
Contents

1 Introduction

<i>T. Arai</i>	1
1.1 The Discovery of X-Rays and Origin of X-Ray Fluorescence Analysis	1
1.2 Historical Progress of Laboratory X-Ray Fluorescence Spectrometers	4
1.3 Measurement of Soft and Ultrasoft X-Rays	8
1.3.1 X-Ray Tubes for Soft and Ultrasoft X-Rays	8
1.3.2 Scientific Research Work on Soft and Ultrasoft X-Rays	9
1.3.3 Synthetic Multilayer Analyzers	9
1.3.4 Total Reflection Mirrors	13
1.4 Analytical Precision and Accuracy in X-Ray Fluorescence Analysis	15
1.4.1 Correction of Matrix Element Effects	16
1.4.2 Quantitative Analysis of Heat Resistance and High Temperature Alloys	19
1.4.3 Segregation Influencing Analytical Accuracy	25
1.5 Concluding Remarks	26
References	26

2 X-Ray Sources

2.1 Introduction	
<i>N. Langhoff and A. Simionovici</i>	33
2.2 X-Ray Tubes	
<i>V. Arkadiev, W. Knüpfer and N. Langhoff</i>	36
2.2.1 Basic Physical Principles	36
2.2.2 Technology of the Components	38
2.2.3 Vacuum Envelope of X-Ray Tubes	46
2.2.4 Tube Housing Assembly	47

VIII Contents

2.2.5	Modern X-Ray Tubes	47
2.2.6	Some Applications	52
2.3	Radioisotope Sources	
<i>T. Čechák and J. Leonhardt</i>	.....	54
2.3.1	Basic Physical Principles	55
2.3.2	Radioisotope Sources	57
2.3.3	Production of Radioactive Sources	63
2.3.4	Radiation Protection Regulations	64
2.4	Synchrotron Radiation Sources	
<i>A. Simionovici and J. Chavanne</i>	.....	66
2.4.1	SR Basics	66
2.4.2	Storage Ring Description	67
2.4.3	Generation of SR	68
2.4.4	SRW Package	72
References	.....	80
3	X-Ray Optics	
3.1	Introduction	
<i>A. Erko</i>	.....	85
3.2	Mirror Optics	
<i>V. Arkadiev and A. Bjeoumikhov</i>	.....	89
2.3.1	Total External Reflection Mirrors	89
2.3.2	Capillary Optical Systems	89
3.3	Diffraction Optics – Elements of Diffraction Theory	
<i>A. Erko</i>	.....	111
3.3.1	Electromagnetic Wave Propagation	111
3.3.2	Fraunhofer Approximation	113
3.3.3	Fresnel Approximation	113
3.3.4	Bragg Diffraction	115
3.4	Optics for Monochromators	
<i>A. Antonov, V. Arkadiev, B. Beckhoff, A. Erko, I. Grigorieva,</i>		
<i>B. Kanngießer and B. Vidal</i>	.....	115
3.4.1	Diffraction Gratings	115
3.4.2	Multilayers for X-Ray Optics	129
3.4.3	HOPG-based Optics	143
3.4.4	Laterally Graded SiGe Crystals	157
3.5	Focusing Diffraction Optics	
<i>A. Erko</i>	.....	167
3.5.1	Zone Plates	167
3.5.2	Reflection Zone Plate and Bragg–Fresnel Optics	179
3.5.3	Bragg–Fresnel Holographic Optics	185
3.6	Refraction X-Ray Optics	
<i>A. Erko</i>	.....	187
3.6.1	Compound Refractive Lens	187
References	.....	190

4 X-Ray Detectors and XRF Detection Channels

4.1 Introduction
F. Scholze 199

4.2 X-Ray Detectors and Signal Processing
A. Longoni and C. Fiorini 203

 4.2.1 Introduction 203

 4.2.2 Basic Properties of X-Ray Detectors 203

 4.2.3 Classification of the Most Commonly Used X-Ray Detectors 216

 4.2.4 Semiconductor Detectors 218

 4.2.5 Silicon Drift Detectors 222

 4.2.6 Basics of Signal Electronics 235

 4.2.7 Shape Factors of some Filtering Amplifiers 249

 4.2.8 Auxiliary Functions 252

 4.2.9 Appendix 1 – The Laplace Transform 256

 4.2.10 Appendix 2 – Calculation of the ENC 257

 4.2.11 Appendix 3 – Digital Pulse Processing 259

4.3 High Resolution Imaging X-Ray CCD Spectrometers
L. Strüder, N. Meidinger and R. Hartmann 262

 4.3.1 Introduction 262

 4.3.2 Fully Depleted Backside Illuminated pn-CCDs 264

 4.3.3 Frame Store pn-CCDs for ROSITA, and XEUS 277

 4.3.4 Conclusion 284

4.4 Wavelength Dispersive XRF and a Comparison with EDS
N. Kawahara and T. Shoji 284

 4.4.1 Dispersion Materials for WDXRF 285

 4.4.2 Detectors and Electronics 288

 4.4.3 Optics Used for the WD Spectrometer and its Components 293

 4.4.4 Types of WDXRF Spectrometer 296

 4.4.5 Selected Applications Suitable for WDXRF 299

 4.4.6 Comparison of WDXRF and EDXRF 301

References 302

5 Quantitative Analysis

5.1 Overview
M. Mantler 309

5.2 Basic Fundamental Parameter Equations
M. Mantler 311

 5.2.1 Fundamental Parameter Equations for Bulk Materials 312

 5.2.2 Direct Excitation 317

 5.2.3 Indirect Excitation 322

 5.2.4 Use of Standards 325

5.3	Matrix Correction Methods and Influence Coefficients	327
5.3.1	The Nature of Influence Coefficients	
	<i>M. Mantler</i>	327
5.3.2	The Lachance–Traill Algorithm	
	<i>J.P. Willis, G.R. Lachance</i>	335
5.3.3	The Claisse–Quintin Algorithm	
	<i>J.P. Willis, G.R. Lachance</i>	340
5.3.4	The COLA Algorithm	
	<i>J.P. Willis, G.R. Lachance</i>	343
5.3.5	The de Jongh Algorithm	
	<i>B.A.R. Vrebos</i>	345
5.3.6	The Broll–Tertian Algorithm	
	<i>K.-E. Mauser</i>	347
5.3.7	The Japanese Industrial Standard Method	
	<i>N. Kawahara</i>	349
5.3.8	The Fundamental Algorithm	
	<i>R.M. Rousseau</i>	350
5.4	Compensation Methods	358
	<i>B.A.R. Vrebos</i>	358
5.4.1	Internal Standards	358
5.4.2	Standard Addition Methods	361
5.4.3	Dilution Methods	362
5.4.4	Scattered Radiation – Compton Scatter	363
5.5	Thin and Layered Samples	
	<i>P.N. Brouwer</i>	369
5.5.1	Direct Excitation by Polychromatic Sources	369
5.5.2	Indirect Excitation by Polychromatic Sources	371
5.5.3	Back-Calculation Schemes	375
5.5.4	Solvability	376
5.5.5	Applications	377
5.6	Complex Excitation Effects and Light Elements	
	<i>N. Kawahara</i>	379
5.6.1	Indirect Excitation Processes in the Low Energy Region	379
5.6.2	Secondary Excitation by Electrons	379
5.6.3	Cascade Effect	382
5.7	Standardless Methods	
	<i>K.-E. Mauser</i>	384
5.7.1	Introduction	384
5.7.2	Semiquantitative Analysis	384
5.7.3	Requirements for a Standardless Method	385
5.8	Monte Carlo Methods	
	<i>M. Mantler</i>	394
5.9	Errors and Reliability Issues	
	<i>M. Mantler</i>	395
5.9.1	Mathematical Treatment of Statistical Errors	397

5.9.2	Counting Statistics	398
5.9.3	Detection Limits	398
5.10	Standardized Methods	
	<i>K.-E. Mauser</i>	400
5.10.1	Introduction	400
5.10.2	General Features of Standardized Methods	400
5.10.3	Standardized Methods Versus Universal Calibrations and Standardless Methods	403
5.10.4	Summary	403
	Symbols and Terminology	404
	References	407
6 Specimen Preparation		
	<i>J. Injuk, R. Van Grieken, A. Blank, L. Eksperiandova and V. Buhrke</i> ..	411
6.1	Introduction	411
6.2	Liquids	412
6.2.1	Direct Analysis of Liquids and Solutions	412
6.2.2	Conversion of Liquids into Quasi-Solid Specimens	413
6.2.3	Conversion of Liquids into Organic Glassy Polymer Specimens	414
6.2.4	Conversion of Liquids into Thin Films	414
6.2.5	Analysis of Solutions after Preconcentration of Microimpurities	415
6.3	Solid Specimens	419
6.3.1	Metallic Specimens	419
6.3.2	Powder Specimens	421
6.3.3	Fused Specimens	424
6.4	Biological Samples	426
6.5	Aerosol and Dust Specimens	427
6.6	Standards	428
	References	429
7 Methodological Developments and Applications		
7.1	Micro X-Ray Fluorescence Spectroscopy	
	<i>B. Kanngießner and M. Haschke</i>	433
7.1.1	Introduction	433
7.1.2	General Description of Micro-XRF Laboratory Units	434
7.1.3	Applications of Micro X-Ray Fluorescence Analysis	442
7.1.4	3D Micro X-Ray Fluorescence Spectroscopy	462
7.2	Micro-XRF with Synchrotron Radiation	
	<i>A. Simionovici and P. Chevallier</i>	474
7.2.1	Introduction	474
7.2.2	The General Setup	475
7.2.3	Quantitative Aspect	481
7.2.4	Elemental Mapping	484
7.2.5	Examples of Application	488

7.3	Total-Reflection X-Ray Fluorescence (TXRF) Wafer Analysis	
	<i>C. Strelt, P. Wobrauschek, L. Fabry, S. Pahlke, F. Comin, R. Barrett,</i>	
	<i>P. Pianetta, K. Lüning and B. Beckhoff</i>	498
7.3.1	Introduction	498
7.3.2	Analysis of Metallic Surface Contamination by Means of TXRF	500
7.3.3	Historic Background	500
7.3.4	Instrumentation of Total Reflection X-Ray Fluorescence Analysis	502
7.3.5	Quantification of TXRF Analysis	503
7.3.6	Surface Analysis	508
7.3.7	Statistical Process Control (SPC)	516
7.3.8	Automated Vapor Phase Decomposition (VPD) Preparation	517
7.3.9	Low Z Determination – Problems – Solutions and Results	519
7.3.10	Synchrotron Radiation Induced TXRF	522
7.3.11	Conclusion and Outlook	553
7.4	Analysis of Layers	
	<i>V. Rößiger and B. Nensel</i>	554
7.4.1	Introduction to the Analysis of Layers	554
7.4.2	Theory of the Quantitative Layer Analysis: Yield Calculation	555
7.4.3	Calculation of the Unknown Measurement Quantities X_{ij} ..	563
7.4.4	The WinFTM [®] Program	567
7.4.5	Instruments	579
7.4.6	Application Examples	586
7.4.7	Summary and Outlook	600
7.5	Environmental Studies	
	<i>S. Kurunczi, J. Osán, S. Török and M. Betti</i>	601
7.5.1	Introduction	601
7.5.2	Water	604
7.5.3	Atmospheric Aerosol	620
7.5.4	Monte Carlo Based Quantitative Methods for Single Particles	627
7.5.5	Radionuclides and Radioactive Materials	635
7.6	Geology, Mining, Metallurgy	
	<i>D. Rammlmair, M. Wilke, K. Rickers, R.A. Schwarzer,</i>	
	<i>A. Möller and A. Wittenberg</i>	640
7.6.1	Introduction	640
7.6.2	Macroscale	642
7.6.3	Mesoscale	648
7.6.4	Microscale	668
7.6.5	Conclusions	685

7.7 Application in Arts and Archaeology	
<i>O. Hahn, I. Reiche and H. Stege</i>	687
7.7.1 General Remarks	687
7.7.2 Materials Groups	689
7.7.3 Conclusions and Perspectives	700
7.8 XRF-Application in Numismatics	
<i>J. Engelhardt</i>	700
7.8.1 Introduction	700
7.8.2 History of XRF Investigations of Coins	701
7.8.3 General Remarks	701
7.8.4 Preparation of Coins for Surface and Bulk Analysis	705
7.8.5 Metals and Standards	706
7.8.6 Accuracy and Precision	706
7.8.7 Some Examples of Typical Questions of the Numismatist ...	707
7.8.8 Conclusion	711
7.8.9 Recommended Reading	712
7.9 Analysis for Forensic Investigations	
<i>J. Zięba-Palus</i>	712
7.9.1 The Specificity of Forensic Research	712
7.9.2 The XRF Method in Forensic Research	714
7.9.3 Conclusions	728
7.10 X-Ray Fluorescence Analysis in the Life Sciences	
<i>G. Weseloh, S. Staub and J. Feuerborn</i>	728
7.10.1 Introduction	728
7.10.2 X-Ray Fluorescence Analysis by Means of X-Ray Tubes and Radioisotopes	729
7.10.3 Total Reflection X-Ray Fluorescence Analysis (TXRF)	736
7.10.4 Synchrotron Radiation Induced TXRF	748
7.10.5 X-Ray Fluorescence Analysis Using Synchrotron Radiation .	751
7.11 Non-Invasive Identification Of Chemical Compounds by EDXRS	
<i>P. Hoffmann</i>	769
7.11.1 Introduction	769
7.11.2 Experimental Part	770
7.11.3 Results	771
7.11.4 Discussion	780
References	783
8 Appendix	
8.1 X-Ray Safety and Protection	
<i>P. Ambrosi</i>	835
8.1.1 Introduction	835
8.1.2 Radiation Protection Quantities	836
8.1.3 Health Hazards	839

XIV Contents

8.1.4 Measuring Instruments	841
8.1.5 System of Radiation Protection	843
References	845
8.2 Useful Data Sources and Links	
<i>R. Wedell and W. Malzer</i>	845
Index	849



<http://www.springer.com/978-3-540-28603-5>

Handbook of Practical X-Ray Fluorescence Analysis
Beckhoff, B.; Kanngießler, B.; Langhoff, N.; Wedell, R.;
Wolff, H. (Eds.)
2006, XXIV, 878 p., Hardcover
ISBN: 978-3-540-28603-5