

SOLID-STATE SCIENCES

J. Stöhr
H.C. Siegmann

Magnetism

From Fundamentals
to Nanoscale
Dynamics

 Springer

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By T. Nakayama and K. Yakubo | 148 Physical Acoustics in the Solid State
By B. Lüthi |
| 141 Excitons in Low-Dimensional Semiconductors
Theory, Numerical Methods, Applications By S. Glusch | 149 Solitary Waves in Complex Dispersive Media
Theory · Simulation · Applications
By V.Yu. Belashov and S.V. Vladimirov |
| 142 Two-Dimensional Coulomb Liquids and Solids
By Y. Monarkha and K. Kono | 150 Topology in Condensed Matter
Editor: M.I. Monastyrsky |
| 143 X-Ray Multiple-Wave Diffraction
Theory and Application
By S.-L. Chang | 151 Particle Penetration and Radiation Effects
By P. Sigmund |
| | 152 Magnetism
From Fundamentals to Nanoscale Dynamics
By J. Stöhr and H.C. Siegmann |

Volumes 90–135 are listed at the end of the book.

J. Stöhr H.C. Siegmann

Magnetism

From Fundamentals
to Nanoscale Dynamics

With 325 Figures and 39 Tables

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To my three favorite women,
my mother Marga, my wife Linda and my daughter Megan,
who have taught me much more than science
and given me the most important gift of all, love.

J. Stöhr

To my collaborators and students
who, through their inspiration and company,
have made my life as a physicist a joyful adventure.

H.C. Siegmann

Preface

This book emerged from a close collaboration of the authors which started in the fall of 2000. Early that year one of us (J.S.) had joined the Stanford faculty after spending nearly 15 years at the IBM Almaden Research Center and the other (H.C.S.) had just retired from a chair at the ETH Zürich and come to Stanford as a visiting professor. Together we organized magnetism meetings of a small group of scientists which oscillated weekly between the Stanford Synchrotron Radiation Laboratory (SSRL) and the Advanced Light Source (ALS) in nearby Berkeley. We also organized annual winter workshops at Lake Tahoe where all participants reported on their research – of course we snuck in a few ski runs, as well. These meetings were great fun and some seemed to go on forever because there was so much interest and enthusiasm and so much to discuss. . . The participants varied over the years and consisted of students, postdocs, Stanford and Berkeley scientists, visiting scientists and participants from industry. In alphabetical order, some of the people involved were Yves Acremann, Scott Andrews, Andreas Bauer, Mark Burkhardt, Venkatesh Chembrolu, Kang Chen, Sug-Bong Choe, Bruce Clemens, Alexander Dobin, Thomas Eimüller, Stefan Eisebitt, Sara Gamble, Alexander Kashuba, Marcus Lörger, Jan Lüning, Gereon Meyer, Hendrik Ohldag, Howard Padmore, Ramon Rick, Andreas Scherz, Bill Schlotter, Andreas Scholl, Christian Stamm, John Paul Strachan, Jan Thiele, Ioan Tudosa, Ashwin Tulapurkar, Shan Wang and Xiaowei Yu. All this would have been impossible without support from the Office of Basic Energy Sciences of the US Department of Energy (DOE), and we gratefully acknowledge DOE's support of our research program.

We have also greatly benefitted from discussions with colleagues and from material they have provided, and we would especially like to thank Elke Arenholz, Sam Bader, Carl Bennemann, Matthias Bode, Patrick Bruno, John Clendenin, Markus Donath, Olle Eriksson, Jürgen Kirschner, Peter Oppeneer, Jürg Osterwalder, Stuart Parkin, Danilo Pescia, Dan Pierce, Theo Rasing, Andrei Rogalev, Kai Starke, Dieter Weller and Ruqian Wu.

With the present book we intend to give an account of the historical development, the physical foundations and the continuing research underlying

VIII Preface

the field of magnetism, one of the oldest and still vital field of physics. Our book is written as a text book for students on the late undergraduate and the graduate levels. It should also be of interest to scientists in academia and research laboratories.

Throughout history, magnetism has played an important role in the development of civilization, starting with the loadstone compass. Our modern society would be unthinkable without the generation and utilization of electricity, wireless communication at the speed of light and the modern high-tech magnetic devices used in information technology. Despite the existence of many books on the topic, we felt the need for a text book that reviews the fundamental physical concepts and uses them in a coherent fashion to explain some of the forefront problems and applications today. Besides covering the classical concepts of magnetism we give a thorough review of the quantum aspects of magnetism, starting with the discovery of the spin in the 1920s. We discuss the exciting developments in magnetism research and technology spawned by the computer revolution in the late 1950s and the more recent paradigm shift starting around 1990 associated with spin-based electronics or “spintronics”. The field of spintronics was largely triggered by the discovery of the giant magnetoresistance or GMR effect around 1988. It utilizes the electron spin to sense, carry or manipulate information and has thus moved the quantum mechanical concept of the electron spin from its discovery in the 1920s to a cornerstone of modern technology.

These historical and modern developments in magnetism are discussed against the background of the development and utilization of spin-polarized electron techniques and polarized photon techniques, the specialties of the authors. It is believed that the technological application of magnetism will continue with a growth rate close to Moore’s law for years to come. Interestingly, the magnetic technology goals of “smaller and faster” are matched by “brighter and faster” X-ray sources, which are increasingly used in contemporary magnetism research. Novel ultra-bright X-ray sources with femtosecond pulse lengths will provide us with snapshots of the invisible ultrafast magnetic nanoworld. These exciting developments are another reason for the present book.

Last not least, this book is born out of our passion for the subjects discussed in it. In the process we had to get to the bottom of many things and understand them better or for the first time. This process took a deep commitment and much time, with “the book” often preoccupying our minds. The process was greatly aided by discussions with our colleagues and students and we would like to thank them at this place. In particular, we need to thank Ioan Tudosa for his critical comments and for helping us with numerous illustrations. In this book we give an account of the field of magnetism that is colored by personal taste and our way of looking at things. We hope that you will enjoy the result.

Stanford, CA
January 2006

Joachim Stöhr
Hans Christoph Siegmann

Contents

1	Introduction	1
1.1	Magnetism: Magical yet Practical	1
1.2	History of Magnetism	3
1.3	Magnetism, Neutrons, Polarized Electrons, and X-rays	12
1.3.1	Spin Polarized Electrons and Magnetism	15
1.3.2	Polarized X-rays and Magnetism	22
1.4	Developments in the Second Half of the 20th Century	25
1.5	Some Thoughts about the Future	30
1.6	About the Present Book	32

Part I Fields and Moments

2	Electric Fields, Currents, and Magnetic Fields	39
2.1	Signs and Units in Magnetism	39
2.2	The Electric Field	39
2.3	The Electric Current and its Magnetic Field	40
2.4	High Current Densities	45
2.5	Magnetic and Electric Fields inside Materials	47
2.6	The Relation of the Three Magnetic Vectors in Magnetic Materials	49
2.6.1	Stray and Demagnetizing Fields of Thin Films	52
2.6.2	Applications of Stray and Demagnetizing Fields	54
2.7	Symmetry Properties of Electric and Magnetic Fields	57
2.7.1	Parity	57
2.7.2	Time Reversal	59
3	Magnetic Moments and their Interactions with Magnetic Fields	61
3.1	The Classical Definition of the Magnetic Moment	61
3.2	From Classical to Quantum Mechanical Magnetic Moments	64

3.2.1	The Bohr Magneton	65
3.2.2	Spin and Orbital Magnetic Moments	66
3.3	Magnetic Dipole Moments in an External Magnetic Field	68
3.4	The Energy of a Magnetic Dipole in a Magnetic Field	69
3.5	The Force on a Magnetic Dipole in an Inhomogeneous Field ..	72
3.5.1	The Stern–Gerlach Experiment	74
3.5.2	The Mott Detector	79
3.5.3	Magnetic Force Microscopy	83
3.6	The Torque on a Magnetic Moment in a Magnetic Field	84
3.6.1	Precession of Moments	85
3.6.2	Damping of the Precession	87
3.6.3	Magnetic Resonance	91
3.7	Time–Energy Correlation	97
3.7.1	The Heisenberg Uncertainty Principle	97
3.7.2	Classical Spin Precession	98
3.7.3	Quantum Mechanical Spin Precession	99
4	Time Dependent Fields	105
4.1	Overview	105
4.2	Basic Concepts of Relativistic Motion	106
4.2.1	Length and Time Transformations Between Inertial Systems	106
4.2.2	Electric and Magnetic Field Transformations between Inertial Systems	107
4.3	Fields of a Charge in Uniform Motion: Velocity Fields	109
4.3.1	Characteristics of Velocity Fields	109
4.3.2	Creation of Large Currents and Magnetic Fields	112
4.3.3	Creation of Ultrashort Electron Pulses and Fields	115
4.3.4	The Temporal Nature of Velocity Fields	118
4.4	Acceleration Fields: Creation of EM Radiation	121
4.4.1	Polarized X-rays: Synchrotron Radiation	125
4.4.2	Brighter and Shorter X-ray Pulses: From Undulators to Free Electron Lasers	133
5	Polarized Electromagnetic Waves	141
5.1	Maxwell’s Equations and their Symmetries	142
5.2	The Electromagnetic Wave Equation	143
5.3	Intensity, Flux, Energy, and Momentum of EM Waves	145
5.4	The Basis States of Polarized EM Waves	147
5.4.1	Photon Angular Momentum	147
5.4.2	Linearly Polarized Basis States	148
5.4.3	Circularly Polarized Basis States	149
5.4.4	Chirality and Angular Momentum of Circular EM Waves	153

5.4.5	Summary of Unit Polarization Vectors	154
5.5	Natural and Elliptical Polarization	155
5.5.1	Natural Polarization	155
5.5.2	Elliptical Polarization	156
5.5.3	The Degree of Photon Polarization	157
5.6	Transmission of EM Waves through Chiral and Magnetic Media	159

Part II History and Concepts of Magnetic Interactions

6	Exchange, Spin–Orbit, and Zeeman Interactions	167
6.1	Overview	167
6.2	The Spin Dependent Atomic Hamiltonian or Pauli Equation ..	169
6.2.1	Independent Electrons in a Central Field	170
6.2.2	Interactions between two Particles – Symmetrization Postulate and Exclusion Principle	172
6.3	The Exchange Interaction	175
6.3.1	Electron Exchange in Atoms	175
6.3.2	Electron Exchange in Molecules	180
6.3.3	Magnetism and the Chemical Bond	186
6.3.4	From Molecules to Solids	188
6.3.5	The Heisenberg Hamiltonian	190
6.3.6	The Hubbard Hamiltonian	193
6.3.7	Heisenberg and Hubbard Models for H ₂	195
6.3.8	Summary and Some General Rules for Electron Exchange	202
6.4	The Spin–Orbit Interaction	203
6.4.1	Fine Structure in Atomic Spectra	203
6.4.2	Semiclassical Model for the Spin–Orbit Interaction ...	204
6.4.3	The Spin–Orbit Hamiltonian	206
6.4.4	Importance of the Spin–Orbit Interaction	209
6.5	Hund’s Rules	209
6.6	The Zeeman Interaction	212
6.6.1	History and Theory of the Zeeman Effect	212
6.6.2	Zeeman Versus Exchange Splitting of Electronic States	218
6.6.3	Importance of the Zeeman Interaction	220
7	Electronic and Magnetic Interactions in Solids	221
7.1	Chapter Overview	221
7.2	Localized versus Itinerant Magnetism: The Role of the Centrifugal Potential	223
7.3	The Relative Size of Interactions in Solids	230
7.4	The Band Model of Ferromagnetism	234
7.4.1	The Puzzle of the Broken Bohr Magneton Numbers ...	234

XII Contents

7.4.2	The Stoner Model	235
7.4.3	Origin of Band Structure	240
7.4.4	Density Functional Theory	243
7.5	Ligand Field Theory	245
7.5.1	Independent-Electron Ligand Field Theory	247
7.5.2	Multiplet Ligand Field Theory	256
7.6	The Importance of Electron Correlation and Excited States ..	261
7.6.1	Why are Oxides often Insulators?	262
7.6.2	Correlation Effects in Rare Earths and Transition Metal Oxides	264
7.6.3	From Delocalized to Localized Behavior: Hubbard and LDA+U Models	271
7.7	Magnetism in Transition Metal Oxides	274
7.7.1	Superexchange	274
7.7.2	Double Exchange	279
7.7.3	Colossal Magnetoresistance	282
7.7.4	Magnetism of Magnetite	283
7.8	RKKY Exchange	290
7.8.1	Point-like Spins in a Conduction Electron Sea	291
7.8.2	Metallic Multilayers	292
7.9	Spin-Orbit Interaction: Origin of the Magnetocrystalline Anisotropy	294
7.9.1	The Bruno Model	295
7.9.2	Description of Anisotropic Bonding	297
7.9.3	Bonding, Orbital Moment, and Magnetocrystalline Anisotropy	299

Part III Polarized Electron and X-Ray Techniques

8	Polarized Electrons and Magnetism	313
8.1	Introduction	313
8.2	Generation of Spin-Polarized Electron Beams	314
8.2.1	Separation of the Two Spin States	314
8.2.2	The GaAs Spin-Polarized Electron Source	315
8.3	Spin-Polarized Electrons and Magnetic Materials: Overview of Experiments	318
8.4	Formal Description of Spin-Polarized Electrons	319
8.4.1	Quantum Behavior of the Spin	319
8.4.2	Single Electron Polarization in the Pauli Spinor Formalism	320
8.4.3	Description of a Spin-Polarized Electron Beam	324
8.5	Description of Spin Analyzers and Filters	327
8.5.1	Incident Beam Polarization: Spin Analyzer	327
8.5.2	Transmitted Beam Polarization: Spin Filter	328

8.5.3	Determination of Analyzer Parameters	329
8.6	Interactions of Polarized Electrons with Materials	329
8.6.1	Beam Transmission through a Spin Filter	329
8.6.2	The Fundamental Interactions of a Spin-Polarized Beam with Matter	331
8.6.3	Interaction of Polarized Electrons with Magnetic Materials: Poincaré's Sphere	337
8.7	Link Between Electron Polarization and Photon Polarization ..	342
8.7.1	Photon Polarization in the Vector Field Representation	343
8.7.2	Photon Polarization in the Spinor Representation	344
8.7.3	Transmission of Polarized Photons through Magnetic Materials: Poincaré Formalism	345
8.7.4	X-ray Faraday Effect and Poincaré Formalism	348
8.7.5	Poincaré and Stokes Formalism	350
9	Interactions of Polarized Photons with Matter	351
9.1	Overview	351
9.2	Terminology of Polarization Dependent Effects	352
9.3	SemiClassical Treatment of X-ray Scattering by Charges and Spins	355
9.3.1	Scattering by a Single Electron	355
9.3.2	Scattering by an Atom	360
9.4	SemiClassical Treatment of Resonant Interactions	361
9.4.1	X-ray Absorption	361
9.4.2	Resonant Scattering	364
9.4.3	Correspondence between Resonant Scattering and Absorption	368
9.4.4	The Kramers–Kronig Relations	368
9.5	Quantum-Theoretical Concepts	370
9.5.1	One-Electron and Configuration Pictures of X-ray Absorption	370
9.5.2	Fermi's Golden Rule and Kramers–Heisenberg Relation	372
9.5.3	Resonant Processes in the Electric Dipole Approximation	374
9.5.4	The Polarization Dependent Dipole Operator	376
9.5.5	The Atomic Transition Matrix Element	378
9.5.6	Transition Matrix Element for Atoms in Solids	381
9.6	The Orientation-Averaged Intensity: Charge and Magnetic Moment Sum Rules	385
9.6.1	The Orientation-Averaged Resonance Intensity	385
9.6.2	Derivation of the Intensity Sum Rule for the Charge ..	386
9.6.3	Origin of the XMCD Effect	389
9.6.4	Two-Step Model for the XMCD Intensity	393
9.6.5	The Orientation Averaged Sum Rules	397

9.7	The Orientation-Dependent Intensity: Charge and Magnetic Moment Anisotropies	401
9.7.1	Concepts of Linear Dichroism	401
9.7.2	X-ray Natural Linear Dichroism	401
9.7.3	Theory of X-ray Natural Linear Dichroism	403
9.7.4	XNLD and Quadrupole Moment of the Charge	406
9.7.5	X-ray Magnetic Linear Dichroism	407
9.7.6	Simple Theory of X-ray Magnetic Linear Dichroism	408
9.7.7	XMLD of the First and Second Kind	411
9.7.8	Enhanced XMLD through Multiplet Effects	415
9.7.9	The Orientation-Dependent Sum Rules	421
9.8	Magnetic Dichroism in X-ray Absorption and Scattering	424
9.8.1	The Resonant Magnetic Scattering Intensity	425
9.8.2	Link of Magnetic Resonant Scattering and Absorption	427
10	X-rays and Magnetism: Spectroscopy and Microscopy	431
10.1	Introduction	431
10.2	Overview of Different Types of X-ray Dichroism	432
10.3	Experimental Concepts of X-ray Absorption Spectroscopy	437
10.3.1	General Concepts	437
10.3.2	Experimental Arrangements	441
10.3.3	Quantitative Analysis of Experimental Absorption Spectra	445
10.3.4	Some Important Experimental Absorption Spectra	449
10.3.5	XMCD Spectra of Magnetic Atoms: From Thin Films to Isolated Atoms	451
10.3.6	Sum Rule Analysis of XMCD Spectra: Enhanced Orbital Moments in Small Clusters	454
10.3.7	Measurement of Small Spin and Orbital Moments: Pauli Paramagnetism	457
10.4	Magnetic Imaging with X-rays	458
10.4.1	X-ray Microscopy Methods	459
10.4.2	Lensless Imaging by Coherent Scattering	463
10.4.3	Overview of Magnetic Imaging Results	468

Part IV Properties of and Phenomena in the Ferromagnetic Metals

11	The Spontaneous Magnetization, Anisotropy, Domains	479
11.1	The Spontaneous Magnetization	480
11.1.1	Temperature Dependence of the Magnetization in the Molecular Field Approximation	481
11.1.2	Curie Temperature in the Weiss–Heisenberg Model	484
11.1.3	Curie Temperature in the Stoner Model	488