Contents

Preface to first edition *page* xiii
Preface to second edition xv
Abbreviations xvii

1 Introduction 1
1.1 Why surfaces? 1
1.2 Ultra-High-Vacuum (UHV), contamination and cleaning 4
1.3 Adsorption at surfaces 8
1.4 Surface analytical techniques 11

2 Surface crystallography and diffraction 15
2.1 Surface symmetry 15
2.2 Description of overlayer structures 21
2.3 Reciprocal net and electron diffraction 23
2.4 Electron diffraction – qualitative consideration 28
2.5 Domains, steps and defects 31
2.6 Surface structure determination using LEED 48
2.6.1 General considerations and the failure of single scattering and Fourier transform methods 48
2.6.2 Basic elements of multiple scattering theories 58
2.6.3 Application of multiple scattering calculations 65
2.7 Thermal effects 72
2.8 Reflection High Energy Electron Diffraction (RHEED) 74
2.9 X-ray methods of surface structure determination 80
2.9.1 Introduction 80
2.9.2 Grazing incidence refraction of X-rays at surfaces 81
2.9.3 Measuring the diffraction pattern 83
2.9.4 Crystal truncation rods 85

2.9.5 Applications of surface X-ray diffraction 90
2.9.6 X-ray standing waves 97
Further reading 104

3 Electron spectroscopies 105
3.1 General considerations 105
3.1.1 Introduction 105
3.1.2 Electron attenuation lengths and surface specificity 105
3.1.3 Electron energy spectrometers 112
3.1.4 Electron energy distributions in electron spectroscopies 124
3.1.5 Electron spectroscopies: core level spectroscopies 126
3.2 X-ray Photoelectron Spectroscopy (XPS) 127
3.2.1 Introduction 127
3.2.2 Photon sources 128
3.2.3 Shapes and shifts 131
3.2.4 XPS as a core level spectroscopy 139
3.2.5 Synchrotron radiation studies 145
3.2.6 Structural effects in XPS 152
3.3 Auger electron spectroscopy (AES) 171
3.3.1 Introduction – basic processes 171
3.3.2 Energy levels, shifts and shapes 173
3.3.3 AES for surface composition analysis 184
3.3.4 Structural effects in AES 195
3.3.5 AES versus XPS – some comparisons 196
3.4 Threshold techniques 198
3.4.1 Appearance Potential Spectroscopy (APS) 198
3.4.2 Ionisation Loss Spectroscopy (ILS) 205
3.4.3 Structural effects in threshold spectroscopies 207
3.5 Ultraviolet Photoelectron Spectroscopy (UPS) 212
3.5.1 Introduction 212
3.5.2 UPS in the elucidation of band structure 213
3.5.3 UPS in the study of adsorbed molecules 228
3.6 Inverse photoemission 243
3.6.1 Introduction 243
3.6.2 Photoemission and inverse photoemission – basic theory 247
3.6.3 Experimental methods in inverse photoemission 249
3.6.4 Applications of IPES and KRIPES 256
Further reading 264

4 Incident ion techniques 266
4.1 Introduction 266
4.2 Charge exchange between ions and surfaces 268
4.2.1 Ion Neutralisation Spectroscopy (INS) 271
4.2.2 INS with metastable intermediates 278
4.2.3 Experimental arrangements for INS 280
4.2.4 Experimental results from neutralisation at metal surfaces 283
4.2.5 Information from INS of metals 289
4.3 Ion scattering techniques 292
4.3.1 LEIS: basic principles 292
4.3.2 Structural effects in LEIS 305
4.3.3 Instrumentation, problems and prospects: LEIS 311
4.3.4 Medium and High Energy Ion Scattering (MEIS and HEIS) 313
4.4 Sputtering and depth profiling 321
4.5 Secondary Ion Mass Spectrometry (SIMS) 338
Further reading 354

5 Desorption spectroscopies 356
5.1 Introduction 356
5.2 Thermal desorption techniques 358
5.2.1 Introduction 358
5.2.2 Qualitative analysis of pressure–time curves 359
5.2.3 Experimental arrangements for flash desorption and TPD 369
5.2.4 Flash desorption and TPD spectra 372
5.3 Electronically stimulated desorption 377
5.3.1 Basic mechanisms 377
5.3.2 Mechanisms for physisorbed layers 388
5.3.3 ESDIAD (ESD Ion Angular Distributions) 390
5.3.4 Instrumentation and measurements 393
5.3.5 Some applications and results 404
Further reading 409

6 Tunnelling microscopy 410
6.1 Field emission 410
6.2 The field emission microscope 414
6.2.1 Factors governing operation 417
6.2.2 Practical microscope configurations 418

6.2.3 Experimental results from Field Emission Microscopy (FEM) 420
6.3 Field ionisation 422
6.4 Field adsorption and field-induced chemisorption 432
6.5 Field evaporation and desorption 435
6.6 The field ion microscope 439
6.7 The atom probe field ion microscope 444
6.8 Electron Stimulated Field Desorption (ESFD) 447
6.9 Scanning tunnelling microscopy 449
6.9.1 Scanning Tunnelling Spectroscopy (STS) 454
6.10 The Scanning Tunnelling Microscope (STM) 457
6.10.1 Other applications of the STM 458
6.11 The Atomic Force Microscope (AFM) 459
Further reading 460

7 Work function techniques 461
7.1 Introduction 461
7.2 Single crystal surfaces 462
7.3 Polycrystalline surfaces 463
7.4 Work function measurements based upon the diode method 466
7.5 Work function measurements based on CPD 473
7.6 Field emission measurements 477
7.7 Photoelectric measurements 480
7.8 Experimental results 481
Further reading 484

8 Atomic and molecular beam scattering 485
8.1 Introduction 485
8.2 The beam–surface interaction 488
8.3 Inelastic scattering, the classical view 491
8.3.1 Inelastic scattering, the quantum mechanical view 495
8.4 Elastic scattering 497
8.4.1 Quantum versus classical formulation 500
8.4.2 Scattering cross-section for diffuse scattering 501
8.5 The production and use of molecular beams 502
8.6 Detectors 508
8.7 Experimental arrangements 508
8.8 Scattering studies 513
Further reading 531

9 Vibrational spectroscopies 532
9.1 Introduction 532
9.2 IRAS 539
9.2.1 Vibrational linewidths 542
9.3 Electron Energy Loss Spectroscopy (EELS) 544
9.4 Experimental methods in IRAS 545
9.4.1 Applications of IRAS 548
9.4.2 Breakdown of the relationship between adsorbate site and vibrational frequency 552
9.5 Experimental methods in HREELS 556
9.5.1 Experimental results from HREELS 557
Further reading 562

References 563
Index 576