

## Contents

**Preface** *ix*

**List of Specimens** *xi*

### **Part I Introduction** *1*

**1 Importance of Electromagnetic Field and Its Visualization** *3*  
References *6*

**2 Maxwell's Equations and Special Relativity** *7*  
2.1 Maxwell's Equations and Electromagnetic Potentials *7*  
2.2 Maxwell's Equations Formulated Using Special Relativity *8*  
References *10*

**3 Basis of Transmission Electron Microscopy** *11*  
References *12*

### **Part II Principles and Practice** *13*

**4 Principles of Electron Holography** *15*  
4.1 Types of Electron Holography *15*  
4.2 Outline of Electron Holography *16*  
4.3 Comparison of Phase Shifts Due to Scalar and Vector Potentials *20*  
4.3.1 Phase Shift Due to Scalar Potential *20*  
4.3.2 Phase Shift Due to Vector Potential *20*  
4.3.3 Effect of Thickness Change on Phase Shifts Due to Scalar and Vector Potentials *22*  
4.3.4 Electric Information *22*  
4.4 Analysis of Reconstructed Phase Images by Computer Simulation *23*  
References *26*

<b>5</b>	<b>Microscope Constitution and Hologram Formation</b>	<b>29</b>
5.1	Basic Constitution of Transmission Electron Microscope	29
5.1.1	Electron Gun System	29
5.1.2	Illumination System	31
5.1.3	Imaging System	33
5.1.3.1	Focal Length	34
5.1.3.2	Spherical Aberration Coefficient	34
5.1.3.3	Chromatic Aberration Coefficient	34
5.1.3.4	Minimum Step of Defocus	34
5.1.4	Observation System	35
5.1.4.1	Television Camera	36
5.1.4.2	Slow-Scan Charge-Coupled Device Camera	37
5.1.5	Operation of Transmission Electron Microscope	38
5.1.5.1	Adjustment of Electron Gun	38
5.1.5.2	Alignment and Astigmatism Correction of Condenser Lenses	38
5.1.5.3	Alignment of Voltage Center and Correction of Objective Lens Astigmatism	38
5.1.5.4	Correction of Intermediate Lens Astigmatism	39
5.1.5.5	Alignment of Projector Lens	40
5.1.5.6	Adjustment of Objective Lens Focus	40
5.2	Biprism System	41
5.3	Coherence Lengths	44
5.4	Formation of Interference Fringes	46
5.4.1	Geometrical-Path Interpretation with Two Virtual Sources	46
5.4.2	Wave-Optical Treatment	47
5.4.2.1	Wave Function at Wire Plane	48
5.4.2.2	Green's Integral Theorem	50
5.4.2.3	Explicit Form of Green's Function	51
5.4.2.4	Intensity Distribution of Interference Fringes	52
5.4.2.5	Stationary Points and Interference Region	54
5.4.2.6	Spacing of Interference Fringes	54
5.5	Simulation of Interference Fringes	55
	References	56
<b>6</b>	<b>Related Techniques and Specialized Instrumentation</b>	<b>59</b>
6.1	Split-Illumination Electron Holography	59
6.2	Dark-Field Electron Holographic Interferometry	62
6.3	Lorentz Microscopy	64
6.3.1	Fresnel Mode (Defocusing Mode)	65
6.3.2	Foucault Mode (In-Focus Mode)	69
6.3.3	Lorentz Microscopy Using Scanning Transmission Electron Microscope	72
6.3.4	Phase Reconstruction Using Transport-of-Intensity Equation	73
6.4	Magnetically Shielded Lens and High-Voltage Electron Microscope	74
6.5	Aberration-Corrected Lens System	77

- 6.6 Multifunctional Specimen Holders with Piezodriving Probes 81
- 6.7 Specimen Preparation Techniques 85
- 6.8 High-Resolution and Analytical Electron Microscopy 88
- 6.8.1 Conventional Microscopy and High-Resolution Electron Microscopy 89
- 6.8.2 High-Angle Annular Dark-Field Method 90
- 6.8.3 Analytical Electron Microscopy 91
- References 96

### **Part III Application 99**

- 7 Electric Field Analysis 101**
  - 7.1 Measurement of Inner Potential 101
  - 7.1.1 Diamond-Like Carbon 101
  - 7.1.2 SiO<sub>2</sub> Particles 101
  - 7.1.3 p–n Junctions and Low-Dimensional Materials 104
  - 7.2 Electric Field Analysis of Precipitates in Multilayer Ceramic Capacitor 105
  - 7.3 Analysis of Spontaneous Polarization in Oxide Heterojunctions 107
  - 7.4 Evaluation of Electric Charge with Laser Irradiation 108
  - 7.5 Analysis of Conductivity with Microstructure Changes 110
  - 7.6 Detection of Electric Field Variation Around Field Emitter 116
  - References 119
- 8 Magnetic Field Analysis 123**
  - 8.1 Quantitative Analysis of Magnetic Flux Distribution of Nanoparticles 123
  - 8.2 Observation of Magnetization Processes 126
  - 8.2.1 Soft Magnetic Materials 126
  - 8.2.2 Hard Magnetic Materials 131
  - 8.2.3 Magnetic Recording Materials 140
  - 8.2.4 Ferromagnetic Shape-Memory Materials 146
  - 8.3 Observation of Magnetic Structure Change with Temperature 147
  - 8.4 Analysis of Three-Dimensional Magnetic Structures 157
  - References 161

### **Part IV Visualization of Collective Motions of Electrons and Their Interpretation 167**

- 9 Charging Effects and Secondary Electron Distribution of Biological Specimens 169**
  - 9.1 Visualization of Stationary Electron Orbits 169
  - 9.1.1 Stationary Electron Orbits Observed Around Microfibrils 169
  - 9.1.2 Simulation of Electron Orbits Around Microfibril 173

9.1.3	Interpretation of Reconstructed Amplitude Image	177
9.1.4	Simulation of Visibility of Interference Fringes for Electron Motion	179
9.1.5	Change in Electron Orbits Due to Insertion of Electrode	181
9.2	Visualization of Accumulative and Collective Motions of Electrons	182
	References	184
<b>10</b>	<b>Collective Motions of Electrons Around Various Charged Insulators</b>	<b>185</b>
10.1	Accumulation of Electrons on Cleaved Surfaces of BaTiO <sub>3</sub>	185
10.2	Dependency of Electron Distribution on Surface Condition of Epoxy Resin and Kidney	188
10.3	Electron Distribution Between Epoxy Resin and Kidney	191
10.4	Control of Electron Distribution Around Cellulose Nanofibers by Applying External Electric Field	191
	References	194
<b>11</b>	<b>Extension of Analysis of Collective Motions of Electrons</b>	<b>195</b>
11.1	Electron Spin Polarization	195
11.2	Accumulation of Electrons on Bulk Insulator Surface	196
	References	198
<b>12</b>	<b>Theoretical Consideration on Visualizing Collective Motions of Electrons</b>	<b>199</b>
12.1	De Broglie's Matter Wave and Wave Function	199
12.2	Disturbance-Free Observation	200
12.3	Electron Interference and General Relativity	203
12.3.1	Einstein's Field Equations Based on General Relativity	204
12.3.2	Infeld and Schild's Approximate Solution to Einstein's Field Equations	205
12.4	Spinning Linear Wave Model	207
12.5	Electron Interference Formulated with Spinning Linear Wave	209
12.5.1	Interpretation of Diffraction Intensity	209
12.5.2	Interpretation of Interference Fringes	212
12.5.3	Simulation of Interference Fringes	215
12.6	Interpretation of Wave-Particle Dualism	215
	References	217
<b>A</b>	<b>Physical Constants, Conversion Factors, and Electron Wavelength</b>	<b>219</b>
	Physical Constants	219
	Conversion Factors	219
	Electron Wavelength and Interaction Constant	220
	<b>Index</b>	<b>221</b>