

CONTENTS

Preface to the series	vii
Preface	ix
Contents	xiii

<i>Chapter 1. Interactions of atomic particles with solids</i>	1
1. Introduction	1
2. The validity of classical treatment	1
3. Interatomic potentials and classification of atomic collisions	4
3.1. The Bohr potential	4
3.2. Potentials based on the Thomas–Fermi model and their approximations	6
3.3. The potential based on the Thomas–Fermi–Dirac statistical atomic model	9
3.4. The Born–Mayer potential	9
3.5. Composite potentials	11
3.6. Classification of collisions	12
4. Kinematics and dynamics of the elementary collision event	14
4.1. Kinematics of the elementary collision event	15
4.2. Dynamics of the elementary collision event	20
4.3. Spatial and energy redistributions of a particle flux due to its interaction with a scattering centre	29
4.3.1. Finite distances. The parallel beam	30
4.3.2. Finite distances. The divergent beam	39
4.3.3. Infinite distances. The parallel beam. Scattering cross sections	45
4.3.4. Infinite distances. The divergent beam	49
4.3.5. The inverse problem	54
4.3.6. Inelastic energy loss in an elementary collision event	60
5. Specific energy loss	61
6. Interaction of atomic particles with crystals	65
7. Charge exchange in ion–surface collisions	72

<i>Chapter 2. Theoretical treatment of particle reflection. Random solids</i>	75
1. Introduction and basic definitions	75
2. The one-deflection model	77
3. Theories of multiple reflection based on a kinetic equation	81
3.1. Theory of small-angle reflection	82
3.1.1. The diffusion approximation	83
(a) Treatment with stopping neglected	84
(b) Treatment with stopping taken into account	86
3.1.2. An approximation based on the inverse-square potential	92
3.2. Reflection theory based on the transport approximation	94
3.3. Treatment based on the transport theory of ranges and deposited energy	101
4. Computer simulations	105
4.1. Models	105
4.2. Total reflection coefficients	111
4.2.1. Dependence on the reduced energy	111
4.2.2. Dependence on the species of incident ions	113
4.2.3. Angular dependences	114
4.2.4. Dependence on inelastic energy loss	117
4.2.5. Dependence on surface conditions and dose of implanted particles	118
4.3. Energy and angular distributions of reflected particles	119
4.3.1. Energy distributions	119
4.3.2. Angular distributions	124
<i>Chapter 3. Theoretical treatment of particle reflection. Ordered solids</i>	125
1. The two-collision model	125
1.1. The three-dimensional model	125
1.2. The two-atom model (the dumbbell model)	126
1.2.1. The approximation of uncorrelated scattering by an atomic pair	126
1.2.2. The approximation of correlated scattering by an atomic pair	128
1.2.3. Fast recoils	132
2. The model of scattering by an isolated atomic row	133
2.1. The discrete atomic row	133
2.1.1. Projectiles	133
2.1.2. Fast recoils	139
2.2. The continuous atomic row (string)	139
3. The model of reflection from a continuous atomic plane	140
4. The surface semichannel model	140
4.1. Computer simulation	141
4.2. The continuum approximation. The transverse plane	147
5. The crystallite model	151

<i>Chapter 4. Experimental techniques and data processing</i>	153
1. Instrument requirements. The Günterschulze-Moore conditions	153
2. Ion accelerators	155
2.1. The 'Boris Kidrič' Institute mass monochromators (Belgrade)	155
2.2. Accelerators of the FOM Institute (The Netherlands)	156
2.3. Mass monochromator of the Institute of Nuclear Physics (Moscow State University)	158
2.4. Mass monochromators of the Moscow Physical Engineering Institute	159
2.5. Ion accelerator of the Bell Laboratories (New Jersey, USA)	159
2.6. The accelerators of the Max-Planck Institut für Plasmaphysik (Garching bei München, FRG)	160
2.7. The University of Groningen accelerator (The Netherlands)	160
2.8. The University of Salford ion accelerator (England)	162
3. Collision chambers. Cleaning of targets. Surface analysis	164
3.1. Vacuum conditions and cleaning of targets	164
3.2. Target holders and collision chambers	169
3.3. Surface control during experiments	171
4. Experimental setups for analysis and detection of the reflected-particle flux	175
4.1. Magnetic analyzers	176
4.2. Electrostatic analyzers	178
4.3. Neutral-particle analyzers	182
4.3.1. The stripping cell method	182
4.3.2. The time-of-flight technique	183
4.3.3. Analysis of the photon emission of excited atoms	185
4.3.4. Surface-barrier detectors	186
4.4. Recording devices	188
4.5. Measuring techniques and data processing	191
4.6. Methods for the determination of the integral characteristics	197
4.6.1. Methods based on analysis of the differential reflection characteristics . .	198
4.6.2. Calorimetric methods	198
4.6.3. The proportional-counter method	201
4.6.4. Methods based on determination of the trapping coefficient	202
4.6.5. The radiotracer technique	202
<i>Chapter 5. General characteristics of the energy and angular distributions of the reflected particles and recoil atoms. Total reflection coefficients</i>	203
1. Principal types of the energy distributions of reflected particles and recoil atoms . .	203
2. Angular distributions	207
3. Total reflection coefficients	209

<i>Chapter 6. Reflection of particles from random solids</i>	210
1. Peak-shaped energy distributions. Dependence of the position and shape of the peak on various parameters	210
2. Precision determination of the peak position. Inelastic energy losses. Comparison with experiments in gases	223
3. Cupola-shaped energy distributions of the reflected particles. Transition from cupola-shaped to peaked energy distributions	226
4. Angular distributions of reflected particles	237
5. Charge exchange during reflection of ions from solid surfaces	241
6. Total reflection coefficients as functions of various parameters	251
6.1. Particle reflection coefficients	251
6.1.1. Dependence on the reduced energy	251
6.1.2. Dependence on the species and type of bombarding particles	254
6.1.3. Dependence on the angle of incidence	255
6.1.4. Effects of bombarding particle implantation and target conditions	256
6.2. Energy reflection coefficients	257
6.2.1. Dependence on the reduced energy	257
6.2.2. Dependence on the species and type of bombarding particles	258
6.2.3. Dependence on the angle of incidence	259
6.2.4. Dependence on the atomic number of the target material	260
<i>Chapter 7. Reflection of particles from ordered solids. Planar scattering. The double-scattering effect</i>	261
1. Introductory remarks	261
2. Early work devoted to the study of ion scattering by crystals. The double-scattering effect	263
3. Dependence on the incident particle energy	268
4. Angular dependence	273
4.1. Dependence on the scattering angle	274
4.2. Dependence on the glancing angle	282
4.3. Dependence on the azimuthal angle of target rotation	284
5. Dependence on the target temperature	295
5.1. Experiments of the first group	295
5.2. Experiments of the second group	298
6. Dependence on the species and type of incident particles	301
7. Dependence on the charge state of incident and reflected particles	305
7.1. The charge state of the primaries	305
7.2. The charge state of the reflected particles	306
8. The double-scattering effect for polycrystals	308

<i>Chapter 8. Reflection of particles from ordered solids. Spatial regularities. The focussing effect</i>	312
1. Early investigations	312
2. The symmetry of the energy and spatial distributions of the reflected particles	315
3. Focussing of particles reflected in surface semichannels (surface semichannelling)	320
4. Spatial distributions of reflected particles under blocking conditions	327
5. Experiments with crystals amorphized under ion bombardment	330
<i>Chapter 9. Emission of fast recoils under ion bombardment</i>	333
1. Introduction	333
2. Energy and angular distributions of fast recoils. Random solids	334
3. Energy and angular distributions of fast recoils. Ordered solids	340
3.1. Energy and angular distributions of the total flux of recoil atoms	340
3.2. Energy and angular distributions of ionized recoils	341
3.2.1. Introductory remarks	341
3.2.2. The geometry of the experiment	345
3.2.3. Dependence on the primary particle energy	352
3.2.4. Dependence on target temperature	353
<i>Chapter 10. Interpretation of experimental data</i>	357
1. Introductory remarks	357
2. The main features of the energy and angular distributions of secondary particles	358
2.1. Peaked energy distributions	358
2.2. Edge-shaped and cupola-shaped energy distributions	361
2.3. Angular distributions	361
2.4. Ion focussing effect	362
3. Special experiments for testing simple models	364
3.1. The binarity of collisions	364
3.2. Investigations devoted to testing the two-atom model	367
3.2.1. Projectiles	367
3.2.2. Fast recoils	370
3.3. Experimental testing of the isolated atomic row model	371
3.3.1. Experimental determination of the row breakthrough angle	371
3.3.2. Projectiles	372
3.3.3. Fast recoils	376
3.4. Determination of the surface semichannelling parameters	378
3.5. Testing of multiple scattering theories	382

<i>Chapter 11. Applications</i>	387
1. Ion-scattering spectroscopy	387
1.1. Compositional analysis of solid surfaces and films	387
1.2. Structural analysis of solid surfaces and films	391
2. Recoil spectroscopy	396
Conclusion	398
Appendix A	400
Appendix B. List of symbols	403
References	406
Author Index	425
Subject Index	436
Cumulative Index	439