SCIENCE OF ENGINEERING MATERIALS

Science of Engineering Materials

Volume 1 Structure of Matter

Volume 2 Materials

Volume 3 Engineering Properties

Science of Engineering Materials

Volume 2

Materials

MANAS CHANDA

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To the loving memory of
The Late Smt. Nityabala Chaudhuri

Foreword

Materials science is an interdisciplinary subject of great importance. It is increasingly being recognised that a course in materials science should form an essential part of engineering science curricula in universities. This is because of the rapid progress being made in the development of sophisticated tailor-made materials of desired properties and specifications to suit specific needs. The subject is, therefore, not only of relevance to engineering but also to physical sciences, medical science, and other disciplines. Thus, modern medical practice makes use of new bio-materials while modern solid state chemistry is concerned with the synthesis of novel kinds of compounds. An introduction to materials science will undoubtedly enable students, teachers and professionals to appreciate the problems related to materials in the modern world.

This book by Dr. Manas Chanda attempts to present an introduction to engineering materials science, which I am sure will be found useful by the scientific and educational community. Dr. Chanda has taken pains to work out examples and problems which will be useful to students. I recommend the book to students and teachers of materials science.

*Indian Institute of Science
Bangalore
22 February 1979*

C N R RAO

Preface

The properties or behaviour of every kind of engineering material depend upon its internal structure, and the hierarchy of such structures ranges from the atomic and molecular level through the crystalline structure to microstructures and macrostructures. Volume 1 of this book dealt, in its five chapters, with the structure of atoms and molecules, the characteristics and molecular make-up of the different states of matter, and the structure of crystalline and amorphous solid phases. The present volume, composed of six chapters, presents an organised study of multiphase systems, dealing with microstructures, macrostructures, and behavioural characteristics of the main classes of engineering materials.

General phase-equilibrium relationships, phase changes and phase or grain characteristics are dealt with in Chapter 1, which also presents a concerted treatment of the major processes that control the grain characteristics, such as recrystallisation, grain growth and sintering, with examples drawn from both metallic and non-metallic systems. Chapter 2 is devoted to a detailed study of phases and phase transformations in iron-carbon systems, in recognition of their great importance in engineering. The next four chapters are concerned with the four main groups of engineering materials—metals and alloys, plastics, ceramics, and composites. The discussion in these chapters emphasises how the internal make-up and structure can be designed or considerably modified by various manufacturing processes and treatments to impart completely different characteristics to the material. Ferrous and non-ferrous alloys are discussed from this angle in Chapter 3,

followed by polymeric materials in Chapter 4. Polymeric materials present a striking example of the fact that we are no longer forced to accept the atomic and molecular arrangements produced by nature, but we can modify and tailor them to produce desired properties for particular applications. Thus, by varying the molecular make-up of polymers, by varying the length of the molecular chain and its characteristics such as its stiffness and symmetry or by controlling the degree and type of cross-linking, we can produce a wide range of materials for different applications. The discussion in Chapter 4 is oriented to emphasise this viewpoint.

Over the last few decades, the ancient art of ceramics has been transformed into the science of materials engineering, helped by an understanding of the relation between structure and properties that permits better control of chemical composition and micro-structure, and designing new materials for technology. A study of ceramic materials from this viewpoint is presented in Chapter 5. The next chapter deals with composite materials, highlighting the factors, such as the nature of the constituents and the relations and interactions between the constituents, which determine the properties and behaviour of composites.

At the end of each chapter, there are problems to enhance the reader's understanding of the concepts discussed in the text. Original references and an important bibliography have been cited at the end of each chapter which should help the readers in their attempts to widen their horizon and deepen their understanding of the subject through further studies.

CGS units have been used throughout the text. However, in view of the growing acceptance of the international (SI) metric system, the book provides a table of basic, derived and supplementary SI units, as well as conversion factors to facilitate conversion to SI units. Besides, in many places in the text, SI equivalents have been given to afford familiarity with this system in relation to the CGS system. This should assist the reader in gradual transition from the present use of mixed units to the SI units.

In writing a book of this kind, one accumulates indebtedness to a wide range of people, not the least to the authors of earlier publications in the field. I particularly wish to acknowledge the help given by Professors I. A. Aksay and J. A. Pask of the

Department of Materials Science and Engineering, University of California, Berkeley, American Society for Metals, Ohio and the American Association for the Advancement of Science, Washington. My faculty colleagues, innumerable students and academic associates in other universities and colleges, have provided much welcome stimulation and direct help. I am much indebted to Professor C. N. R. Rao for writing a foreword to the book. I wish to thank Messrs. M. N. Chandrashekara, P. Raghavendrachar and C. C. Lakshmanan, who performed the task of proof-reading during my visit abroad. The grant of subsidy from the National Book Trust of India for the publication of the book is gratefully acknowledged.

Bangalore
February, 1979

MANAS CHANDA

Basic Units and Conversion Factors

<i>Quantity</i>	<i>English</i>	<i>CGS</i>	<i>SI (MKS)</i>
Length	1 ft = 12 in	30.48 cm	0.3048 m
Volume	1 ft ³ = 7.481 gal	28,320 cm ³ = 28.32 litres	0.0283 m ³
Mass	1 lbm	453.6 g	0.4536 kg
Density	1 lbm/ft ³	0.01602 g/cm ³	16.02 kg/m ³
Force	1 lbf	4.448 × 10 ⁵ dyn	4.448 Newton(N)
Pressure	1 bar	10 ⁶ dyn/cm ²	10 ⁵ N/m ²
	1 psi	6.895 × 10 ⁴ dyn/cm ²	6.895 × 10 ³ N/m ² = 6.895 × 10 ³ Pascal (Pa)
Energy	1 Btu (mean)	252.03 cal	1.056 × 10 ³ Joule (J)
Work	1 ft. lbf	1.356 × 10 ⁷ erg	1.356 J
Power	1 Btu/sec = 778.3 ft. lbf/sec	1.056 × 10 ¹⁰ erg/sec	1.056 Watt (W)
Surface tension	6.854 × 10 ⁻⁵ lbf/ft	1 dyn/cm	10 ⁻³ N/m
Viscosity	0.0672 lbm/ft. sec	1 poise (dyn. sec/cm ²)	0.1 N. sec/m ²
Viscosity, kinematic		1 Stoke (cm ² /sec)	10 ⁻⁴ m ² /sec

Additional Conversion Units

$$1 \text{ \AA} = 10^{-8} \text{ cm} = 10^{-10} \text{ m}$$

$$1 \text{ kgf/mm}^2 = 100 \text{ kgf/cm}^2$$

$$1 \text{ }\mu = 10^{-4} \text{ cm} = 10^{-6} \text{ m}$$

$$= 9.807 \times 10^6 \text{ N/m}^2$$

$$1 \text{ atm} = 76 \text{ cm Hg (at } 0^\circ\text{C)}$$

$$1 \text{ HP} = 550 \text{ ft. lbf/sec} = 2545 \text{ Btu/hr}$$

$$= 14.696 \text{ psi}$$

$$= 746 \text{ W}$$

$$1 \text{ ev} = 1.602 \times 10^{-12} \text{ erg}$$

$$t^\circ \text{ C} = (1.8t + 32)^\circ \text{ F}$$

$$1 \text{ cal} = 4.19 \text{ J}$$

$$t^\circ \text{ F} = \frac{9}{5} (t - 32)^\circ \text{ C}$$

$$1 \text{ ev/molecule} = 23,061 \text{ cal/mole}$$

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