

# Contents

## Part I Basics of Synchrotron Radiation

<b>1</b>	<b>Introduction to Synchrotron Radiation</b> . . . . .	3
	Antonella Balerna and Settimio Mobilio	
1.1	Introduction . . . . .	3
1.2	Storage Rings and Synchrotron Radiation Sources . . . . .	4
1.3	Synchrotron Radiation Properties . . . . .	8
1.4	Radiated Power and Time Structure . . . . .	9
1.5	Angular, Spectral and Intensity Distribution. . . . .	12
1.6	Polarization . . . . .	17
1.7	Spectral Brightness and Emittance . . . . .	19
1.8	Insertion Devices . . . . .	20
	References . . . . .	28
<b>2</b>	<b>Characteristics and Properties of Synchrotron Radiation</b> . . . . .	29
	Giorgio Margaritondo	
2.1	Introduction: Broad Picture of a Synchrotron Light Source . . .	29
2.2	Relativistic Effects in a Nutshell . . . . .	31
2.3	Definition of the Main Parameters . . . . .	34
2.3.1	Spectral Distribution Features . . . . .	34
2.3.2	Total Emission. . . . .	34
2.3.3	Brightness . . . . .	35
2.3.4	Polarization . . . . .	37
2.3.5	Time Features . . . . .	38
2.3.6	Coherence Parameters. . . . .	38
2.4	Bending Magnets . . . . .	42
2.5	Wigglers . . . . .	44
2.6	Undulators . . . . .	44
2.7	Free Electron Lasers . . . . .	50
2.7.1	The Gain Length . . . . .	52
2.7.2	Infrared FELs Versus X-FELs . . . . .	53
2.7.3	The Subtle Effects of Relativity . . . . .	54
2.7.4	Saturation . . . . .	55
2.7.5	Seeding . . . . .	57

2.8	Why Are Synchrotron and X-FELs Sources Important? . . . . .	57
2.9	New Types of Synchrotron-Related Sources . . . . .	60
2.10	A Few Practical Equations. . . . .	61
	References . . . . .	61
<b>3</b>	<b>Instrumentation at Synchrotron Radiation Beamlines . . . . .</b>	<b>65</b>
	Giuliana Aquilanti, Lisa Vaccari, Jasper Rikkert Plaisier and Andrea Goldoni	
3.1	Introduction . . . . .	65
3.2	Beamlines in the Hard X-Ray Range (2000–50000 eV). . . . .	69
3.2.1	Hard X-Ray Optics . . . . .	70
3.2.2	X-Ray Detectors. . . . .	77
3.2.3	Diffraction Beamlines: MCX at Elettra . . . . .	79
3.2.4	Absorption Beamlines: the XAFS Beamline at Elettra . . . . .	80
3.3	Soft X-Ray and Vacuum Ultraviolet Beamlines . . . . .	81
3.3.1	Soft X-Ray Energy Optics . . . . .	83
3.3.2	Layout for a Soft X-Ray Energy Beamline . . . . .	85
3.3.3	Low Energy VUV (4–40 eV) and Visible-Infrared Beamlines . . . . .	87
3.3.4	Experimental Examples to Test the Beamline Performance. . . . .	91
3.4	Cooling of Optics and Other Beamline Parts . . . . .	94
3.5	X-Ray Optics for Microscopy . . . . .	95
3.5.1	X-Ray Focusing Optics . . . . .	96
	References . . . . .	102

## Part II Fundamental Interactions

<b>4</b>	<b>Introduction to Matter Radiation Interaction . . . . .</b>	<b>107</b>
	Settimio Mobilio	
4.1	Introduction . . . . .	107
4.2	Classical Description of Electromagnetic Waves and Their Interaction with the Matter . . . . .	109
4.2.1	Electromagnetic Waves in the Vacuum . . . . .	109
4.2.2	Electromagnetic Waves in Matter. . . . .	111
4.2.3	Classical Microscopic Description of the Complex Index of Refraction. . . . .	114
4.2.4	The Scattering and its Classical Description . . . . .	118
4.2.5	Elastic Scattering at High Energy. . . . .	119
4.2.6	Anomalous Scattering . . . . .	122
4.3	Semiclassical Description of the Interaction Between Matter and Radiation . . . . .	124

4.3.1	Quantum Description of the Matter. . . . .	124
4.3.2	Semiclassical Description of the Interaction. . . . .	125
4.3.3	Absorption Coefficient in the Semiclassical Approach. . . . .	125
4.3.4	The Scattering in the Semi-classical Approach. . . . .	127
4.4	Quantum Description of the Absorption and Scattering. . . . .	130
4.4.1	Quantum Description of the Electromagnetic Field. . . . .	130
4.4.2	Quantum Description of the Interaction of Electromagnetic Fields and Matter . . . . .	131
4.4.3	Absorption Cross Section . . . . .	132
4.4.4	First Order Scattering . . . . .	132
4.4.5	Second Order Scattering: Anomalous and Resonant Scattering . . . . .	135
4.4.6	High Energy Behaviour of the Second Order Scattering . . . . .	137
4.5	Relativistic Scattering . . . . .	137
4.5.1	First Order Relativistic Contribution to the Scattering . . . . .	138
4.5.2	Second Order Relativistic Scattering. . . . .	139
4.5.3	Total Scattering Cross Section at High Energy. . . . .	140
	References . . . . .	143
<b>5</b>	<b>Quantum Description of the Matter-Radiation Interaction. . . . .</b>	<b>145</b>
	Carlo Maria Bertoni	
5.1	The Classical Description of the Free Electromagnetic Field . . . . .	145
5.2	The Quantized Free Electromagnetic Field . . . . .	148
5.3	Moving Charges in Interaction with the Electromagnetic Field . . . . .	153
5.4	The Expansion of the Amplitude of Transition. . . . .	155
5.5	Elementary Processes . . . . .	157
5.6	The Matrix Element . . . . .	158
5.7	Beyond the Dipole Approximation . . . . .	160
5.8	Absorption. . . . .	161
5.9	Photoemission . . . . .	163
5.10	Thomson Scattering . . . . .	170
5.11	Second Order Processes. . . . .	171
5.12	Resonant Raman Scattering . . . . .	172
5.13	Conclusions . . . . .	174
5.14	Appendix. . . . .	174
	References . . . . .	177

### Part III Experimental Methods

<b>6</b>	<b>Introduction to X-Ray Absorption Spectroscopy</b> . . . . .	181
	Paolo Fornasini	
6.1	A Phenomenological Introduction to XAFS . . . . .	181
6.2	Photoelectric Absorption of X-Rays . . . . .	184
	6.2.1 Golden Rule and Further Approximations . . . . .	185
	6.2.2 De-excitation Mechanisms . . . . .	187
6.3	Basic EXAFS Theory . . . . .	188
	6.3.1 The EXAFS Function . . . . .	188
	6.3.2 Approximate Derivation of EXAFS . . . . .	190
	6.3.3 Disorder Effects on EXAFS . . . . .	194
	6.3.4 Summary . . . . .	197
6.4	Interpretation of EXAFS Parameters . . . . .	197
	6.4.1 EXAFS Distance and Crystallographic Distance . . . . .	198
	6.4.2 Parallel and Perpendicular MSRDS . . . . .	199
	6.4.3 Structural Disorder . . . . .	201
6.5	Experimental Techniques . . . . .	201
	6.5.1 Optical Apparatus . . . . .	202
	6.5.2 Measurement Apparatus . . . . .	203
6.6	EXAFS Analysis . . . . .	205
	6.6.1 Extraction of the EXAFS signal . . . . .	205
	6.6.2 Fourier Transform and Back-Transform . . . . .	207
	6.6.3 Quantitative Determination of Structural Parameters . . . . .	209
	References . . . . .	210
<b>7</b>	<b>A Close Look into the Low Energy Region of the XAS Spectra: The XANES Region</b> . . . . .	213
	Maurizio Benfatto and Carlo Meneghini	
7.1	Introduction . . . . .	213
7.2	The Origin of Near Edge Features . . . . .	215
7.3	Semi-quantitative Understanding of XANES Features . . . . .	218
7.4	Theoretical Background and the Fit of the XANES Energy Region . . . . .	220
7.5	Conclusions . . . . .	237
	References . . . . .	238
<b>8</b>	<b>X-Ray Diffraction by Crystalline Materials</b> . . . . .	241
	Davide Viterbo and Giuseppe Zanotti	
8.1	Introduction . . . . .	241
	8.1.1 The Crystal . . . . .	242
	8.1.2 Crystal Symmetries . . . . .	243

8.1.3	The X-Rays . . . . .	245
8.1.4	Some Useful Mathematical Concepts . . . . .	245
8.2	X-Ray Diffraction. . . . .	252
8.2.1	X-Ray Scattering . . . . .	253
8.2.2	Interference of Scattered Waves . . . . .	255
8.2.3	Scattering by Matter . . . . .	256
8.2.4	Diffraction by a Crystal. . . . .	257
8.2.5	Other Useful Relations and Concepts . . . . .	261
8.3	The Phase Problem . . . . .	263
8.3.1	Patterson Methods . . . . .	264
8.3.2	Direct Methods . . . . .	265
8.3.3	Other Methods Used to Solve the Phase Problem. . . . .	265
8.4	Refinement of the Crystal Structure . . . . .	266
8.5	Diffraction by Polycrystalline Samples . . . . .	267
8.5.1	Experimental Techniques for Obtaining Powder Diffraction Patterns . . . . .	268
8.5.2	Analysis of Powder Diffraction Patterns . . . . .	271
	References . . . . .	272
<b>9</b>	<b>Photoemission Spectroscopy: Fundamental Aspects . . . . .</b>	<b>275</b>
	Carlo Mariani and Giovanni Stefani	
9.1	Introduction . . . . .	275
9.2	Basic Concepts. . . . .	276
9.3	Energy Conservation, Binding Energy and Photoelectron Energy . . . . .	278
9.4	Satellite Structures . . . . .	281
9.4.1	Spin-Orbit Splitting. . . . .	284
9.4.2	Multiplet Splitting . . . . .	284
9.4.3	Chemical Shift . . . . .	286
9.5	Molecular Photoelectron Spectroscopy . . . . .	287
9.5.1	Vibrational Overtones . . . . .	287
9.6	Photoelectron Angular Distributions . . . . .	291
9.7	Core Hole State Relaxation . . . . .	294
9.7.1	The Auger Decay . . . . .	295
9.7.2	Resonant Auger and Photoemission . . . . .	298
9.8	Photoemission from Solids: The Three-Step Model . . . . .	300
9.9	Spectral Function of Interacting Electrons in a Solid . . . . .	303
9.10	Energy Distribution Curves . . . . .	305
9.10.1	Valence Band Examples (Cross-Section Exploitation and Cooper Minima). . . . .	305
9.10.2	Core Level Examples . . . . .	307
9.11	Angular Resolved PhotoElectron Spectroscopy. . . . .	309
9.11.1	Band Structures . . . . .	309
9.11.2	Adsorbates. . . . .	309

9.11.3	Graphite and Graphene as Exemplary 2D System. . . . .	311
9.12	Final Considerations and Perspectives. . . . .	314
	References . . . . .	315
<b>10</b>	<b>Powder Diffraction and Synchrotron Radiation . . . . .</b>	<b>319</b>
	Gilberto Artioli	
10.1	Powder Diffraction . . . . .	319
10.2	Flat Plate Sample (Bragg-Brentano Geometry). . . . .	322
10.3	Cylindrical Sample (Debye Geometry) . . . . .	324
10.4	The Implementation of Capillary Geometry at Synchrotron Sources, Case Examples . . . . .	325
10.5	Basics of Instrumental Strategies . . . . .	327
10.6	Time Resolved Experiments, Kinetics, Non-ambient Conditions . . . . .	328
10.7	Simultaneous and Combined Studies. . . . .	331
	References . . . . .	333
<b>11</b>	<b>Small Angle X-Ray Scattering (SAXS) with Synchrotron Radiation Sources. . . . .</b>	<b>337</b>
	Stefano Polizzi and Francesco Spinozzi	
11.1	The Physical Phenomenon . . . . .	337
11.1.1	Why Small Angles? . . . . .	338
11.1.2	How Small Is “Small”? . . . . .	338
11.1.3	What Is an “Object” for SAXS? . . . . .	339
11.2	Data Analysis. . . . .	343
11.2.1	Guinier’s Approximation . . . . .	344
11.2.2	Porod’s Law . . . . .	345
11.2.3	The Scattering Power . . . . .	346
11.2.4	Debye’s Approximation and Kratky Plot. . . . .	347
11.2.5	Distance Distribution Function. . . . .	347
11.2.6	Fractality. . . . .	348
11.3	Experimental . . . . .	349
11.4	Case Studies . . . . .	351
	References . . . . .	358
<b>12</b>	<b>Resonant and Magnetic X-Ray Diffraction. . . . .</b>	<b>361</b>
	Luigi Paolasini	
12.1	Introduction . . . . .	361
12.1.1	Theoretical Aspects of Magnetic and Resonant X-Ray Scattering . . . . .	362
12.1.2	X-Rays Scattering Amplitudes . . . . .	363
12.2	Experimental Methods. . . . .	366
12.2.1	Polarization Analysis and Azimuthal Scans . . . . .	366
12.2.2	Circular Polarisation . . . . .	367

12.3	Magnetic Diffraction . . . . .	369
12.3.1	Linear Polarisation Analysis of a Simple Antiferromagnetic Structure . . . . .	370
12.3.2	Exemple II: Circular Polarisation Analysis in Multiferroics . . . . .	372
12.4	Resonant X-Rays Scattering . . . . .	375
12.4.1	Interplay Between Magnetic and Orbital Ordering in $\text{KCuF}_3$ . . . . .	378
12.4.2	High Order Multipoles in $\text{V}_2\text{O}_3$ . . . . .	380
12.5	Conclusions . . . . .	383
	References . . . . .	384
<b>13</b>	<b>Hard X-Ray Synchrotron Imaging Techniques and Applications . . . . .</b>	<b>389</b>
	Jean-Yves Buffiere and José Baruchel	
13.1	Introduction . . . . .	389
13.2	Imaging Techniques . . . . .	391
13.2.1	Absorption Radiography . . . . .	391
13.2.2	Microtomography . . . . .	393
13.2.3	Phase Imaging . . . . .	394
13.2.4	Microbeam Based X-Ray Imaging Techniques/Nano Imaging . . . . .	398
13.2.5	X-Ray Bragg Diffraction Imaging . . . . .	400
13.3	Selected Examples of the Application of Synchrotron Radiation Imaging Techniques . . . . .	403
13.4	Conclusion . . . . .	406
	References . . . . .	407
<b>14</b>	<b>X-Ray Microscopy . . . . .</b>	<b>409</b>
	Diane Eichert	
14.1	Introduction . . . . .	409
14.2	Fundamentals of X-Ray Microscopy . . . . .	411
14.2.1	X-Ray Sources . . . . .	411
14.2.2	X-Ray Optics . . . . .	412
14.2.3	Detectors . . . . .	412
14.3	Imaging Modes . . . . .	413
14.3.1	Interactions of X-Rays with Matter . . . . .	413
14.3.2	Contrast Mechanisms . . . . .	414
14.4	Imaging Methods . . . . .	417
14.4.1	Projection Microscopy . . . . .	418
14.4.2	Transmission X-Ray Microscope . . . . .	419
14.4.3	Scanning Transmission X-Ray Microscope . . . . .	420
14.4.4	Complementary Techniques and Methodological Developments . . . . .	421

14.5	Experimental Conditions . . . . .	423
14.5.1	Experimental Conditions . . . . .	424
14.5.2	Conditions of Analysis . . . . .	424
14.6	Applications. . . . .	426
14.6.1	Materials Science . . . . .	427
14.6.2	Environmental Science . . . . .	428
14.6.3	Life Science. . . . .	429
14.7	Conclusions . . . . .	431
	References . . . . .	432
<b>15</b>	<b>Infrared Synchrotron Radiation: From the Production to the Scientific Applications . . . . .</b>	<b>437</b>
	Andrea Perucchi, Lisa Vaccari and Stefano Lupi	
15.1	Introduction . . . . .	437
15.2	IRSR Figures of Merits . . . . .	438
15.2.1	Definitions. . . . .	438
15.2.2	Emitted Power . . . . .	441
15.2.3	Brilliance. . . . .	442
15.3	Unconventional SR Sources . . . . .	444
15.3.1	Edge Radiation. . . . .	444
15.3.2	Superradiance Phenomena and Terahertz Coherent Radiation . . . . .	445
15.4	Application of IRSR . . . . .	446
15.4.1	Applications of IRSR at High Pressure . . . . .	446
15.4.2	Terahertz Spectroscopy . . . . .	449
15.4.3	Synchrotron Radiation Infrared Microspectroscopy for Biology and Medicine . . . . .	453
15.4.4	Synchrotron Radiation Infrared Microspectroscopy for Cultural Heritage. . . . .	457
	References . . . . .	458
<b>16</b>	<b>The High-Frequency Atomic Dynamics of Disordered Systems Studied by High-Resolution Inelastic X-Ray Scattering . . . . .</b>	<b>461</b>
	Giulio Monaco	
16.1	Introduction . . . . .	461
16.2	The High-Resolution Inelastic X-Ray Scattering Experiment . . . . .	464
16.3	Models to Describe the IXS Spectra . . . . .	466
16.4	Selected Results . . . . .	470
16.4.1	High-Frequency Sound Waves in Glasses . . . . .	470
16.4.2	Relaxation Processes in Liquids . . . . .	474
16.4.3	The Non-Ergodicity Factor . . . . .	477
16.5	Conclusions . . . . .	480
	References . . . . .	480



**Part IV Applications**

<b>17 Applications of XAFS to Nanostructures and Materials Science . .</b>	<b>485</b>
Federico Boscherini	
17.1 XAFS in Materials and Nanoscience . . . . .	485
17.2 Dopants . . . . .	486
17.2.1 Arsenic Dopants in Silicon Ultra-Shallow Junctions . . . . .	486
17.2.2 Solar Grade Silicon . . . . .	487
17.2.3 Silicon in Gallium Arsenide . . . . .	489
17.3 Defect Complexes . . . . .	490
17.4 Bulk and Heterostructure Semiconductor Alloys . . . . .	491
17.5 Phase Transitions . . . . .	492
17.6 Correlated Oxides . . . . .	494
17.7 Thin Films . . . . .	495
17.8 Semiconductor Dots . . . . .	496
17.9 Metallic Clusters . . . . .	497
References . . . . .	497
<b>18 Diffraction from Nanocrystalline Materials . . . . .</b>	<b>499</b>
Paolo Scardi and Luca Gelisio	
18.1 Introduction . . . . .	499
18.2 From Single Crystal to Powder Diffraction . . . . .	501
18.3 Powder Diffraction Line Profiles . . . . .	503
18.4 Atomistic Modeling of Powder Diffraction from Nanocrystals . . . . .	511
18.5 Conclusions . . . . .	516
References . . . . .	517
<b>19 High-Energy Resolution Core Level Photoelectron Spectroscopy and Diffraction: Powerful Tools to Probe Physical and Chemical Properties of Solid Surfaces . . . . .</b>	<b>519</b>
Alessandro Baraldi	
19.1 Introduction . . . . .	519
19.2 Single-Element Clean Metal Surfaces . . . . .	521
19.2.1 Surface Core Level Shifts . . . . .	521
19.2.2 Surface Reconstruction . . . . .	523
19.2.3 From Surface Structure to Chemical Identity . . . . .	525
19.3 Atoms and Molecules on Solid Surfaces . . . . .	526
19.3.1 Adsorption and Co-Adsorption: The Adsorbate Core-Levels . . . . .	526
19.3.2 Adsorption on Stepped Surfaces . . . . .	529
19.3.3 Vibrational Excitations in Chemisorbed Molecules . . . . .	530
19.3.4 Adsorbate-Induced Surface Core Level Shifts . . . . .	531

19.4	New Opportunities for Core Level Photoelectron Spectroscopy from Epitaxial Graphene . . . . .	534
	References . . . . .	537
<b>20</b>	<b>Spin Polarization of the Photoelectrons and Photon Polarization of X-Ray Absorption: Spectroscopy and Magnetometry . . . . .</b>	<b>539</b>
	Giorgio Rossi	
20.1	Introduction . . . . .	539
20.2	Definition and Measure of the Spin Polarization of the Photoelectrons . . . . .	541
	20.2.1 Detecting the Electron Spin . . . . .	542
	20.2.2 LS Mott Scattering . . . . .	543
	20.2.3 Exchange Scattering . . . . .	546
20.3	Towards the Complete Electron Spectroscopy . . . . .	547
	20.3.1 Spin Polarized ARPES . . . . .	547
	20.3.2 Spin Polarization of the Quantum Yield . . . . .	548
	20.3.3 Matrix Element Effects . . . . .	550
	20.3.4 Core Levels . . . . .	550
	20.3.5 Band States . . . . .	553
20.4	Symmetry Breaking Mechanisms . . . . .	556
20.5	Time Resolved Experiments and High Excitation Density . . . . .	559
20.6	X-Ray Absorption Dichroism . . . . .	559
	20.6.1 The XMCD as Diagnostic of Magnetization . . . . .	562
	20.6.2 The XMCD as a Magnetometer . . . . .	564
	20.6.3 The XLD . . . . .	567
	20.6.4 The X-Ray Measurement of Ferromagnetic Resonance . . . . .	568
20.7	Conclusions . . . . .	569
	References . . . . .	569
<b>21</b>	<b>Chemical and Magnetic Imaging with X-Ray Photoemission Electron Microscopy . . . . .</b>	<b>571</b>
	Andrea Locatelli and Tevfik Onur Mentes	
21.1	Introduction . . . . .	571
21.2	Photoemission Electron Microscopy . . . . .	572
	21.2.1 Instrumental Aspects . . . . .	573
	21.2.2 Combination with Low Energy Electron Microscopy . . . . .	575
	21.2.3 PEEM Methods . . . . .	576
21.3	Applications and Examples . . . . .	578
	21.3.1 Chemical Imaging of Nano-Structured Surfaces and Interfaces . . . . .	578
	21.3.2 Graphene . . . . .	580

21.3.3	Biominerals . . . . .	581
21.3.4	Magnetic Imaging. . . . .	584
21.4	Conclusions and Outlook. . . . .	587
	References . . . . .	588
<b>22</b>	<b>Medical Imaging with Synchrotron Radiation . . . . .</b>	<b>593</b>
	Giuliana Tromba	
22.1	Introduction . . . . .	593
22.2	Advantages of Synchrotron Radiation for Medical Imaging . . . . .	594
22.3	Current Research Status at SR Beamlines . . . . .	595
22.3.1	Angiography . . . . .	595
22.3.2	Microangiography. . . . .	596
22.3.3	Bronchography. . . . .	597
22.3.4	Breast Imaging. . . . .	597
22.3.5	Imaging of Cartilages . . . . .	601
22.3.6	Lungs Imaging. . . . .	603
22.3.7	Microvascularization and Imaging of Soft Tissues . . . . .	606
22.3.8	Brain Imaging . . . . .	608
22.4	Conclusions . . . . .	609
	References . . . . .	611
<b>23</b>	<b>Synchrotron Radiation and Bio-crystallography. . . . .</b>	<b>615</b>
	Marco Nardini and Martino Bolognesi	
23.1	Macromolecular Crystals . . . . .	615
23.1.1	Physical and Chemical Properties. . . . .	616
23.1.2	Crystal Growth. . . . .	616
23.1.3	Crystal Handling and Radiation Damage. . . . .	618
23.2	X-Ray Diffraction and Phasing Problem . . . . .	620
23.2.1	Fundamentals of Crystallography . . . . .	620
23.2.2	Solution of the Phase Problem . . . . .	623
23.2.3	The MIR Method . . . . .	624
23.2.4	The SIRAS Method . . . . .	626
23.2.5	The MAD Method . . . . .	628
23.2.6	The Molecular Replacement Method. . . . .	629
23.3	Density Modification . . . . .	631
23.4	Crystallographic Refinement . . . . .	632
23.4.1	Least Squares Refinement . . . . .	632
23.4.2	Maximum-Likelihood Refinement . . . . .	634
23.4.3	Quality of the Model . . . . .	636
23.5	The Protein Data Bank . . . . .	637
23.6	Structural Genomics . . . . .	638
	References . . . . .	639

<b>24</b>	<b>Synchrotron Radiation in the Earth Sciences</b> . . . . .	641
	Simona Quartieri	
24.1	Introduction . . . . .	641
24.2	X-Ray Diffraction . . . . .	644
	24.2.1 X-Ray Powder Diffraction . . . . .	644
	24.2.2 Single-Crystal X-Ray Diffraction . . . . .	644
24.3	X-Ray Absorption Spectroscopy . . . . .	646
24.4	X-Ray Fluorescence Microanalysis . . . . .	648
24.5	Materials Under Extreme Conditions . . . . .	649
	24.5.1 Single-Crystal and Powder X-Ray Diffraction . . . . .	653
	24.5.2 Single-Crystal and Powder IR Spectroscopy . . . . .	653
	24.5.3 X-Ray Absorption Spectroscopy . . . . .	654
	24.5.4 HP Synchrotron Mössbauer . . . . .	655
24.6	X-Ray Tomography and Topography . . . . .	655
24.7	Future Prospects . . . . .	656
	References . . . . .	656
<b>25</b>	<b>Synchrotron Radiation and Environmental Sciences</b> . . . . .	661
	Giovanni De Giudici, Piero Lattanzi and Daniela Medas	
25.1	Introduction: What Is Environmental Science? . . . . .	661
25.2	Overview of the Most Common Techniques . . . . .	663
	25.2.1 Synchrotron-Based X-Ray Diffraction . . . . .	664
	25.2.2 X-Ray Absorption Spectroscopy . . . . .	664
	25.2.3 Microbeam Techniques . . . . .	666
	25.2.4 Surface Techniques . . . . .	669
25.3	Case History: Zinc Biomineralization at Naracauli, Sardinia . . . . .	671
25.4	Concluding Remarks . . . . .	673
	References . . . . .	674
<b>26</b>	<b>Synchrotron Radiation in Art, Archaeology and Cultural Heritage</b> . . . . .	677
	Simona Quartieri	
26.1	Introduction . . . . .	677
26.2	Examples of SR-X-Ray Diffraction Studies of Cultural Heritage . . . . .	678
26.3	Archaeometric Applications of X-Ray Absorption Spectroscopy . . . . .	682
26.4	SR-Based FT-Infrared Micro-Spectroscopy Applied to Cultural Heritage . . . . .	688
26.5	SR-Based Techniques for Non-Destructive Sub-surface Analysis of Painted Cultural Heritage Artifacts . . . . .	688
26.6	X-Ray Computed Tomography in Cultural Heritage Studies . . . . .	689

26.7	Application of SR-Based Techniques to the Study of Paleontological Findings . . . . .	691
26.8	Recent and Future Trends . . . . .	693
	References . . . . .	693
<b>27</b>	<b>Synchrotron Radiation and Chemistry: Studies of Materials for Renewable Energy Sources . . . . .</b>	<b>697</b>
	Antonino Martorana, Francesco Giannici and Alessandro Longo	
27.1	Introduction . . . . .	697
27.2	Metal-Organic Frameworks . . . . .	699
27.3	Hydrides for Hydrogen Storage . . . . .	701
27.4	Dye-Sensitized Solar Cells. . . . .	704
27.5	Oxide-Ion and Proton Conductors. . . . .	706
27.6	Electrodes for Fuel Cells . . . . .	710
27.7	Conclusions . . . . .	713
	References . . . . .	713
<b>28</b>	<b>Catalyst Characterization by XAS and XES Spectroscopies: In Situ and Operando Experiments. . . . .</b>	<b>717</b>
	Francesca Bonino, Elena Groppo, Carmelo Prestipino, Giovanni Agostini, Andrea Piovano, Diego Gianolio, Lorenzo Mino, Erik Gallo and Carlo Lamberti	
28.1	Introduction . . . . .	718
28.2	Methods and Instrumentation . . . . .	719
28.3	Understanding the Structure of the Ti Active Site in TS-1 Catalyst: A XAS/XES Study . . . . .	721
28.4	Understanding the Chemistry of the Oxychlorination Catalysis by In Situ and Operando Experiments. . . . .	727
28.5	Conclusions and Perspectives. . . . .	731
	References . . . . .	733
<b>29</b>	<b>Studies of Matter at Extreme Conditions. . . . .</b>	<b>737</b>
	Sakura Pascarelli	
29.1	High Pressure Research. . . . .	737
29.1.1	Introduction . . . . .	738
29.1.2	Matter Under “Extreme Conditions” . . . . .	738
29.1.3	High Pressure to Study Earth’s Interior, Understand Climate Change, Explore New Sources of Energy . . . . .	739
29.1.4	Tools and Experimental Methods . . . . .	741
29.2	Physics . . . . .	744
29.2.1	Collapse of Ferromagnetism in the 3d Metals . . . . .	744
29.2.2	Examples of Recent Work on Fe, Co and Ni . . . . .	746

29.3	Earth Science . . . . .	750
29.3.1	Fe Partitioning in the Earth Mantle. . . . .	750
29.3.2	Fe Partitioning at and Beyond the Core-Mantle Boundary. . . . .	753
29.4	Energy, Environment, Climate . . . . .	755
29.4.1	The Deep Carbon Cycle . . . . .	755
29.4.2	Stability of Hydrocarbons in the Deep Earth . . . . .	756
29.4.3	Exploring the Nature of C-bearing Minerals . . . . .	757
	References . . . . .	759
<b>30</b>	<b>Science Frontiers with X-Ray Free Electron Laser Sources . . . . .</b>	<b>761</b>
	Flavio Capotondi, Martina Dell'Angela, Marco Malvestuto and Fulvio Parmigiani	
30.1	Introduction . . . . .	762
30.2	Coherent Free Electron Laser Sources. . . . .	763
30.3	Coherent Diffraction Imaging with Free Electron Lasers. . . . .	765
30.4	Spectroscopy on Solids at FELs . . . . .	768
30.4.1	Photoelectron Spectroscopy . . . . .	770
30.4.2	X-Ray Absorption Spectroscopy. . . . .	773
30.4.3	Resonant X-Ray Emission Spectroscopy . . . . .	774
30.5	Magneto-Dynamical Studies. . . . .	778
30.5.1	Ultra Fast X-Ray Experiments . . . . .	781
30.5.2	Ferromagnetism and Superconductivity: A Background Starting Point . . . . .	782
30.5.3	Physics of FM/SC Heterostructures. . . . .	783
30.5.4	New and Promising Fields of Research and Innovation . . . . .	783
	References . . . . .	784
	<b>Index . . . . .</b>	<b>787</b>



<http://www.springer.com/978-3-642-55314-1>

Synchrotron Radiation

Basics, Methods and Applications

Mobilio, S.; Boscherini, F.; Meneghini, C. (Eds.)

2015, XXIV, 799 p. 389 illus., 150 illus. in color.,

Hardcover

ISBN: 978-3-642-55314-1