical papers delivered in Cleveland, Ohio, on 22 and 23 October 1963, to commemorate the 100th anniversary of the discovery of the microstructure of steel by Henry Clifton Sorby. This centennial was sponsored by the Society for the History of Technology, the American Society for Metals, and the Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers.

The authors of the 33 papers include many of those who, over the past 50 or more years, have made important contributions to the theory and practice of the science of metallurgy, and who have helped in providing acceptable theories in this relatively new field. In consequence, this volume provides a unique survey of the origins and developments that have stemmed from Sorby's original observations in 1863.

The book is edited by Cyril Stanley Smith, who has written a delightful and scholarly preface. He has outlined the background for calling the Conference and explained the reasons for the very diverse collection of contributions that make up the whole. He rightly draws attention in his foreword to an unfortunate gap in what is otherwise a well-balanced record. Professor Arthur Quarrell, representing the University of Sheffield, gave an introductory talk which was one of the highlights of the meeting. He had brought with him a unique collection of Sorby's records including photographs, microsections, and diaries, many of which had not previously been recorded. The omission of the transcript of his lecture spoils the completeness of the historical part of the Symposium.

This is not an easy book to review, as it contains such a variety of contributions: some of them purely historical, others autobiographical, some learned scientific treatises on highly specialised metallurgical themes. It is understandable that it is not a natural task for the scientist to turn historian, and many of the papers suffer from the inability of the scientist to make the history of his subject a living thing. However, there are in this record a number of outstanding chapters both from the historical and scientific aspect.

It is clearly not possible to criticise or provide an adequate résumé of each one of these papers. Many of these are isolated and individual contributions that fail to fit in with the general pattern. The writer of this review is left with only one possible approach, namely, to draw attention to those parts that focus attention on the important milestones of the metallurgical story of the last hundred years.

The series starts with three papers specifically devoted to the man Sorby himself; it is interesting to note that Sorby was one of the last of the

genuine *amateur* scientists, in that he was not attached to any one company or research organisation but worked entirely on his own. He was fortunate in having sufficient financial resources to provide his own equipment and laboratory facilities. He published during his life well over 200 papers; these cover a tremendous range of study, and include work in forensic science, biology, botany, petrology – in fact, his metallographic researches represent only a small proportion of his contributions. Higham and Humphries have painted an entertaining picture of Sheffield scientific life in Sorby's time. They bring out the important part that the Sheffield Literary Philosophical Society played in providing a forum for the discussion of Sorby's many lectures.

The next section of the record contains a number of biographical and in some instances autobiographical papers. Amongst these are two outstanding contributions. The first of these is from Harold Moore, who describes S. E. Stead's work; Stead followed up Sorby's original metallographic studies and established, on a firm basis, the use of the microscope as a tool in the control of steel making and steel working operations.

The second outstanding paper in this section is the one by S. A. Main, who describes the pioneer work of Sir Robert Hadfield; Hadfield, if not the father of alloy steel, was certainly one of its great pioneers. His careful and painstaking work on iron-manganese-carbon and iron-silicon alloys led to two great metallurgical discoveries. One was manganese steel, which, incidentally, is still made today to almost exactly the same composition as Hadfield had worked out in 1882, and which has proved such an outstanding contribution in the field of wear- and abrasion-resisting materials. Hadfield's other great contribution, which has received less publicity but was perhaps equally if not more important, was the development of the 4% silicon steels, which, through their use in motors and transformers, revolutionised the electrical industry.

It is interesting to speculate on the extent to which Sorby, Arnold, and Hadfield, by virtue of their close association in Sheffield, and their friendship with Stead, influenced the important expansion and development of the steel industry in Great Britain at the end of the nineteenth and the beginning of the twentieth century.

Contributions by Wever, Bastin, and Sandorsky describe the developments in Germany, France, and Russia, and help us to remember how much we owe to Osmund, Le Chatelier, Martens, Tschernoff, and other European metallurgists, in increasing our understanding of the principles underlying the working, heat treatment, and alloying of steel.

Among the specialised papers that follow, the one by Cohen on the β-iron controversy deserves special mention. The arguments over the existence or non-existence of β-iron represent one of the most bitterly fought scientific problems of the early twentieth century; such famous protagonists as Rosenhain, Ewing, Arnold, Carpenter, Roberts-Austen, and Osmond all playing an important role in the battle. Yet, Cohen seems to sum it all up in his final comment – ". . . blind men in a dark cellar looking for a black cat that wasn't there"! Still, it must be remembered how all these arguments helped not only to enliven the proceedings of the Iron and Steel Institute, but played their part in establishing this body as the natural place where the problems of the Industry were discussed. Out of all this disputation, the new scientific approach to metallurgy was being born.

Mehl's paper on the Widmanstätten structure could be read with advantage by today's young students of metallurgy, who, perhaps, are over-influenced by the new tools at their command. Many are the uses of electron microscopes and electron-probe micro-analysers, but much is still to be learnt from the relatively coarse methods of examination provided by study of the macrostructure of metals and alloys. In addition, Mehl does not let us forget how much we owe to the work of Willard Gibbs, and Roozeboom on the phase rule, work which paved the way for the determination of many hundreds of phase diagrams of alloys.

Hunsicker and Stumpf take us through the history of the development of precipitation- or age-hardening, tracing the story from the original observations of Wilm that led to the discovery of duralumin, and the modern discoveries of the nimonic and titanium alloys that have played such a vital part in answering the problems of the aircraft and space industries of our modern age. It is pleasant to find here proper acknowledgement to the work of Rosenhain, Gayler, and Hanson at the National Physical Laboratory on the age-hardening alloys of aluminium in the period 1915 to 1925.

Beck provides a concise record on recrystal-

lisation and reminds us of the experiments of Carpenter and Elam, which led to the production of large single crystals by critical strain followed by annealing, thus providing the physical metallurgist with a basic material to study.

Hume-Rothery traces the development of the theory of alloying, naturally surveying much of his own work on the size-factor principle, and is it significant to note his conclusions – ". . . the electron theory of alloys is in an unsatisfactory state", and "The theory of alloys is thus at the stage of Kepler and not of Newton".

Sir Geoffrey Taylor and Orowan have contributed two papers on dislocation theories that are worthy of close study.

Amongst the later specialist papers, there is a little gem by Mme Weill on non-destructive testing. She directs attention to Archimedes' early experiments on density determinations, rightly pointing out that these represent the first studies on this subject. With humour and much scientific perception, she takes us through the work of Röntgen and the development of "X" rays, to the modern techniques of Jacquet for electropolishing; thus securely forging a link with Sorby, the man who is honoured in this series of papers.

O'Neill on hardness testing is always enjoyable and entertaining. He reminds us of his own student days in Sheffield, when Arnold and Ibbotson were teaching and laying the foundations of modern metallurgical teaching, not forgetting to remind us of the importance of Brearley's contributions to the practical side of the subject. The study of the hardness of metals has undoubtedly helped greatly in the gradual evolution of new alloys.

Amongst the remaining contributions, the one by Coolidge describing the steps that led to the development of ductile tungsten provides an example of how determination and well-directed teamwork can overcome what in the early stages appeared almost insuperable difficulties.

Yeo and Miller have provided an interesting story of the development of nickel steels. As has so often happened in scientific discovery, the stimulus of armament requirements provided the beginning of the era of these alloys. The improved properties of both projectiles and armour plate made from low-nickel steels led naturally to their use for engineering purposes at the beginning of the century. It is sometimes forgotten that the first of the stainless steels contained nickel and was of the austenitic type. This was developed by Krupps and exhibited at the Malmö exhibition in 1914; it preceded Brearley's work on the martensitic 12/14% steels. The next 50 years were to see advances leading to the marageing steels of the present day, with their yield strengths of over 250,000 lb/in^2.

To sum up the whole of this volume is a difficult task, but there is no doubt that it is a work of considerable importance. It not only covers the history of metallurgical development over the past hundred years, but also contains valuable chapters on both fundamental theory and practical applications that have been built up from the discoveries of the scientists who contributed to our knowledge of this new science.

The book contains much of interest for both practical and theoretical workers in the field of metals. It should not only be read by metallurgists, engineers, and historians, but should be used as an important book of reference. Though, admittedly, relatively expensive, it should be available to borrowers from all scientific libraries.

E. W. COLBECK