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Goerg H. Michler

Electron Microscopy of Polymers

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Preface

Electron microscopy and atomic force microscopy have developed into powerful tools in the field of polymer science. By using different techniques and methods, morphological details at length scales from the visible (0.1 mm) up to a few 0.1 nm can be detected. Consequently, the microscopic techniques used in polymer research support the tendency, over the last two decades, to shift the level of interest from the μm-scale to the nm-scale region. Systems with at least one structural dimension below ~100 nm are now considered to comprise a new class of materials, the so-called *nanostructured polymers* or *nanocomposites*. In addition, the influence of several parameters can be studied by changing the morphology of the material. In particular, the influence of the actual, local morphology on mechanical loading effects can be determined. The micromechanical properties or mechanisms that occur at nano- and microscopic levels form the bridge between structure, morphology and mechanical properties. Therefore, electron microscopy and atomic force microscopy directly contribute to a better understanding of structure–property correlations in polymers.

Part I offers an overview of electron microscopy and atomic force microscopy techniques and summarises distinctive applications of polymeric materials. The wide variety of preparation methods used to study polymers with the different microscopic techniques are presented and illustrated with typical micrographs in the chapters of Part II. Each technique is discussed in detail, highlighting its application for solving specific problems arising in the characterisation of materials. The applicability of the microscopic techniques and preparation methods described in Parts I and II to the main classes of polymers is documented in Part III. All relevant groups of solid polymers used domestically, industrially, in research and in medicine are mentioned. The characteristic features and also the variety of structures and morphologies of the different polymer classes are illustrated with typical micrographs. In particular, the application of different microscopic techniques is shown to reveal similar polymeric structures, enabling laboratories that possess only some of the techniques to use them beneficially. As well as descriptions of characteristic morphologies and micromechanical properties the most commonly occurring defects and failures are also illustrated.

The volume is directed at polymer scientists from research institutes and industry, and aims to demonstrate the widespread possibilities enabled by the application of microscopic techniques in polymer research and development. Each of these techniques allows one to solve a number of problems, as even for the specialist it is not always evident which technique is best suited to solving a given problem. The monograph is also directed at research and applied technicians, since it provides a basic understanding of the principles of the different microscopic techniques and exhausts all of the possibilities of using these techniques to solve specific research problems. All of the preparation methods applied for the study of a variety of polymeric materials using different techniques are described in depth, which will also aid laboratory assistants or students that are new to microscopy, as well as those that wish to improve their skills. Finally, the book will be also helpful for students of polymer physics, chemistry and engineering, as well as those researchers interested in the micro- and nanoscopic world of polymers.

This volume draws upon the experiences and studies of the working groups of the editor in research institutes, industry, and academia in the period from 1970 onwards (i.e. over three decades). The authors or coauthors of the various chapters are:

Dr. R. Godehardt (Chaps. 2, 3, 4, 5)
Dr. R. Adhikari (Chaps. 5, 19)
Dr. G.-M. Kim (Chaps. 18, 21, 22, 24)
Dr. S. Henning (Chaps. 9, 11, 16, 23)
DP V. Seydewitz (Chap. 4)
DP W. Lebek (Chaps. 7, 10, 12, 13)

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Finally, I also wish to gratefully acknowledge the coworkers at Springer-Verlag for their understanding and help during the preparation of the manuscript.

Halle/Merseburg, March 2008 *Goerg H. Michler*

Abbreviations

General techniques

AFM	Atomic force microscope
AM	Amplitude modulation
BSE	Backscattered electrons
CCD	Charge-coupled device
CRT	Cathode ray tube
EDX(A)	Energy dispersive X-ray analysis
EELS	Electron energy-loss spectroscopy, electron energy-loss spectrometer
EFTEM	Energy-filtered transmission electron microscopy
ELNES	Energy-loss near-edge structure
EM	Electron microscope
ESI	Electron spectroscopic imaging
ESD	Electron spectroscopic diffraction
ESEM	Environmental scanning electron microscope
FEG	Field-emission gun
FIB	Focussed ion beam
FM	Frequency modulation
GIF	Gatan imaging filter
GSED	Gaseous secondary electron detector
HRTEM	High-resolution transmission electron microscope
HVTEM	High-voltage transmission electron microscope
ID	Interparticle distance
LFM	Lateral force microscope
LVTEM	Low-voltage transmission electron microscope
M_W	Molecular weight
MCA	Multichannel analyser
MDS	Minimum-dose systems
MOS	Metal-oxide semiconductor
PE	Primary electrons
PEELS	Parallel electron energy-loss spectroscopy
PFM	Pulsed force mode
ROI	Region of interest
SE	Secondary electrons

SEM	Scanning electron microscope
SFM	Scanning force microscope
SNOM	Scanning near-field optical microscope
SPM	Scanning probe microscope
STEM	Scanning transmission electron microscope
STM	Scanning tunnelling microscope
TEM	Transmission electron microscope
T_g	Glass transition temperature
TM	Tapping mode
TMAFM	Tapping-mode atomic force microscope
WD	Working distance
WDX(A)	Wavelength dispersive X-ray analysis

Materials/polymers

ABS	Acrylonitrile-butadiene-styrene
ASA	Acrylonitrile-styrene-acrylate
BR	Butadiene rubber
AN	Acrylonitrile
COC	Cyclic olefin copolymer
EB	Ethylene-butadiene copolymer
EOC	Ethylene/1-octene copolymer
EPDM	Ethylene propylene diene rubber
EPR	Ethylene propylene rubber
HDPE	High-density polyethylene
HIPS	High-impact polystyrene
iPP	Isotactic polypropylene
LDPE	Low-density polyethylene
LLDPE	Linear low-density polyethylene
MMT	Montmorillonite
MWCNT	Multiwalled carbon nanotube
NBR	Acrylonitrile-butadiene rubber
NR	Natural rubber
OsO_4	Osmium tetroxide
PBMA	Poly(*n*-butylmethacrylate)
PB	Polybutadiene
PC	Polycarbonate
PCH	Polyvinylcyclohexane
PE	Polyethylene
PET	Polyethylene terephthalate
PEB	Ethylene-butylene copolymer
PFS	Poly(ferrocenyl-dimethylsilane)

PI	Polyisoprene
PMMA	Polymethylmethacrylate
PnBA	Poly(*n*-butylacrylate)
PNC	Polymer nanocomposite
POSS	Polyhedral oligosilsesquioxane
PP	Polypropylene
PS	Polystyrene
PTFE	Polytetrafluoroethylene
PVC	Polyvinylchloride
PVDF	Polyvinylidenefluoride
RuO_4	Ruthenium tetroxide
PVP	Poly(2-vinylpyridene)
SAN	Polystyrene-acrylonitrile
SIS	Polystyrene-*block*-polyisoprene-*block*-polystyrene
SBS	Polystyrene-polybutadiene-polystyrene triblock copolymer, polystyrene-*block*-polybutadiene-*block*-polystyrene *block* copolymer
TPE	Thermoplastic elastomer
UHMWPE	Ultrahigh molecular weight polyethylene
VLDPE	Very low density polyethylene

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