MATERIALS CHARACTERIZATION SERIES

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

材料表征原版系列丛书

摩擦材料的表征

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SECOND EDITION

William A. Glaeser

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Second Edition

EDITOR

William A. Glaeser

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

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Surfaces, Interfaces, Thin Films

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

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Characterization of Organic Thin Films, Abraham Ulman

Preface to the Second Edition

Tribology is a discipline concerned with contacting surfaces. This book shows how surface analytical techniques can be used together with the knowledge of basic principles of tribology to help understand failure processes. For instance, Chapter 8 shows how precision ball bearings and their critical lubrication requirements require knowledge of lubricant behavior of very thin films and surface reaction (boundary lubrication) for reliable performance. Thus if a bearing material is altered, it may be necessary to determine its effect on surface chemistry of lubricants. Surface analysis, including wear scar analysis, can be factored into test programs as a supplemental component or as an integral part of the set up.

The purpose of this second edition revision of *Characterization of Tribological Materials* is to update the contents and to clarify some of the discussions. To this end, four figures have been added to Chapter 1, the Introduction, to illustrate real surface contact. The use of the Environmental SEM (ESEM) in examining wear of fiber glass-filled PTFE has been added to Chapter 4. Chapter 5 contains new information on the wear of ceramics. Chapter 6 is updated for new analytical systems. The 17 Appendices have been completely revamped with essential information organized into convenient tables.

A new Chapter 9 is added, which deals with the Atomic Force Microscope (AFM). This instrument has rapidly increased its range of applications and is becoming a useful tool in the field of nanotribology. Not only can it provide full microtopography of surface roughness, but it also can be used to measure nanofriction and nanohardness of surface films.

William A. Glaeser

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 online 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 thick 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 10–18 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. Appendices 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, Jr.

Preface to the Reissue of *Characterization of Tribological Materials*

There have been many advances in the area of tribology since this volume was originally published in 1993, but the basic principles and understanding of the roles of adhesion, friction, abrasive wear, and lubrication, as discussed in the first four chapters, have not changed. Likewise, the two specific technologies discussed as examples where understanding of tribological materials is important (magnetic recording and bearings) have seen changes and advances, but many of the principles and the methods for characterization of the materials involved are still valid. After the reissue of this volume, in a form close to the original, it is our intention that updates, covering advances that have occurred, will be released as downloads as they become available.

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

Preface

Characterization of Tribological Materials was written to illustrate the ways in which surface characterization is being used in tribology and the expected future trends. Since tribology is a discipline involving the moving contacts of surfaces, it should not be surprising that surface science must play a role. Although materials used in bearings, gears, sliding seals, brakes, clutches, electrical contacts, and magnetic recording devices have been developed expressly for these applications, the materials are not unique. Most have been adapted from conventional engineering materials. For tribological use, however, parts require some surface characterization. Currently, surface analysis during manufacture includes the determination of roughness, optical properties, surface hardness, and surface coating thickness and bond strength. More sophisticated surface analysis is not, as a rule, used routinely—except for magnetic recording media. Advanced surface analytical techniques are used mostly in the investigation of the mechanisms of friction, lubrication, and wear.

This volume presents several chapters that describe the basics of tribological phenomena and examples of the use of characterization equipment to further the understanding of these phenomena. These chapters also serve to show where surface science can play a role in advancing our knowledge of friction, wear, and lubrication. Two chapters describe current uses of advanced surface characterization techniques for routine inspection of manufactured components (rolling contact bearings and magnetic recording media).

William A. Glaeser

Acronyms

ADAM	Angular Distribution Auger Microscopy
AED	Auger Electron Diffraction
AES	Auger Electron Spectroscopy
AEM	Analytical Electron Microscopy
AFM	Atomic Force Microscopy
ATR	Attenuated Total Reflection
BSE	Backscattered Electron
CARS	Coherent Anti-Stokes Raman Scattering
CBED	Convergent Beam Electron Diffraction
CL	Cathodluminescence
CTEM	Conventional Transmission Electron Microscopy
EDAX	Company selling EDX equipment
EDS	Energy Dispersive (X-Ray) Spectroscopy
EDX	Energy Dispersive X-Ray Spectroscopy
EPMA	Electron Probe Microanalysis (also known as Electron Probe)
ESCA	Electron Spectroscopy for Chemical Analysis
FCC	Face centered cubic crystal
FTIR	Fourier Transform Infrared (Spectroscopy)
FT Raman	Fourier Transform Raman Spectroscopy (see Raman)
GC-FTIR	Gas Chromatography FTIR
GIXD	Grazing Incidence X-Ray Diffraction (also known as GIXRD)
HRTEM	High Resolution Transmission Electron Microscopy
IR	Infrared (Spectroscopy)
IRAS	Infrared Reflection Absorption Spectroscopy
KE	Kinetic Energy
LEED	Low-Energy Electron Diffraction
LTEM	Lorentz Transmission Electron Microscopy
Magnetic SIMS	SIMS using a Magnetic Sector Mass Spectrometer (also known as Sector SIMS)
OES	Optical Emission Spectroscopy
PISIMS	Post-Ionization SIMS
PHD	Photoelectron Diffraction
Q-SIMS	SIMS using a Quadruple Mass Spectrometer
RA	Reflection Absorption (Spectroscopy)
Raman	Raman Spectroscopy
RBS	Rutherford Backscattering Spectrometry
RRS	Resonant Raman Scattering

RS	Raman Scattering
SAD	Selected Area Diffraction
SAM	Scanning Auger Microscopy
SE	Secondary Electron
SEM	Scanning Electron Microscopy
SEMPA	Secondary Electron Microscopy with Polarization Analysis
SERS	Surface Enhanced Raman Spectroscopy
SFM	Scanning Force Microscopy
SIMS	Secondary Ion Mass Spectrometry (Static and Dynamic)
SPM	Scanning Probe Microscopy
STEM	Scanning Transmission Electron Microscopy
STM	Scanning Tunneling Microscopy
TEM	Transmission Electron Microscopy
TGA-FTIR	Thermo Gravimetric Analysis FTIR
TOF-SIMS	SIMS using Time-of-Flight Mass Spectrometer
WDS	Wavelength Dispersive (X-Ray) Spectroscopy
WDX	Wavelength Dispersive X-Ray Spectroscopy
XAS	X-Ray Absorption Spectroscopy
XPS	X-Ray Photoelectron Spectroscopy
XPD	X-Ray Photoelectron Diffraction
XRD	X-Ray Diffraction

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