

ADVANCES IN MATERIALS SCIENCE AND ENGINEERING

This is a series of Pergamon scientific reference works, each volume providing comprehensive, self-contained and up-to-date coverage of a selected area in the field of materials science and engineering. The series has been developed primarily from the highly acclaimed *Encyclopedia of Materials Science and Engineering*, published in 1986. Other titles in the series are listed below.

BEVER[†] (ed.)

Concise Encyclopedia of Materials Economics, Policy & Management

BROOK (ed.)

Concise Encyclopedia of Advanced Ceramic Materials

CAHN & LIFSHIN (eds.)

Concise Encyclopedia of Materials Characterization

CARR & HERZ (eds.)

Concise Encyclopedia of Mineral Resources

CORISH (ed.)

Concise Encyclopedia of Polymer Processing & Applications

EVETTS (ed.)

Concise Encyclopedia of Magnetic & Superconducting Materials

MAHAJAN & KIMERLING (eds.)

Concise Encyclopedia of Semiconducting Materials & Related Technologies

MOAVENZADEH (ed.)

Concise Encyclopedia of Building & Construction Materials

SCHNIEWIND (ed.)

Concise Encyclopedia of Wood & Wood-Based Materials

WILLIAMS (ed.)

Concise Encyclopedia of Medical & Dental Materials

CONCISE ENCYCLOPEDIA OF
COMPOSITE MATERIALS
REVISED EDITION

Editor

ANTHONY KELLY

*Extraordinary Fellow, Churchill College
Cambridge, UK*

Executive Editor

ROBERT W CAHN

University of Cambridge, UK

Senior Advisory Editor

MICHAEL B BEVER[†]

MIT, Cambridge, MA, USA



PERGAMON

UK	Elsevier Science Ltd, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, England
USA	Elsevier Science Inc, 660 White Plains Road, Tarrytown, New York 10591-5133, USA
JAPAN	Elsevier Science Japan, Tsunashima Building Annex, 3-20-12 Yushima, Bunkyo-ku, Tokyo 113, Japan

Copyright © 1994 Elsevier Science Ltd

All rights reserved. No part of this publication may be reproduced, stored in any retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic tape, mechanical, photocopying, recording or otherwise, without permission in writing from the publishers.

Revised edition 1994

Library of Congress Cataloging in Publication Data

Concise encyclopedia of composite materials / editor, Anthony Kelly; executive editor, Robert W. Cahn; senior advisory editor, Michael B. Bever. — Rev. ed.
p. cm. — (Advances in materials science and engineering)
Includes index.

1. Composite materials—Encyclopedias. I. Kelly, A.
(Anthony) II. Cahn, R. W. (Robert W.), 1924– . III. Series.
TA418.9.C6C635 1994
620.1'18'03—dc20 93–48542

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN 0-08-042300-0

Transferred to Digital Printing 2009

HONORARY EDITORIAL ADVISORY BOARD

Chairman

Walter S Owen

MIT, Cambridge, MA, USA

Senior Advisory Editor

Michael B Bever†

MIT, Cambridge, MA, USA

H Kent Bowen
MIT, Cambridge, MA, USA

Jack W Christian FRS
University of Oxford, UK

Sir Peter Hirsch FRS
University of Oxford, UK

Gilbert Y Chin†
*AT&T Bell Laboratories
Murray Hill, NJ, USA*

Derek Hull FRS
University of Liverpool, UK

Anthony Kelly CBE FRS
University of Cambridge, UK

FOREWORD

In the time since its publication, the *Encyclopedia of Materials Science and Engineering* has been accepted throughout the world as the standard reference about all aspects of materials. This is a well-deserved tribute to the scholarship and dedication of the late Editor-in-Chief, Professor Michael Bever, the Subject Editors and the numerous contributors.

During its preparation, it soon became clear that change in some areas is so rapid that publication would have to be a continuing activity if the Encyclopedia were to retain its position as an authoritative and up-to-date systematic compilation of our knowledge and understanding of materials in all their diversity and complexity. Thus, the need for some form of supplementary publication was recognized at the outset. The Publisher has met this challenge most handsomely: both a continuing series of Supplementary Volumes to the main work and a number of smaller encyclopedias, each covering a selected area of materials science and engineering, have now been published.

Professor Robert Cahn, the Executive Editor, was previously the editor of an important subject area of the main work and many other people associated with the Encyclopedia have contributed to its Supplementary Volumes and derived Concise Encyclopedias. Thus, continuity of style and respect for the high standards set by the *Encyclopedia of Materials Science and Engineering* are assured. They have been joined by some new editors and contributors with knowledge and experience of important subject areas of particular interest at the present time. Thus, the Advisory Board is confident that the new publications will significantly add to the understanding of emerging topics wherever they may appear in the vast tapestry of knowledge about materials.

Walter S Owen
Chairman
Honorary Editorial Advisory Board

EXECUTIVE EDITOR'S PREFACE

As the publication of the *Encyclopedia of Materials Science and Engineering* approached, Pergamon resolved to build upon the immense volume of work which had gone into its creation by embarking on a follow-up project. This project had two components. The first was the creation of a series of Supplementary Volumes to the Encyclopedia itself. The second component of the new project was the creation of a series of Concise Encyclopedias on individual subject areas included in the Main Encyclopedia to be called *Advances in Materials Science and Engineering*.

These Concise Encyclopedias are intended, as their name implies, to be compact and relatively inexpensive volumes (typically 400–600 pages in length) based on the relevant articles in the Encyclopedia (revised where need be) together with some newly commissioned articles, including appropriate ones from the Supplementary Volumes. Some Concise Encyclopedias offer combined treatments of two subject fields which were the responsibility of separate Subject Editors during the preparation of the parent Encyclopedia (e.g., dental and medical materials).

Eleven Concise Encyclopedias have been published. These and their editors are listed below.

<i>Concise Encyclopedia of Advanced Ceramic Materials</i>	Prof. Richard J Brook
<i>Concise Encyclopedia of Building & Construction Materials</i>	Prof. Fred Moavenzadeh
<i>Concise Encyclopedia of Composite Materials</i>	Prof. Anthony Kelly
<i>Concise Encyclopedia of Magnetic & Superconducting Materials</i>	Dr Jan Evetts
<i>Concise Encyclopedia of Materials Characterization</i>	Prof. Robert W Cahn FRS & Dr Eric Lifshin

<i>Concise Encyclopedia of Materials Economics, Policy & Management</i>	Prof. Michael B Bever [†]
<i>Concise Encyclopedia of Medical & Dental Materials</i>	Prof. David F Williams
<i>Concise Encyclopedia of Mineral Resources</i>	Dr Donald D Carr & Prof. Norman Herz
<i>Concise Encyclopedia of Polymer Processing & Applications</i>	Mr P J Corish
<i>Concise Encyclopedia of Semiconducting Materials & Related Technologies</i>	Prof. Subhash Mahajan & Dr Lionel C Kimerling
<i>Concise Encyclopedia of Wood & Wood-Based Materials</i>	Prof. Arno P Schniewind

Many of the new or substantially revised articles in the Concise Encyclopedias have been published in one or other of the Supplementary Volumes, which are designed to be used in conjunction with the Main Encyclopedia. The Concise Encyclopedias, however, are “free-standing” and are designed to be used without necessary reference to the parent Encyclopedia.

The Executive Editor is personally responsible for the selection of topics and authors of articles for the Supplementary Volumes. In this task, he has the benefit of the advice of the Senior Advisory Editor and of other members of the Honorary Editorial Advisory Board, who also exercise general supervision of the entire project. The Executive Editor is responsible for appointing the Editors of the various Concise Encyclopedias and for supervising the progress of these volumes.

Robert W Cahn FRS
Executive Editor