

Contents

Part I Fundamentals and Theory

1	Single Nanomagnet Behaviour: Surface and Finite-Size Effects	3
	Oscar Iglesias and Hamid Kachkachi	
1.1	Introduction	3
1.1.1	Finite-Size Versus Boundary Effects	4
1.2	Basic Theoretical Models and Computing Tools	6
1.2.1	Macrospin Approach	7
1.2.2	Many-Spin Approach	9
1.3	Results	16
1.3.1	Finite-Size Effects	16
1.3.2	Effects of Shape and Surface Anisotropy	21
1.4	Conclusion	33
	References	34
2	Interparticle Interactions: Theory and Mesoscopic Modeling	39
	Marianna Vasilakaki, George Margaris, and Kalliopi Trohidou	
2.1	Introduction	39
2.2	Case Studies	42
2.2.1	Case Study 1: Magnetic Behavior of Nanoparticle Assemblies: Interplay of Nanoparticles Morphology (Core/Surface and Core/Shell) with the Interparticle Interactions	42
2.2.2	Case Study 2: Magnetic Behavior of Nanoparticle Assemblies: Effect of Assemblies Morphology (Nanoparticles Clustering)	49
2.2.3	Case Study 3: Effect of an AFM Matrix in the Magnetic Behavior of Magnetic Nanoparticle Assemblies	56

2.3	Concluding Remarks—Prospects	60
	References	61
3	Collective Magnetic Behaviour	65
	Roland Mathieu and Per Nordblad	
3.1	Introduction	65
	3.1.1 Systems of Magnetic Nanoparticles	66
	3.1.2 Interaction Mechanisms	67
	3.1.3 Time Scales	68
	3.1.4 Model Behaviour Contra Collective Phenomena	69
3.2	Case Studies: Superspin Glasses	71
	3.2.1 Frozen Ferrofluids	71
	3.2.2 Compacts	72
3.3	Outlook	77
	3.3.1 Superspin Dimensionality	77
	3.3.2 Nanocomposites	79
	3.3.3 Superstructures	82
	References	83
 Part II Magnetic Nano Architectures Design		
4	Core/Shell Bimagnetic Nanoparticles	87
	Elin L. Winkler and Roberto D. Zysler	
4.1	Introduction	87
4.2	Synthesis and Production of Core/Shell Nanoparticles	89
4.3	Interface Coupling Phenomenology and Models	90
	4.3.1 Exchange Bias Effect	90
	4.3.2 Exchange Spring Behavior	96
4.4	Tuning the Magnetic Properties by the Interface Exchange Coupling	99
4.5	Future and Perspectives	101
	References	103
5	Magneto-Plasmonic Nanoparticles	107
	César de Julián Fernández and Francesco Pineider	
5.1	Introduction	107
5.2	Optical and Magnetic Properties of MP Nanoparticles	109
5.3	General Applications of MP Nanoparticles	117
5.4	Magneto-Optical Effects in MP Nanoparticles	121
5.5	Perspectives	125
	References	129

6	Hollow Magnetic Nanoparticles	137
	Hafsa Khurshid, Zohreh Nemati, Óscar Iglesias, Javier Alonso, Manh-Huong Phan, and Hariharan Srikanth	
6.1	Introduction	138
6.2	Synthesis of Hollow MNPS	139
6.3	Magnetic Properties of Hollow MNPs	143
6.3.1	Basic Magnetic Behavior	143
6.3.2	Surface Anisotropy and Spin Disorder	144
6.3.3	Exchange Bias Versus Minor Loops	145
6.4	Evolution from Core–Shell to Core–Void–Shell to Hollow	147
6.5	Monte Carlo Simulations	149
6.6	Applications	152
6.7	Summary and Future Outlook	155
	References	156
7	Nature Driven Magnetic Nanoarchitectures	159
	María Luisa Fdez-Gubieda, Lourdes Marcano, Alicia Muela, Ana García-Prieto, Javier Alonso, and Iñaki Orue	
7.1	An Introduction to Magnetotactic Bacteria	160
7.2	Biom mineralization Process of the Magnetosome	163
7.3	Magnetic Properties of Magnetosomes and Magnetosome Chains in <i>Magnetospirillum gryphiswaldense</i>	166
7.3.1	The Verwey Transition in the Magnetosomes	166
7.3.2	Magnetic Interactions in the Magnetosome Chain	166
7.3.3	Magnetization Process of the Chain: The Stoner-Wohlfarth Approach	169
7.4	Applications	171
7.5	Future Perspectives	175
	References	176
8	Magnetic Self-Assembling of Spherical Co Nanoparticles Used as Building Blocks: Syntheses, Properties and Theory	181
	Johannes Richardi, C. Petit, and Isabelle Liseiecki	
8.1	Introduction	182
8.2	Synthesis of Uniform Spherical Co Nanoparticles	184
8.2.1	Synthesis by Micellar Approach	184
8.3	Synthesis by Organometallic Approach	190
8.4	Assemblies of Cobalt Nanoparticles	192
8.4.1	Key Parameters Involved in the Nanoparticle Organization	192
8.5	2D Self-Organizations of Cobalt Nanoparticles Synthesized by Micellar Approach	194

8.6	2D Self-Organizations of Cobalt Nanoparticles Synthesized by Organometallic Approach	197
8.6.1	3D Self-Organizations of Cobalt Nanoparticles.	198
8.7	Theory of Self-Organization of Magnetic Nanoparticles Under Magnetic Field	207
8.8	Conclusion	211
	References	212

Part III Advanced Characterization Techniques

9	Magnetism of Individual Nanoparticles Probed by X-Ray Photoemission Electron Microscopy	219
	Armin Kleibert	
9.1	Introduction	219
9.2	X-Ray Photoemission Electron Microscopy	221
9.2.1	Instrumentation	222
9.2.2	XPEEM Fundamentals	222
9.2.3	Sample Requirements	224
9.3	XPEEM Investigations of 3 <i>d</i> Transition Metal Nanoparticles	225
9.3.1	Enhanced Magnetism and Metastable Properties in Iron Nanoparticles	227
9.3.2	In Situ Oxidation of Iron Nanoparticles—The Role of the Surface	229
9.3.3	Iron Nanoparticles Deposited on Different Substrates—The Role of the Interface	231
9.3.4	Comparison with Cobalt, Nickel and Iron–Cobalt-Alloy Nanoparticles	234
9.4	Conclusions and Perspectives	234
	References	237
10	Measuring Atomic Magnetic Moments in Magnetic Nanostructures Using X-Ray Magnetic Circular Dichroism (XMCD)	241
	Chris Binns, José Angel de Toro, and Peter Normile	
10.1	Introduction	241
10.2	Example System: Fe@Cr Core–Shell Nanoparticles	248
10.3	Future Perspectives	252
10.3.1	Spatially Resolved XMCD: Domain Imaging in Patterned Structures	252
10.3.2	Time-Resolved XMCD Measurements in Exchange-Coupled Layers	253
	References	255

11 Electron Tomography	257
P. Torruella, J. Blanco-Portals, Ll. Yedra, L. López-Conesa, J. M. Rebled, F. Peiró, and S. Estradé	
11.1 Introduction: Fundamentals of Electron Tomography and Overview of Classic Reconstruction Methods	258
11.1.1 Mathematical Principles and Reconstruction Methods	259
11.2 Analytical Tomography and the Spectrum Volume Approach	263
11.2.1 Compressed Sensing (CS)	264
11.2.2 EELS Tomography: From Spectrum Image Tilt Series to the Spectrum Volume	267
11.2.3 A Case Study: 3D Visualization of Iron Oxidation State in FeO/Fe ₃ O ₄ Core–Shell Nanocubes Through Compressed Sensing	272
11.3 Emerging Techniques and Future Perspectives for EELS-SV	275
11.3.1 Clustering Analysis: Mathematical Principles	276
11.3.2 Application of Clustering to EELS	277
11.3.3 Future Perspectives. Clustering Data in EELS-SV Tomographic Reconstructions	281
References	281
12 Magnetic Force Microscopy and Magnetic Nanoparticles: Perspectives and Challenges	285
Daniele Passeri, Livia Angeloni, and Marco Rossi	
12.1 Introduction	285
12.2 Magnetic Force Microscopy	287
12.3 Magnetic Force Microscopy and Magnetic Nanoparticles	289
12.3.1 Quantitative Nanomagnetic Characterization	289
12.3.2 Detection of Magnetic Nanoparticles in Nano-systems	293
12.3.3 Manipulation	296
12.4 Conclusions, Perspectives and Challenges	298
References	298
Part IV Advanced Magnetic Nanoparticles Systems for Applications	
13 Magnetic Nanoparticles for Life Sciences Applications	303
C. Marquina	
13.1 Introduction	303
13.2 Penetration and Transport of Magnetic Nanoparticles in Living Plants	306
13.2.1 Nanoparticle Application by Injection	308

13.2.2	Nanoparticle Application by Spray	312
13.2.3	Nanoparticle Application by the Roots	313
13.3	Interaction of Silica Coated Magnetic Nanoparticles with Pathogenic Fungi	316
13.3.1	Internalization of Fe ₃ O ₄ @SiO ₂ Nanoparticles by Fungal Cells	316
13.3.2	Fe ₃ O ₄ @SiO ₂ Nanoparticle Toxicity on <i>F. Oxysporum</i> Hyphal Cells	321
13.4	Summary and Perspectives	321
	References	323
14	Medical Applications of Magnetic Nanoparticles	327
	Matteo Avolio, Claudia Innocenti, Alessandro Lascialfari, Manuel Mariani, and Claudio Sangregorio	
14.1	Introduction	328
14.2	Magnetic Resonance Imaging and Magnetic Fluid Hyperthermia: An Overview	329
14.3	Physical Principles	330
14.3.1	Magnetic Resonance Imaging	330
14.3.2	Magnetic Fluid Hyperthermia	333
14.4	Design of MNPs as Contrast Agents and Heat Mediators	336
14.5	Clinical Applications: State of the Art and Perspectives	342
14.6	Conclusions	346
	References	347
15	Smart Platforms for Biomedical Applications	353
	Tarun Vemulkar and Russell P. Cowburn	
15.1	Colloidally Synthesized Nanoparticles	353
15.1.1	Applications	354
15.2	Lithographically Defined Particles	359
15.2.1	Applications	361
15.3	Case Studies	362
15.3.1	Exploring the Potential of MPI In Vivo for the First Time	362
15.3.2	Fuller Treatments of Hyperthermia in Nanoparticle Systems	363
15.3.3	The Top-Down Engineering of Application Specific Nanoparticles	365
15.3.4	Magnetically Driven Labs-On-Chips	367
15.4	Future Perspectives	368
	References	372
16	Magnetic Fluids for Thermoelectricity	381
	Sawako Nakamae	
16.1	Introduction	381

16.1.1	Basic Mechanisms of Thermoelectric Conversion in Fluids (3 Pages)	383
16.1.2	Motivation for Using Ferrofluids (2 Pages)	387
16.2	Experimental Investigation of Seebeck Coefficients in Ferrofluids	388
16.2.1	Experimental Approach	388
16.2.2	Experimental Determination of Eastman Entropy of Transfer in Ferrofluids	389
16.2.3	The Effect of Ionic Environment on the Initial Seebeck Coefficient of Aqueous Ferrofluids	391
16.2.4	Magnetic Nanoparticle Adsorption Phenomena at the Liquid/metal Interface	393
16.2.5	Magnetic Field Effect (3 Pages)	395
16.3	Future Research Direction and Perspectives	396
16.3.1	Fundamental Challenge—Understanding the Phenomena Through Theoretical and Experimental Explorations	396
16.3.2	Possible Research Directions in Light of Increasing Thermoelectric Energy Conversion Efficiency	397
	References	399
17	Nanocomposites for Permanent Magnets	403
	Isabelle de Moraes and Nora M. Dempsey	
17.1	Permanent Magnets	404
17.1.1	A Brief History of Permanent Magnets	404
17.1.2	Hard—Soft Magnetic Nanocomposites	406
17.2	Chemical Synthesis of Hard-Soft Nanocomposites	410
17.2.1	Case Study #1—FePt/Fe ₃ Pt Nanocomposites	410
17.2.2	Case Study #2—FePd/ α -Fe Nanocomposites	416
17.2.3	Case Study #3—SmCo ₅ / α -Fe Nanocomposites	420
17.3	Challenges and Future Prospects for Hard-Soft Nanocomposites	425
17.3.1	Outline of the Challenges Faced in Producing Hard-Soft Nanocomposites	425
17.3.2	Compaction of Hard-Soft Nanocomposites	427
17.3.3	Alignment of Hard-Soft Nanocomposites	428
17.3.4	Advanced Magnetic Characterisation of Hard-Soft Nanocomposites	429
17.4	Conclusions	430
	References	430
	Index	435