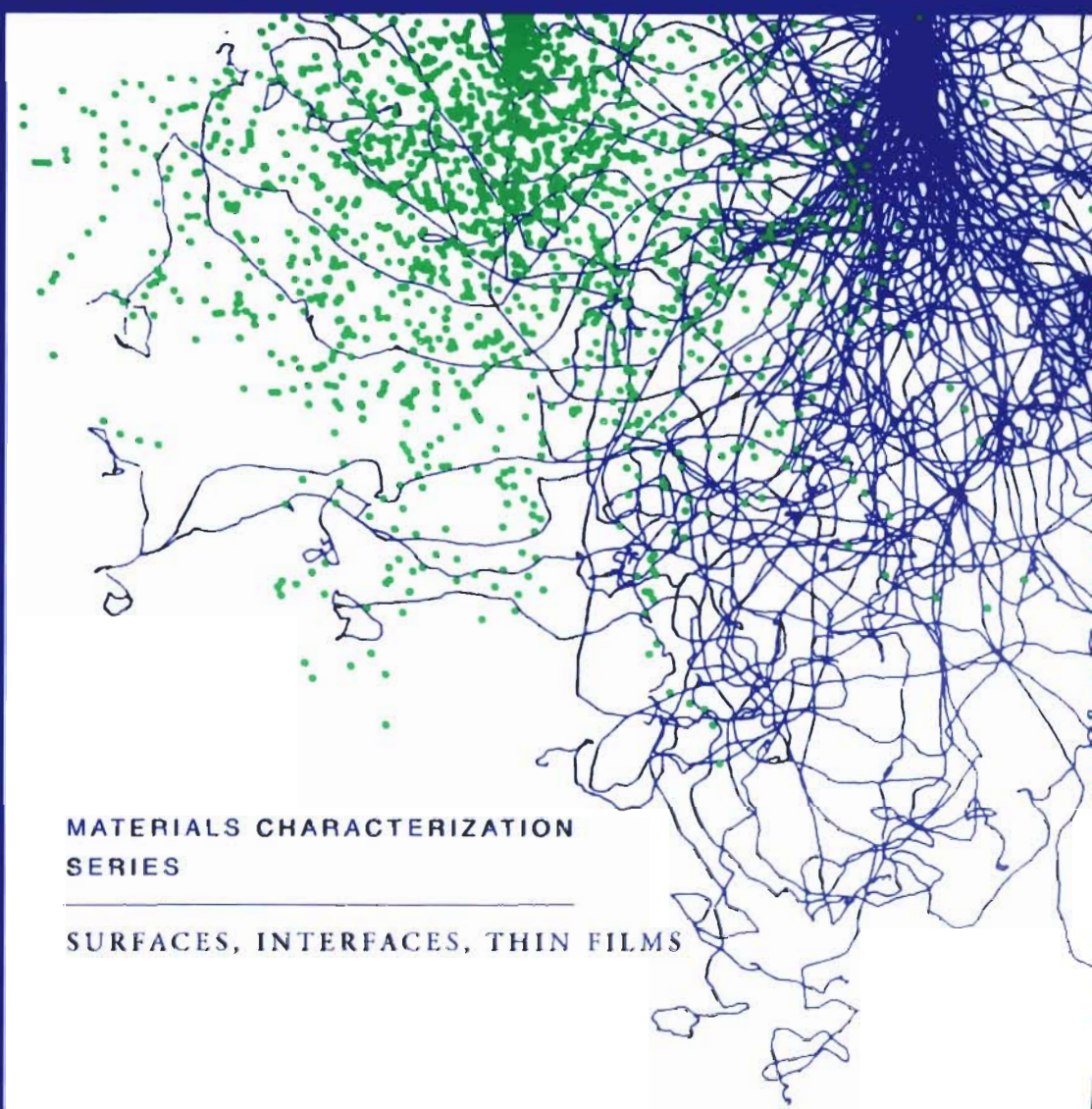
ENCYCLOPEDIA OF MATERIALS CHARACTERIZATION

C. Richard Brundle
Charles A. Evans, Jr.
Shaun Wilson



MATERIALS CHARACTERIZATION SERIES

SURFACES, INTERFACES, THIN FILMS

ENCYCLOPEDIA OF MATERIALS CHARACTERIZATION

MATERIALS CHARACTERIZATION SERIES

Surfaces, Interfaces, Thin Films

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

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Surfaces, Interfaces, Thin Films

EDITORS

C. Richard Brundle
Charles A. Evans, Jr.
Shaun Wilson

MANAGING EDITOR

Lee E. Fitzpatrick

BUTTERWORTH-HEINEMANN
Boston London Oxford Singapore Sydney Toronto Wellington

MANNING
Greenwich

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Stoneham, MA 02180

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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 10–18 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

This volume contains 50 articles describing analytical techniques for the characterization of solid materials, with emphasis on surfaces, interfaces, thin films, and microanalytical approaches. It is part of the *Materials Characterization Series*, copublished by Butterworth-Heinemann and Manning. This volume can serve as a stand-alone reference as well as a companion to the other volumes in the Series which deal with individual materials classes. Though authored by professional characterization experts the articles are written to be easily accessible to the materials user, the process engineer, the manager, the student—in short to all those who are not (and probably don't intend to be) experts but who need to understand the potential applications of the techniques to materials problems. Too often, technique descriptions are written for the technique specialist.

With 50 articles, organization of the book was difficult; certain techniques could equally well have appeared in more than one place. The organizational intent of the Editors was to group techniques that have a similar physical basis, or that provide similar types of information. This is not the traditional organization of an encyclopedia, where articles are ordered alphabetically. Such ordering seemed less useful here, in part because many of the techniques have multiple possible acronyms (an *Acronyms Glossary* is provided to help the reader).

The articles follow a standard format for each technique: A clear description of the technique, the range of information it provides, the range of materials to which it is applicable, a few typical examples, and some comparison to other related techniques. Each technique has a "quick reference," one-page summary in Chapter 1, consisting of a descriptive paragraph and a tabular summary.

Some of the techniques included apply more broadly than just to surfaces, interfaces, or thin films; for example X-Ray Diffraction and Infrared Spectroscopy, which have been used for half a century in bulk solid and liquid analysis, respectively. They are included here because they have by now been developed to also apply to surfaces. A few techniques that are applied almost entirely to bulk materials (e.g., Neutron Diffraction) are included because they give complementary information to other methods or because they are referred to significantly in the 10 materials volumes in the Series. Some techniques were left out because they were considered to be too restricted to specific applications or materials.

We wish to thank all the many contributors for their efforts, and their patience and restraint in dealing with the Editors who took a fairly demanding approach to establishing the format, length, style, and content of the articles. We hope the readers will consider our efforts worthwhile. Finally, we would like to thank Lee Fitzpatrick of Manning Publications Co. for her professional help as Managing Editor.

C.R.Brundle *C.A. Evans, Jr.* *S.Wilson*

Acronyms Glossary

This glossary lists all the acronyms referred to in the encyclopedia together with their meanings. The major technique acronyms are listed alphabetically. Alternatives to these acronyms are listed immediately below each of these entries, if they exist. Related acronyms (variations or subsets of techniques; terminology used within the technique area) are grouped together below the major acronym and indented to the right. Most, but not all, of the techniques listed here are the subject of individual articles in this volume.

AAS	Atomic Absorption Spectroscopy
AA	Atomic Absorption
VPD-AAS	Vapor Phase Decomposition-Atomic Absorption Spectroscopy
GFAA	Graphite Furnace Atomic Absorption
FAA	Flame Atomic Absorption
AES	Auger Electron Spectroscopy
Auger	Auger Electron Spectroscopy
SAM	Scanning Auger Microscopy
SAM	Scanning Auger Microprobe
AED	Auger Electron Diffraction
ADAM	Angular Distribution Auger Microscopy
KE	Kinetic Energy
CMA	Cylindrical Mirror Analyzer
AIS	Atom Inelastic Scattering
BET	Brunauer, Emmett, and Teller equation
BSDF	Bidirectional Scattering Distribution Function
BRDF	Bidirectional Reflective Distribution Function
BTDF	Bidirectional Transmission Distribution Function
CL	Cathodluminescence
CLSM	Confocal Scanning Laser Microscope
EDS	Energy Dispersive (X-Ray) Spectroscopy
EDX	Energy Dispersive X-Ray Spectroscopy
EDAX	Company selling EDX equipment
EELS	Electron Energy Loss Spectroscopy
HREELS	High-Resolution Electron Energy-Loss Spectroscopy
REELS	Reflected Electron Energy-Loss Spectroscopy
REELM	Reflection Electron Energy-Loss Microscopy
LEELS	Low-Energy Electron-Loss Spectroscopy

PEELS	Parallel (Detection) Electron Energy-Loss Spectrscopy
EXELFS	Extended Energy-Loss Fine Structure
EELFS	Electron Energy-Loss Fine Structure
CEELS	Core Electron Energy-Loss Spectroscopy
VEELS	Valence Electron Energy-Loss Spectroscopy
EPMA	Electron Probe Microanalysis
Electron Probe	Electron Probe Microanalysis
ERS	Elastic Recoil Spectrometry
HFS	Hydrogen Forward Scattering
HRS	Hydrogen Recoil Spectrometry
FRS	Forward Recoil Spectrometry
ERDA	Elastic Recoil Detection Analysis
ERD	Elastic Recoil Detection
PRD	Particle Recoil Detection
EXAFS	Extended X-Ray Absorption Fine Structure
SEXAFS	Surface Extended X-Ray Absorption Fine Structure
NEXAFS	Near-Edge X-Ray Absorption Fine Structure
XANES	X-Ray Absorption Near-Edge Structure
XAFS	X-Ray Absorption Fine Structure
FMR	Ferromagnetic Resonance
FTIR	See IR
FT Raman	See Raman
HREELS	See EELS
HRTEM	See TEM
GDMS	Glow Discharge Mass Spectrometry
GDQMS	Glow Discharge Mass Spectrometry using a Quadruple Mass Analyser
Gloquad	Manufacturer name
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP	Inductively Coupled Plasma
LA-ICP-MS	Laser Ablation ICP-MS
ICP-Optical	Inductively Coupled Plasma Optical Emission
ICP	Inductively Coupled Plasma
IETS	Inelastic Electron Tunneling Spectroscopy
IR	Infrared (Spectroscopy)
FTIR	Fourier Transform Infra-Red (Spectroscopy)
GC-FTIR	Gas Chromatography FTIR
TGA-FTIR	Thermo Gravimetric Analysis FTIR
ATR	Attenuated Total Reflection

RA	Reflection Absorption (Spectroscopy)
IRAS	Infrared Reflection Absorption Spectroscopy
ISS	Ion Scattering Spectrometry
LEIS	Low-Energy Ion Scattering
RCE	Resonance Charge Exchange
LEED	Low-Energy Electron Diffraction
LIMS	Laser Ionization Mass Spectrometry
LAMMA	Laser Microprobe Mass Analysis
LAMMS	Laser Microprobe Mass Spectrometry
LIMA	Laser Ionization Mass Analysis
NRMPI	Nonresonant Multi-Photon Ionization
MEISS	Medium-Energy Ion Scattering Spectrometry
MEIS	Medium-Energy Ion Scattering
MOKE	Magneto-Optic Kerr Rotation
SMOKE	Surface Magneto-Optic Kerr Rotation
NAA	Neutron Activation Analysis
INAA	Instrumental Neutron Activation Analysis
NEXAFS	Near Edge X-Ray Absorption Fine Structure
XANES	X-Ray Absorption Near Edge Structure
NIS	Neutron Inelastic Scattering
NMR	Nuclear Magnetic Resonance
MAS	Magic-Angle Spinning
NRA	Nuclear Reaction Analysis
OES	Optical Emission Spectroscopy
PAS	Photoacoustic Spectroscopy
PIXE	Particle Induced X-Ray Emission
HIXE	Hydrogen/Helium Induced X-ray Emission
PL	Photoluminescence
PLE	Photoluminescence Excitation
PR	Photoreflectance
EBER	Electron Beam Electroreflectance
RDS	Reflection Difference Spectroscopy
Raman	Raman Spectroscopy
FT Raman	Fourier Transform Raman Spectroscopy
RS	Raman Scattering
RRS	Resonant Raman Scattering
CARS	Coherent Anti-Stokes Raman Scattering

SERS	Surface Enhanced Raman Spectroscopy
RBS	Rutherford Backscattering Spectrometry
HEIS	High-Energy Ion Scattering
RHEED	Reflected High Energy Electron Diffraction
SREM	Scanning Reflection Electron Microscopy
SALI	Surface Analysis by Laser Ionization
PISIMS	Post-Ionization Secondary Ion Mass Spectrometry
MPNRPI	Multi-Photon Nonresonant Post Ionization
MRRPI	Multiphoton Resonant Post Ionization
RPI	Resonant Post Ionization
MPI	Multi-Photon Ionization
SPI	Single-Photon Ionization
SIRIS	Sputter-Initiated Resonance Ionization Spectroscopy
SARIS	Surface Analysis by Resonant Ionization Spectroscopy
TOFMS	Time-of-Flight Mass Spectrometer
SAM	See AES
SEM	Scanning Electron Microscopy Scanning Electron Microprobe Secondary Electron Miscroscopy
SE	Secondary Electron
BSE	Backscattered Electron
SEMPA	Secondary Electron Microscopy with Polarization Analysis
SFM	Scanning Force Microscopy Scanning Force Microscope
AFM	Atomic Force Microscopy
SPM	Scanning Probe Microscopy
SIMS	Secondary Ion Mass Spectrometry
Dynamic SIMS	Dynamic Secondary Ion Mass Spectrometry
Static SIMS	Static Secondary Ion Mass Spectrometry
Q-SIMS	SIMS using a Quadruple Mass Spectrometer
Magnetic SIMS	SIMS using a Magnetic Sector Mass Spectrometer
Sector SIMS	See Magnetic SIMS
TOF-SIMS	SIMS using Time-of-Flight Mass Spectrometer
PISIMS	Post Ionization SIMS
SNMS	Sputtered Neutrals Mass Spectrometry Secondary Neutrals Mass Spectrometry
SNMSd	Direct Bombardment Electron Gas SNMS
SSMS	Spark Source Mass Spectrometry
Spark Source	Spark Source Mass Spectrometry
STEM	See TEM
STM	Scanning Tunneling Microscopy

	Scanning Tunneling Microscope
SPM	Scanning Probe Microscopy
TEAS	Thermal Energy Atom Scattering
TEM	Transmission Electron Microscopy Transmission Electron Microscope
CTEM	Conventional Transmission Electron Microscopy
STEM	Scanning Transmission Electron Microscopy
HRTEM	High Resolution Transmission Electron Microscopy
SAD	Selected Area Diffraction
AEM	Analytical Electron Microscopy
CBED	Convergent Beam Electron Diffraction
LTEM	Lorentz Transmission Electron Microscopy
TLC	Thin Layer Chromatography
TSRLM	Tandem Scanning Reflected-Light Microscope
TSM	Tandem Scanning Reflected-Light Microscope
TXRF	See XRF
UPS	Ultraviolet Photoelectron Spectroscopy Ultraviolet Photoemission Spectroscopy
MPS	Molecular Photoelectron Spectroscopy
VASE	Variable Angle Spectroscopic Ellipsometry
WDS	Wavelength Dispersive (X-Ray) Spectroscopy
WDX	Wavelength Dispersive X-Ray Spectroscopy
XAS	X-Ray Absorption Spectroscopy
XPS	X-Ray Photoelectron Spectroscopy X-Ray Photoemission Spectroscopy
ESCA	Electron Spectroscopy for Chemical Analysis
XPD	X-Ray Photoelectron Diffraction
PHD	Photoelectron Diffraction
KE	Kinetic Energy
XRD	X-RayDiffraction
GIXD	Grazing Incidence X-Ray Diffraction
GIXRD	Grazing Incidence X-Ray Diffraction
DCD	Double Crystal Diffractometer
XRF	X-Ray Fluorescence
XFS	X-Ray Fluorescence Spectroscopy
TXRF	Total Reflection X-Ray Fluorescence
TRXFR	Total Reflection X-Ray Fluorescence
VPD-TXRF	Vapor Phase Decomposition Total X-Ray Fluorescence

Contributors

Mark R. Antonio
BP Research International
Cleveland, OH

Extended X-Ray Absorption Fine Structure

J. E. E. Baglin
IBM Almaden Research Center
San Jose, CA

Elastic Recoil Spectrometry

Scott Baumann
Charles Evans & Associates
Redwood City, CA

Rutherford Backscattering Spectrometry

Christopher H. Becker
SRI International
Menlo Park, CA

Surface Analysis by Laser Ionization

Albert J. Bevolo
Ames Laboratory,
Iowa State University
Ames, IA

Reflected Electron Energy-Loss Spectroscopy

J. B. Bindell
AT&T Bell Laboratories
Allentown, PA

Scanning Electron Microscopy

Filippo Radicati di Brozolo
Charles Evans & Associates
Redwood City, CA

Laser Ionization Mass Spectrometry

C. R. Brundle
IBM Almaden Research Center
San Jose, CA

X-Ray Photoelectron Spectroscopy;
Ultraviolet Photoelectron Spectroscopy

Daniele Cherniak
Rennsselaer Polytechnic Institute
Troy, NY

Nuclear Reaction Analysis

Paul Chu
Charles Evans & Associates
Redwood City, CA

Dynamic Secondary Ion Mass Spectrometry

Carl Colvard
Charles Evans & Assoociates
Redwood City, CA

Photoluminescence

J. Neal Cox
INTEL, Components Research
Santa Clara, CA

Fourier Transform Infrared Spectroscopy

John Gustav Delly
McCrone Research Institute
Chicago, IL

Light Microscopy

Hellmut Eckert
University of California, Santa Barbara
Santa Barbara, CA

Solid State Nuclear Magnetic Resonance

Peter Eichinger
GeMeTec Analysis
Munich

Total Reflection X-Ray Fluorescence

P. Fenter
Rutgers University
Piscataway, NJ

Medium-Energy Ion Scattering with Channeling and Blocking

David E. Fowler
IBM Almaden Research Center
San Jose, CA

Magneto-Optic Kerr Rotation

S. M. Gaspar
University of New Mexico
Albuquerque, NM

Optical Scatterometry

Roy H. Geiss
IBM Almaden Research Center
San Jose, CA

Energy-Dispersive X-Ray Spectroscopy

Torgny Gustafsson
Rutgers University
Piscataway, NJ

Medium-Energy Ion Scattering With Channeling and Blocking

William L. Harrington
Evans East
Plainsboro, NJ

Spark Source Mass Spectrometry

Brent D. Hermsmeier
IBM Almaden Research Center
San Jose, CA

X-Ray Photoelectron and Auger Electron Diffraction

K.C. Hickman
University of New Mexico
Albuquerque, NM

Optical Scatterometry

Tim Z. Hossain
Cornell University
Ithica, NY

Neutron Activation Analysis

Rebecca S. Howland
Park Scientific Instruments
Sunnyvale, CA

Scanning Tunneling Microscopy and Scanning Force Microscopy

John C. Huneke
Charles Evans & Associates
Redwood City, CA

Sputtered Neutral Mass Spectrometry, Glow-Discharge Mass Spectrometry

Ting C. Huang
IBM Almaden Research Center
San Jose, CA

X-Ray Fluorescence

William Katz
Evans Central
Minnetonka, MN

Static Secondary Ion Mass Spectrometry

Michael D. Kirk
Park Scientific Instruments
Sunnyvale, CA

Scanning Tunneling Microscopy and Scanning Force Microscopy

Bruce E. Koel
University of Southern California
Los Angeles, CA

High-Resolution Electron Energy Loss Spectrometry

Max G. Lagally
University of Wisconsin,
Madison, WI

Low-Energy Electron Diffraction

W. A. Lanford
State University of New York,
Albany, NY

Nuclear Reaction Analysis

Charles E. Lyman
Lehigh University
Bethlehem, PA

Scanning Transmission Electron Microscopy

Susan MacKay
Perkin Elmer
Eden Prairie, MN

Surface Analysis by Laser Ionization

John R. McNeil
University of New Mexico
Albuquerque, NM

Optical Scatterometry

Ronald G. Musket
Lawrence Livermore National Laboratory
Livermore, CA

Particle-Induced X-Ray Emission

S. S. H. Naqvi
University of New Mexico
Albuquerque, NM

Optical Scatterometry

Dale E. Newbury
National Institutes of Science and Technology
Gaithersburg, MD

Electron Probe X-Ray Microanalysis

David Norman
SERC Daresbury Laboratory
Daresbury, Cheshire

Surface Extended X-Ray Absorption Fine Structure, Near Edge X-Ray Absorption Fine Structure

John W. Olesik
Ohio State University
Columbus, OH

Inductively Coupled Plasma–Optical Emission Spectroscopy

Fred H. Pollak
Brooklyn College, CUNY
New York, NY

Modulation Spectroscopy

Thomas P. Russell
IBM Almaden Research Center
San Jose, CA

Neutron Reflectivity

Donald E. Savage
University of Wisconsin
Madison, WI

Reflection High-Energy Electron Diffraction

Kurt E. Sickafus
Los Alamos National Laboratory
Los Alamos, NM

Transmission Electron Microscopy

Paul G. Snyder
University of Nebraska
Lincoln, NE

Variable Angle Spectroscopic Ellipsometry

Gene Sparrow Advanced R&D St. Paul, MN	Ion Scattering Spectroscopy
Fred A. Stevie AT&T Bell Laboratories Allentown, PA	Surface Roughness: Measurement, Formation by Sputtering, Impact on Depth Profiling
Yale E. Strausser Surface Science Laboratories Mountainview, CA	Auger Electron Spectroscopy
Barry J. Streusand Applied Analytical Austin, TX	Inductively Coupled Plasma Mass Spectrometry
Raymond G. Teller BP Research International Cleveland, OH	Neutron Diffraction
Michael F. Toney IBM Almaden Research Center San Jose, CA	X-Ray Diffraction
Wojciech Vieth Charles Evans & Assoociates Redwood City, CA	Glow-Discharge Mass Spectrometry
William B. White Pennsylvania State University University Park, PA	Raman Spectroscopy
S.R. Wilson University of New Mexico Albuquerque, NM	Optical Scatterometry
John A. Woollam University of Nebraska Lincoln, NE	Variable Angle Spectroscopic Ellipsometry
Ben G. Yacobi University of California at Los Angeles Los Angeles, CA	Cathodoluminescence
David J. C. Yates Consultant Poway, CA	Physical and Chemical Adsorption for the Measurement of Solid Surface Areas
Nestor J. Zaluzec Argonne National Laboratory Argonne, IL	Electron Energy-Loss Spectroscopy in the Transmission Electron Microscope