

# Contents

<i>Preface</i>	<i>page xi</i>
<i>Introduction</i>	1
1 Principles of image formation by a lens	7
1.1 Introduction	7
1.2 Elementary concepts of image formation by a thin lens	7
1.3 Image formation by a thin lens in terms of Fourier optics	13
1.4 The Porter experiments	22
1.5 Imaging a defect in a periodic structure	31
1.6 Coherence	33
2 The transmission electron microscope	37
2.1 Introduction	37
2.2 The optical microscope	37
2.3 General description of the transmission electron microscope	39
2.4 The electron wavelength	41
2.5 Lens aberrations and the practical limit of resolution	42
2.6 Defect of focus	44
2.7 Specimens and specimen preparation	49
2.8 Modes of operation	50
3 Kinematical theory of electron diffraction	52
3.1 Introduction	52
3.2 Derivation of the Laue equations	52
3.3 Reciprocal lattice	57
3.4 Ewald sphere construction in reciprocal space	58
3.5 The relative intensities of the waves diffracted by a unit cell: the structure factor $F(hkl)$	60

3.6	The atomic scattering factor	63
3.7	Intensity of the wave diffracted from a perfect crystal	69
3.8	The electron diffraction camera	74
3.9	Kikuchi lines and bands	75
3.10	Convergent beam electron diffraction (CBED)	82
3.11	Image contrast in terms of the kinematical theory of diffraction	84
3.12	Reexamination of the foundations of the kinematical theory	87
4	Dynamical theory of electron diffraction	90
4.1	Introduction	90
4.2	Solution of the Schrödinger equation	92
4.3	The dispersion surface	95
4.4	Selection of active tie points: boundary conditions at entrance face of the crystal	99
4.5	The exit waves	101
4.6	Calculation of the intensities of the transmitted and diffracted waves without absorption	102
4.7	Discussion of $I_0$ and $I_g$ for no absorption	108
4.8	Absorption	112
4.9	Discussion of $I_0(a)$ and $I_g(a)$	119
4.10	The Darwin-Howie-Whelan equations	122
5	The observation of crystal defects	127
5.1	General ideas	127
5.2	Mathematical formulation of the contrast from a crystal defect	134
5.3	Planar defects	136
5.4	Dislocations	147
5.5	Kinematical and weak beam dark field (WBDF) images of dislocations	154
5.6	Determination of Burgers vectors	161
5.7	Small inclusions and precipitates	163
5.8	Density of dislocations and other defects	170
6	High-resolution transmission electron microscopy	172
6.1	Introduction	172
6.2	Experimental variables	172
6.3	Experimental techniques	177
6.4	Interpretation of HRTEM images	179

	6.5 Discussion of HRTEM images	180
	6.6 Moiré patterns	181
7	Chemical analysis in the transmission electron microscope	185
	7.1 Introduction	185
	7.2 Inelastically scattered electrons: mechanisms of energy loss	188
	7.3 X-ray microanalysis with EDX spectrometers	189
	7.4 ALCHEMI	193
8	Mineralogical applications of TEM – I. Defects and microstructures in undeformed specimens	197
	8.1 Introduction	197
	8.2 Brazil twin boundaries in quartz	197
	8.3 Stacking faults, twinning, and polytypism in wollastonite	204
	8.4 Albite-law microtwins in plagioclase feldspars	212
	8.5 Twins and twin boundaries	219
	8.6 Dauphiné twin boundaries in quartz	221
	8.7 Transformation-induced twinning and modulated structures	226
	8.8 Antiphase domain boundaries	234
	8.9 Grain boundaries in mineral systems	238
	8.10 Exsolution microstructures	248
	8.11 Chemically distinct intergrowths observed by HRTEM	262
	8.12 Determination of site-occupancies in silicates using ALCHEMI	267
	8.13 Radiation-induced defects	268
9	Mineralogical applications of TEM – II. Dislocations and microstructures associated with deformation	284
	9.1 Slip and the need for dislocations	285
	9.2 Experimental deformation techniques	288
	9.3 Dislocation processes involved in deformation	291
	9.4 Deformation of “wet” synthetic quartz	296
	9.5 Experimental deformation of single crystals of natural quartz	312
	9.6 Deformation of feldspars	324
	9.7 Deformation of carbonates	328
	9.8 Deformation of olivine	334

9.9	Deformation of pyroxenes	341
9.10	Dislocations in experimentally deformed perovskites	349
9.11	Deformation microstructures in naturally deformed rocks and their use in estimating the mechanisms, history, and conditions of deformation	352
	<i>References</i>	365
	<i>Index</i>	383