MATERIALS CHARACTERIZATION SERIES

SERIES EDITORS: C. Richard Brundle and Charles A. Evans, Jr.

材料表征原版系列丛书

复合材料的表征

CHARACTERIZATION OF Composite Materials

Hatsuo Ishida

哈爾濱工業大學出版社
HARBIN INSTITUTE OF TECHNOLOGY PRESS

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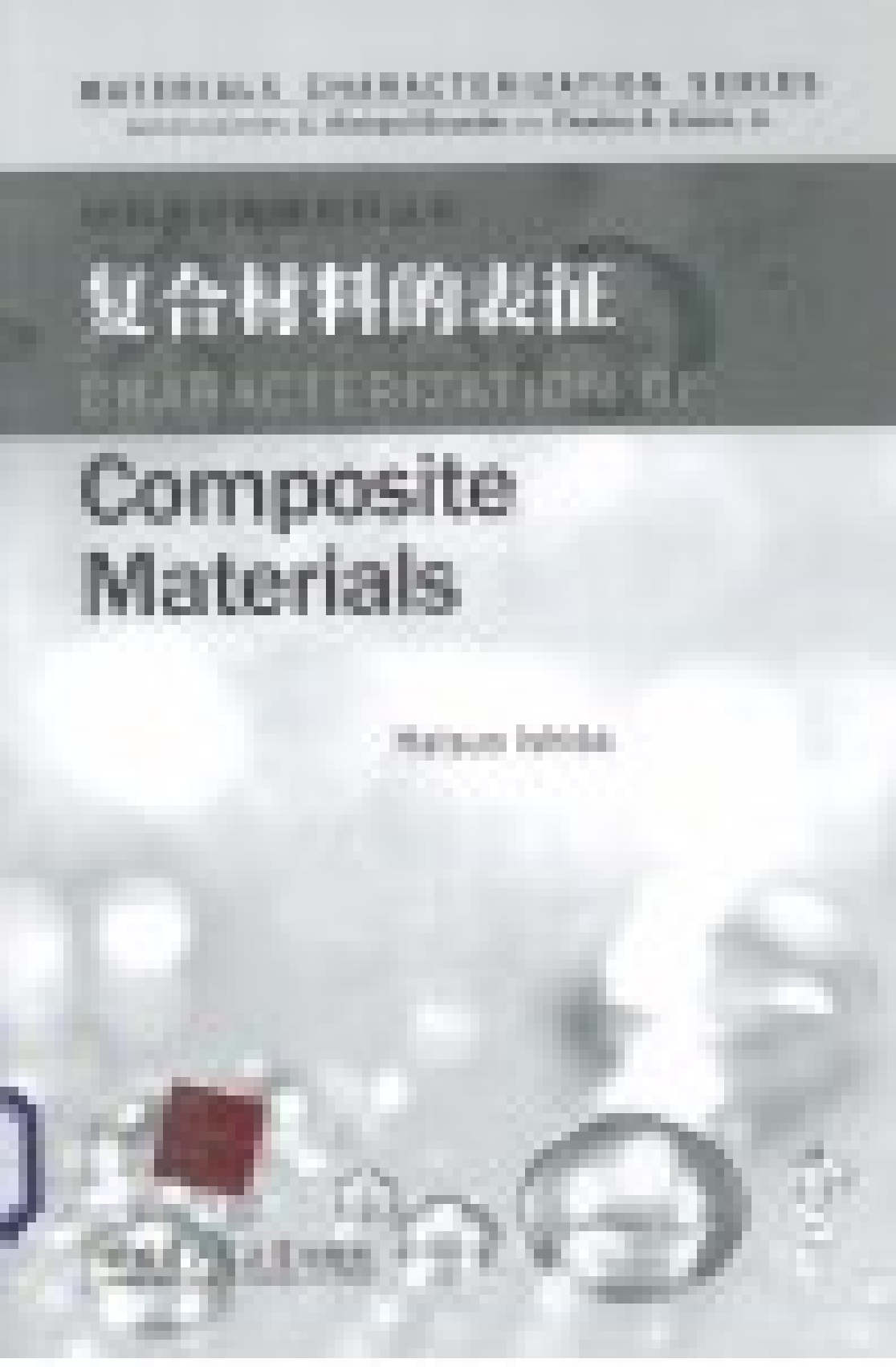
Characterization of Composite Materials



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CHARACTERIZATION OF COMPOSITE MATERIALS

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MATERIALS CHARACTERIZATION SERIES

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Preface to the Reissue of the Materials Characterization Series

The 11 volumes in the *Materials Characterization Series* were originally published between 1993 and 1996. They were intended to be complemented by the *Encyclopedia of Materials Characterization*, which provided a description of the analytical techniques most widely referred to in the individual volumes of the series. The individual materials characterization volumes are no longer in print, so we are reissuing them under this new imprint.

The idea of approaching materials characterization from the material user's perspective rather than the analytical expert's perspective still has great value, and though there have been advances in the materials discussed in each volume, the basic issues involved in their characterization have remained largely the same. The intent with this reissue is, first, to make the original information available once more, and then to gradually update each volume, releasing the changes as they occur by on-line subscription.

C. R. Brundle and C. A. Evans, October 2009

Preface to Series

This Materials Characterization Series attempts to address the needs of the practical materials user, with an emphasis on the newer areas of surface, interface, and thin film microcharacterization. The Series is composed of the leading volume, *Encyclopedia of Materials Characterization*, and a set of about 10 subsequent volumes concentrating on characterization of individual materials classes.

In the *Encyclopedia,* 50 brief articles (each 10 to 18 pages in length) are presented in a standard format designed for ease of reader access, with straightforward technique descriptions and examples of their practical use. In addition to the articles, there are one-page summaries for every technique, introductory summaries to groupings of related techniques, a complete glossary of acronyms, and a tabular comparison of the major features of all 50 techniques.

The 10 volumes in the Series on characterization of particular materials classes include volumes on silicon processing, metals and alloys, catalytic materials, integrated circuit packaging, etc. Characterization is approached from the materials user's point of view. Thus, in general, the format is based on properties, processing steps, materials classification, etc., rather than on a technique. The emphasis of all volumes is on surfaces, interfaces, and thin films, but the emphasis varies depending on the relative importance of these areas for the materials class concerned. Appendixes in each volume reproduce the relevant one-page summaries from the *Encyclopedia* and provide longer summaries for any techniques referred to that are not covered in the *Encyclopedia.*

The concept for the Series came from discussion with Marjan Bace of Manning Publications Company. A gap exists between the way materials characterization is often presented and the needs of a large segment of the audience—the materials user, process engineer, manager, or student. In our experience, when, at the end of talks or courses on analytical techniques, a question is asked on how a particular material (or processing) characterization problem can be addressed the answer often is that the speaker is "an expert on the technique, not the materials aspects, and does not have experience with that particular situation." This Series is an attempt to bridge this gap by approaching characterization problems from the side of the materials user rather than from that of the analytical techniques expert.

We would like to thank Marjan Bace for putting forward the original concept, Shaun Wilson of Charles Evans and Associates and Yale Strausser of Surface Science Laboratories for help in further defining the Series, and the Editors of all the individual volumes for their efforts to produce practical, materials user based volumes.

C.R. Brundle and C.A. Evans

Preface to the Reissue of *Characterization of Composite Materials*

Composite materials, by definition, are heterogeneous on some dimensional scale. Classically this meant fiber reinforced polymers, but now days it includes nanoscale mixtures and compounds, and sub-nanoscale molecular compounds. The historical approach to understanding composites was based largely on direct evaluation of the mechanical properties. The modern approach requires an understanding at the nanoscale of the composition, structure, and bonding; this is the subject matter of the present volume. Though there have been advances since it was originally published, the underlying principles have not changed. The basics of the techniques used for analysis and characterization of composites remain also valid, though there have obviously been many incremental technological improvements here. Following the reissue of the volume, in close to its original form, it is our intention to release updates and new chapters as on-line downloads, as they become available.

C. R. Brundle and C. A. Evans, December 2009

Preface

Development of new materials is becoming increasingly difficult, both because of increased environmental concerns and because the number of useful materials made from simple components is limited. We are thus motivated to focus our attention on the improved use of existing materials. Composite materials are ideal candidates for this purpose. Composite materials can be narrowly defined to be fiber-reinforced polymers, such as carbon fiber-reinforced epoxy resin. However, as composite technology has advanced, the definition of composite materials has become broader, to include materials such as molecular composites and nanocomposites which are also similar to immiscible blends. From a characterization perspective, these materials can be treated as heterogeneous materials. While all characterization techniques can be used for homogeneous materials, the subject discussed in this volume emphasizes the unique features of composite characterization.

There are many techniques that can be used to characterize composite materials, and reviewing all of them is beyond the scope of this volume. Characterization techniques are divided into three categories: those which are considered extremely easy and routine, those which require special knowledge or advanced techniques but are available without extreme difficulties, and those which are quite unusual and of limited availability, to few laboratories. This volume focuses on the second category of characterization techniques, to provide maximum benefits for researchers in composite and heterogeneous materials. Each chapter contains a significant amount of instructional material rather than just a review of the author's or other researchers' works. This feature is helpful for the novice researchers in the field. Each chapter also contains state-of-the-art knowledge. For the beginners, this can be regarded as the milestone or current limitation of the respective technique, and for the more experienced, a convenient reminder of what is being done in this rapidly developing field.

The characterization techniques chosen are mostly atomic, molecular, and rheological techniques. Mechanical techniques are excluded, as there are already many excellent introductory materials available. Historically, composite materials have been studied by evaluating mechanical properties, leading to a lack of molecular and chemical understanding. For this reason, we hope that this volume will be a guide to this poorly exploited, yet important field of materials research.

We wish to thank the staff of Manning Publications for their role in helping this book to be published, and in particular Marjan Bace in the conceptual stages, Lee Fitzpatrick during the protracted writing of the manuscript, and Stephen Adams during book production.

Hatsuo Ishida

Acronyms

AAS	Atomic Absorption Spectroscopy
AES	Auger Electron Spectroscopy
AFM	Atomic Force Microscopy
AIS	Atom Inelastic Scattering
ATR	Attenuated Total Reflection
BET	Brunauer, Emmett, and Teller equation
CLSM	Confocal Scanning Laser Microscope
EDX	Energy Dispersive X-Ray Spectroscopy
EELS	Electron Energy Loss Spectroscopy
ESCA	Electron Spectroscopy for Chemical Analysis
FTIR	Fourier Transform Infrared Spectroscopy
FT Raman	Fourier Transform Raman Spectroscopy
GC-FTIR	Gas Chromatography Fourier Transform Infrared Spectroscopy
HREELS	High-Resolution Electron Energy Loss Spectroscopy
HRTEM	High-Resolution Transmission Electron Microscopy
IETS	Inelastic Electron Tunneling Spectroscopy
IR	Infrared Reflection/Absorption Spectroscopy
ISS	Ion Scattering Spectrometry
KE	Kinetic Energy
LEED	Low-Energy Electron Diffraction
MAS	Magic-Angle Spinning
NMR	Nuclear Magnetic Resonance
PAS	Photoacoustic Spectroscopy
PL	Photoluminescence
Raman	Raman Spectroscopy
RAS	Reflection Absorption Spectroscopy
RBS	Rutherford Backscattering Spectrometry
RRS	Resonant Raman Scattering
RS	Raman Scattering
SERS	Surface Enhanced Raman Spectroscopy
SEM	Scanning Electron Microscopy
SIMS	Secondary Ion Mass Spectrometry (Static and Dynamic)
STEM	Scanning Transmission Electron Microscopy
STM	Scanning Tunneling Microscopy
TEM	Transmission Electron Microscopy
TGA-FTIR	Thermo Gravimetric Analysis FTIR
TLC	Thin Layer Chromatography
XPS	X-Ray Photoelectron Spectroscopy

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