

CHARACTERIZATION SERIES

C. Richard Brundle and Charles A. Evans, Jr.

材料表征原版系列丛书

金属与合金的表征

CHARACTERIZATION OF

Metals and Alloys

Paul H. Holloway
P. N. Vaidyanathan



哈尔滨工业大学出版社
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MATERIALS CHARACTERIZATION SERIES

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

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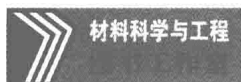
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CHARACTERIZATION OF METALS AND ALLOYS

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Paul H. Holloway and P. N. Vaidyanathan

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C. Richard Brundle and Charles A. Evans, Jr.



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MATERIALS CHARACTERIZATION SERIES

Surfaces, Interfaces, Thin Films

Series Editors: C. Richard Brundle and Charles A. Evans, Jr.

Series Titles

Encyclopedia of Materials Characterization, C. Richard Brundle, Charles A. Evans, Jr.,
and Shaun Wilson

Characterization of Metals and Alloys, Paul H. Holloway and P.N. Vaidyanathan

Characterization of Ceramics, Ronald E. Loehman

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Characterization of Tribological Materials, William A. Glaeser

Characterization of Organic Thin Films, Abraham Ulman

The editors dedicate this book to Bette, Kim, Brian, Mike, Laura, and Kathy Holloway for their love, support, and understanding and to Mr. Narayana Iyer, Mrs. Meenakshi, and Mr. P. N. Vaidyanathan, Sr., for their inspiration, understanding, love, and support.

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 C. A. Evans, Jr.

Preface to the Reissue of *Characterization of Metals and Alloys*

This volume consists of ten chapters from experts in academia (four authors), government institutions (three authors), and from industry (four authors), with two of the authors acting as editors to keep the material cohesive. The emphasis is on understanding how the microstructure of metals and alloys affects their properties, and specifically on the importance of effects at external and internal surfaces (grain boundaries). Characterization of these chemical and physical effects, and the analytical approaches for this, make up the majority of the chapters, covering areas ranging from the original mineral processing through to the use of metals and alloys in thin films. Though there have been incremental advances in many of the analytical techniques used since the original publication of the volume, the basics of the metallurgical information and the application of the analytical approaches discussed remain valid. Following reissue of the volume, in close to its original form, it is our intention to release updates and new material, as online downloads, as they become available.

C. R. Brundle and C. A. Evans, March 2010

Preface

This book resulted from the efforts of a number of people. The idea was introduced to the editors by Marjan Bace of Manning Publications. He provided encouragement to see the volume through to completion. This was accomplished on a more frequent basis (sometimes daily) by Lee Fitzpatrick, also of Manning Publications. Encouragement and assistance for the style and content was given by one of the series editors, C. Richard “Dick” Brundle. The form of the book took place under the watchful eye of the editorial staff at Butterworth-Heinemann Publishing.

We were supported in our efforts by our colleagues and associates in the Department of Materials Science and Engineering at the University of Florida. In particular, Ms. Ludie Hampton worked tirelessly in support of the book. Finally, the people doing the majority of the work were the authors of the chapters. Without their expertise and efforts, the book would not exist or would be worthless. To all of these persons, we say a heartfelt “thank you” for making the project a success.

*Paul Holloway
P. N. Vaidyanathan*

Acronyms Glossary

AED	Auger Electron Diffraction
AES	Auger Electron Spectroscopy
CL	Cathodoluminescence
DR	Differential Reflectometry
EDS, EDX	Energy-Dispersive X-ray Spectroscopy
EELS	Electron Energy-Loss Spectroscopy
EPMA, EMP	Electron Probe X-ray Microanalysis
ERS	Elastic Recoil Spectrometry
EXAFS	Extended X-ray Absorption Fine Structure
FIM	Field Ion Microscopy
FTIR	Fourier Transform Infrared Spectroscopy
GDMS	Glow-Discharge Mass Spectrometry
HREELS	High-Resolution Electron Energy Loss Spectroscopy
ICPMS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectroscopy
IR	Infrared Reflection/Absorption Spectroscopy
ISS	Ion Scattering Spectroscopy
LEED	Low-Energy Electron Diffraction
LEEM	Low-Energy Electron Microscopy
LIMS	Laser Ionization Mass Spectrometry
MEIS	Medium-Energy Ion Scattering
MOKE	Magneto-Optic Kerr Effect
NAA	Neutron Activation Analysis
NEXAFS	Near Edge X-ray Absorption Fine Structure
NMR	Nuclear Magnetic Resonance
NRA	Nuclear Reaction Analysis
OMR	Optical Micro-Reflectometry
PAS	Photoacoustic Spectroscopy
PEEM	Photoelectron Emission Microscopy
PIXE	Particle-Induced X-ray Emission
PL	Photoluminescence
RBS	Rutherford Backscattering Spectrometry
REELS	Reflected Electron Energy-Loss Spectroscopy
RHEED	Reflection High-Energy Electron Diffraction
SALI	Surface Analysis by Laser Ionization
SEM	Scanning Electron Microscopy
SERS	Surface Enhanced Raman Spectroscopy

SEXAFS	Surface Extended X-ray Absorption Fine Structure
SFM	Scanning Force Microscopy
SHG	Second Harmonic Generation
SIMS	Secondary Ion Mass Spectrometry (Static and Dynamic)
SNMS	Sputtered Neutral Mass Spectrometry
SSMS	Spark Source Mass Spectrometry
STEM	Scanning Transmission Electron Microscopy
STM	Scanning Tunneling Microscopy
TEM	Transmission Electron Microscopy
TPD	Temperature Programmed Desorption
TXRF	Total Reflection X-ray Fluorescence Analysis
UPS	Ultraviolet Photoelectron Spectroscopy
VASE	Variable-Angle Spectroscopic Ellipsometry
XPD	X-ray Photoelectron Diffraction
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
XRS	X-ray Spectrometry (also known as EDS or EDX)

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Failure Analysis

Chemical Properties

Mechanical Properties and Interfacial
Analysis

Mineral Processing and Metal
Reclamation

Introduction; Surface and Thin Film
Analysis of Diffusion in Metals; Coatings
and Thin Films

Characterization of the Cleaning of
Surfaces of Metals and Metal Alloys

Mineral Processing and Metal
Reclamation

Coatings and Thin Films

Machining and Working of Metals

Melting and Casting

Introduction

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