
Contents

Preamble	ix
Introduction	xi
Chapter 1. Fundamentals of Ion-solid Interactions with a Focus on the Nanoscale	1
1.1. General considerations	1
1.1.1. Wavelengths of ions, electrons and X-rays	1
1.1.2. Penetration depths of ions, electrons and X-rays	7
1.2. Basic physical concepts	8
1.2.1. Energy loss and range of ions in matter	8
1.2.2. Energy straggling	11
1.2.3. Elastic scattering	13
1.3. Channeling, shadowing and blocking	20
1.3.1. Channeling	20
1.3.2. Shadowing	23
1.3.3. Blocking	30
1.4. 1D layers: limits to depth resolution	34
1.5. 2D and 3D objects: aspects of lateral resolution	38
1.5.1. Beam focusing	38
1.5.2. Simulation of nanostructures	43
Chapter 2. Instruments and Methods	45
2.1. Instruments	45
2.1.1. Accelerators	45
2.1.2. Detectors and data acquisition	48
2.1.3. Analysis chambers	54

2.2. Methods	55
2.2.1. RBS and MEIS	56
2.2.2. ERDA.	62
2.2.3. Narrow resonance profiling	64
Chapter 3. Applications	69
3.1. Example of resonances/light element profiling	69
3.1.1. Introduction	69
3.1.2. Channeling study of the SiO ₂ /Si interface	70
3.1.3. Narrow resonance profiling and stable isotopic tracing studies of the oxidation of silicon	73
3.1.4. Thermal oxidation of silicon carbide	76
3.1.5. Diffusion and reaction of CO in thermal SiO ₂ : transport, exchange and SiC nanocrystal growth	81
3.2. Quantitative analysis/heavy element profiling	86
3.2.1. RBS quantitative analysis of quantum dots and quantum wells	86
3.2.2. CMOS transistors and the race for miniaturization	114
3.3. Examples of HR-ERD analysis	131
3.3.1. Introduction	131
3.3.2. HRBS/HR-ERD comparison	132
3.3.3. HR-ERD profiles of Al ₂ O ₃ /TiO ₂ nanolaminates	133
3.4. Channeling/defect profiling	135
3.4.1. Introduction	135
3.4.2. Arsenic implant in ultra-shallow-junctions	135
3.5. Blocking/strain profiling	147
3.5.1. Introduction	147
3.5.2. GaN/AlN system	151
3.5.3. Si/Ge system.	180
3.6. 3D MEIS/real space structural analysis	195
3.6.1. Electrostatic analyzer method.	196
3.6.2. Time-of-flight method	199
Chapter 4. The Place of NanoIBA in the Characterization Forest	203
4.1. Introduction.	203
4.2. Scope of physical and chemical characterization.	203
4.2.1. Targeted information by material characterization	204
4.2.2. Basic principle and instrumentation of material characterization	205

4.3. Ion-based characterization techniques overview	209
4.4. Ion-mass-spectroscopy-based characterization techniques versus IBA	211
4.4.1. Secondary ion mass spectrometry	211
4.4.2. Atom probe tomography	217
4.5. Other characterization techniques versus IBA	219
4.5.1. X-ray photoelectron spectroscopy	220
4.5.2. X-ray diffraction	222
4.5.3. X-ray absorption fine structure	223
4.5.4. Analytical electron microscopy	223
4.6. Emerging ion-beam-based techniques	225
4.6.1. Low energy ion scattering	226
4.6.2. Iono-luminescence	226
4.6.3. Scanning helium ion microscopy	226
4.6.4. Grazing incidence fast atoms diffraction	228
List of Acronyms	231
Bibliography	237
Index	257