J. Appl. Cryst. (1982). **15**, 579

Mössbauer spectroscopy and its chemical applications. Edited by *John G. Stevens* and *Gopal K. Shenoy*. **Advances in chemistry series No. 194.** Pp. xiii + 642. American Chemical Society, Washington, DC, 1981. Price DM 62.00, US $28.20.

This substantial volume is based on a symposium of the American Chemical Society at Houston in March 1980 in that twenty-nine papers were selected for publication (seven of them in an extended form) to illustrate *Mössbauer spectroscopy and its chemical applications*. Although some of the results described are available elsewhere in the literature, the style of presentation in this volume is more discursive than usual, and a number of the contributions contain extensive and valuable review material. The large number of authors prevents individual mention, but many of the names will be very familiar to the cognoscenti. The papers have been grouped under eight main headings, although the resulting arrangement seems rather curious, and the distinction between extended and shorter papers is less marked than may have been the original intention.

The section on *Chemical bonding* features two papers on molecular-orbital calculations as applied to chlorine, bromine and iodine compounds, and to chemical bonding in gold compounds and alloys. The layman may find these difficult to digest at first reading.

Conversion electron Mössbauer spectroscopy is reviewed by Tricker, who gives a useful account of the principles of the technique as applied to ^{57}Fe and ^{119}Sn and its application to materials and surface science. The three supporting papers give details of preliminary experiments using ^{151}Eu and ^{169}Tm; depth-selective measurements for ^{57}Fe using an electron spectrometer; and some typical results for ^{57}Fe implanted in copper foils and for glazes on ancient artefacts.

Four of the five papers on *Environmental applications* are concerned with various aspects of the characterization of coal by means of the iron mineral content; the exception discusses the analysis of iron oxides in soil.

The review under the heading of *Analytical applications* concentrates specifically on the steel industry and the characterization of ores, coal and steel products.

A short paper by Munck on *Biological applications* gives the recent evidence for a new three-iron centre in ferredoxins, and is an excellent illustration of the complementary use of EPR and Mössbauer spectroscopy in this field.

Five papers on the less commonly used isotopes cover ^{67}Zn in the zinc chalcogenides, ^{237}Np in organoneptunium compounds, ^{121}Sb in the reaction products of $SbCl_5$ with ketimines, ^{127}I in cations and anions of iodine, and ^{125}Te, ^{129}I in tellurium metal under high pressures.

The four papers on *Phase analysis* are introduced by an excellent paper by Gütlich on spin-crossover phenomena which has been one of the most fruitful areas of application of the technique; the shorter contributions discuss spin-crossover effects under high pressure, relaxation effects associated with magnetic transitions, and ferroelectric transitions studied with the ^{181}Ta resonance.

The final seven papers discuss various *Energy and catalyst applications* including such diverse topics as hydrogen storage materials, battery materials, and various catalyst systems. A comprehensive index is also included.

This volume illustrates the trend in recent years for Mössbauer spectroscopy to be used more extensively in materials research, and the range of topics covered shows how successful this change in emphasis has been. Many of the authors have shown commendable candour in discussing the limitations of and the problems associated with their work. Although this is not a comprehensive account of the chemical applications of Mössbauer spectroscopy, the book nevertheless does give a good flavour of what is being achieved, and is a praiseworthy addition to the *Advances in Chemistry Series*.

TERENCE C. GIBB

Department of Inorganic and Structural Chemistry
University of Leeds
Leeds LS2 9JT
England

J. Appl. Cryst. (1982). **15**, 579

Chemical vapor deposition 1960–1980, a bibliography. Edited by *D. T. Hawkins*. Pp. xi + 736. New York: IFI Data Base Library (a division of Plenum), 1981. Price US $ 115.00.

This 736 page book is intended as a reference book for those working in the field of chemical vapour deposition (CVD). The number of articles on CVD showed an enormous increase around 1966 to more than 500 papers per year between 1970 and 1980. CVD started with the purification of materials, later protective coatings were made. The main emphasis, however, comes from the electronics industry, where CVD plays an increasingly useful role in the deposition of high-purity materials, metals, semiconductor materials and refractories in the form of monocrystalline (epitaxial), polycrystalline or amorphous deposits. Recently, solid-state lasers have been made by CVD techniques to produce the light transmitted through optical fibres also made by CVD.

The bibliography contains over 5000 entries, complete with the title of the paper, and is organized in 17 sections: *Theory, Models, Calculations*; *Apparatus, Methods, Techniques*; *Thermodynamics*, and a number of sections on specific materials. Very conveniently also, abstract numbers from *Chemical Abstracts* and *Science Abstracts A* and *B* are listed. No section on structure is available but such information can be found in the permuted title (key word in context) index in which three pages show the word 'structure' to appear in the titles of about 230 papers. This type of index has proven to be of great help in searching the literature for a specific problem, a number of checks confirmed this point. More than half of the content of the book is devoted to this index. An alphabetic index on all the authors with the title of the papers concludes the reference book.

In conclusion, the book will be very useful as a handy reference to existing literature, especially at the start of a new line of work. By nature the number of readers will be restricted to the rather large CVD community in which the study of thermodynamics, equilibrium and kinetics, structure and defects go hand in hand with, for example, gas flow dynamics, surface studies, and optical tools to identify reaction intermediates.

J. BLOEM

Research Laboratories
NV Philips' Gloeilampenfabrieken
PO Box 80,000
5600 *JA Eindhoven*
The Netherlands

J. Appl. Cryst. (1982). **15**, 579–580

Neutron transmutation doped silicon. Edited by *Jens Guldberg*. Pp xi + 505. New York: Plenum Press, 1981. Price US $ 59.50.

This volume contains the papers presented at the Third International Conference on Neutron Transmutation Doping (NTD) held in Copenhagen on 27–29 August 1980. The two first symposia on NTD were arranged in Oak Ridge (1976) and in the University of Missouri (1978), and the next one will be held in Gaithersberg (June 1982).

The microscopic variations of dopant concentrations in crystals pulled either by float zone (FZ) or by Czochralski (CZ) techniques were shown to be the limiting factor of the high-voltage breakdown in thyristor technology. In order to avoid these striations, NTD of high-resistivity silicon as a method to manufacture a well-defined phosphorus-doped silicon was applied in 1973.

The reactions involved are:

$$n + {}^{30}Si \rightarrow {}^{31}Si + \gamma\text{-rays} \rightarrow {}^{31}P + \beta^-\text{-rays}.$$

Typical results in resistivity gradients and tolerances are divided by a factor of two to three in comparison to the standard doping during pulling, but the minority carrier lifetime is reduced by a factor two to ten.

The main markets involved are power thyristors (8 tons year^{-1}), high-power transistors and diodes (30 tons in 1980) and frequency thyristors. Companies suppling NTD silicon are: in the USA (Monsanto), in Europe (Wacker, Topsil) and in Japan (Japan Silicon, Komatsu, Shin Etsu).

The contributions in this volume can be classified in two main categories:

Quality of the material: defects produced by the irradiation, characterization of the defects, annealings, homogeneity of the resistivity.

Industrial requirements: safety aspects, optimization of nuclear parameters, reactor facilities, future applications.

Quality of the material: During irradiation by neutrons, and during radioactive decay, particles with high energy, β^-- or γ-rays and fast neutrons (more than 50 keV) can induce recoil of silicon atoms and generate defects: vacancies or clusters of vacancies, interstitials. One communication shows that a simple cascade model can give a good idea of this recoil. Hundreds of atoms are recoiled for each atom of phosphor created, and this number increases with the proportion of fast neutrons in the flux of thermal neutrons. Annealing is then necessary to restore the quality of the crystal, which is studied in many of the contributed communications.

The quality of the materi l for industrial use is determined by various characterizations: resistivity (four-point probe, spreading resistance, Hall effect), lifetime, device characteristics (leakage currents), and mechanical strength.

But the main effort is directed towards the characterization of defects and their annealing evolution: photoluminescence, photoconductivity, deep-level transient spectroscopy, optical properties (infrared absorption), electron spin resonance, electron paramagnetic resonance, Raman scattering, neutron scattering and transmission electron microscopy are used in these investigations.

The main defects found are two-, four- and five-vacancy, and vacancy–phosphor and vacancy–oxygen centers. For instance, one four-vacancy is created at each cascade as their number is almost identical.

The defects are annealed at various temperatures, the majority of them at under 870 K. It seems that a 1020 K, 30 min thermal treatment restores the quality of the crystal, except for the lifetime which cannot be longer than 0·5 ms. In CZ crystals, such a thermal treatment generates donor states due to the oxygen (with a large role for carbon), and the electrical homogeneity in resistivity is not reached.

Industrial requirements: Safety is an important concern: two products of the irradiation are radioactive with an emission of β^--rays, ^{31}Si and ^{32}P. ^{31}Si has a short half-life (2·6 h), so that each day after the irradiation, the radioactivity due to this isotope is reduced by a factor of 1000. After one week, the radioactivity has cancelled. ^{32}P has a longer half-life (14·3 d). If the doping is large (resistivity less than 20 Ω cm) the radioactivity of silicon is larger than the safety specifications [0·2 pCi g^{-1} (0·074 aBq s^{-1} g^{-1})] and silicon cannot be used until the radioactivity has decreased to this value. Some weeks may be necessary (10 weeks for a 5 Ω cm resistivity).

Various industrial processes of NTD silicon production compared to standard FZ are presented. Many communications study the influence of the design of the reactor (heavy water or water, graphite reflectors, stainless-steel absorbers), flux of neutrons, position of the crystals in the reactor and length (30 to 50 cm) and diameter (8 cm) of the crystals on the characteristics of irradiation: homogeneity of irradiation, proportion of high-energy neutrons, time necessary to reach the doping level. Great attention is given to the measurements of parameters, neutron flux for instance.

Future trends are developed in two communications: NTD silicon can be employed with both FZ and CZ grown extrinsic silicon precisely to compensate residual shallow acceptors present. This material is used in infrared detector technology with gallium or indium doping. Long photocarrier lifetimes and high infrared responsitivities (50 A W^{-1}) have been obtained, with compensations as low as 10^{12} atoms cm^{-3}. NTD was also used for doping GaAs as reactions of neutrons with gallium generates germanium atoms and with arsenic generates selenium.

This book updates the information not only for people involved in neutron transmutation technology, but also for all the scientists working on defects in silicon, especially defects due to the irradiation, and their evolution during annealings.

BERNARD LEROY

Compagnie IBM France
BP58 91102 *Corbeil Essonnes CEDEX*
France

Books Received

The following books have been received by the Editor. Brief and generally uncritical notices are given of works of marginal crystallographic interest; occasionally a book of fundamental interest is included under this heading because of difficulty in finding a suitable reviewer without great delay.

J. Appl. Cryst. (1982). **15**, 580

Crystallography: an introduction for earth science (and other solid state) students. By *E. J. W. Whittaker.* Pp. xii + 254. Oxford: Pergamon Press, 1981. Price £8·35, US $19·95 (softback); £13·50, US $32·50 (hardback). A review of this book, by Martin J. Buerger, has been published in the July 1982 issue of *Acta Crystallographica*, Section A, page 560.

Semiconductor technologies, 1982, edited by *J. Nishizawa*, Pp. iv + 348; **Amorphous semiconductor technologies and devices, 1982,** edited by *Y. Hamakawa*, Pp. v + 380; **Optical devices and fibres, 1982,** edited by *Y. Suematsu*, Pp. v + 391; **Computer science and technologies, 1982,** edited by *T. Kitagawa*, Pp. iv + 365: together comprising Vols. 1–4 of an international edition of **Japan Annual Reviews in Electronics, Computers and Telecommunications,** published cooperatively by Ohmsha, Tokyo, and North Holland, Amsterdam, 1982. Price (each volume) Dfl. 310.00, or US $124.00. There is little in any of these four volumes of *direct* relevance to the crystallographer but they do illustrate the present sophistication of this field of applied science. The objective of the two collaborating publishers has been to bring Japanese work to the attention of the West by the production of this special *international* (wholly in English) edition of the *Japan Annual Reviews.* Each of these volumes has about 25 articles and about 50 authors (each carefully profiled at the back), with many references to the original (including Japanese language) literature. The English is mostly good but is just occasionally perplexing. Despite an abject confession, in the preface to Vol. 1, that in Japan 'there has been little original research and development', these volumes are crammed with an impressive variety of examples of solid-state devices, described and illustrated in great detail. For Western scientists in the electronic industries this publication must be a mine of information.