

B. Heinrich J.A.C. Bland (Eds.)

Ultrathin Magnetic Structures II

*Measurement Techniques and
Novel Magnetic Properties*

With 171 Figures and 7 Tables

Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo
Hong Kong Barcelona
Budapest

Contents

1. Magnetic Metal Films on Semiconductor Substrates

G.A. Prinz (With 35 Figures)	1
1.1 3d Transition Metals on Zincblende Structures	3
1.1.1 bcc Fe	5
1.1.2 bcc Co	24
1.1.3 τ -MnAl	33
1.2 3d Transition Metals on the Diamond Structure	33
1.2.1 fcc Ni on C	34
1.2.2 Cu on Si	34
1.2.3 Fe on Ge	35
1.3 Rare Earths	35
1.4 Applications	36
1.4.1 Non-Volatile Magnetic Memory	36
1.4.2 Microwave Devices	37
1.4.3 Spin Injection Devices	39
Appendix	42
References	42

2. Magnetic Coupling and Magnetoresistance

2.1 Theory of Exchange Coupling in Magnetic Multilayers	
K.B. Hathaway (With 19 Figures)	45
2.1.1 RKKY-Like Models	46
2.1.2 Non-Perturbation Calculations for Strongly Hybridized Systems.	51
2.1.3 Oscillation of the Exchange Coupling with Interlayer Thickness, d	60
2.1.4 Non-Oscillatory Exchange Terms and Anderson-Like Models	62
2.1.5 Non-Heisenberg Exchange	69
2.1.6 Band Structure Results	72
2.1.7 Temperature Dependence of Exchange Coupling	78
2.1.8 Conclusions	81
2.2 Interlayer Coupling and Magnetoresistance in Multilayers	
A. Fert and P. Bruno (With 15 Figures).	82

2.2.1 Interlayer Coupling. Review of Experiments	82
2.2.2 Interlayer Exchange Coupling. Theoretical Models	88
2.2.3 Magnetoresistance: A Survey	97
2.2.4 Theoretical Models of the Magnetoresistance	102
2.2.5 Review and Discussion of Magnetoresistance Data	106
2.3 Investigation of Exchange Coupled Magnetic Layers by Scanning Electron Microscopy with Polarization Analysis (SEMPA) D.T. Pierce, J. Unguris, and R.J. Celotta (With 14 Figures)	117
2.3.1 The SEMPA Technique	118
2.3.2 SEMPA Measurements of Exchange Coupled Multilayers	132
2.4 Giant Magnetoresistance and Oscillatory Interlayer Coupling in Polycrystalline Transition Metal Multilayers S.S.P. Parkin (With 29 Figures)	148
2.4.1 Preparation of Multilayers	150
2.4.2 Antiferromagnetic Coupling and Giant Magnetoresistance in Fe/Cr Multilayers	152
2.4.3 Magnetoresistance of Ferromagnetic Metals	155
2.4.4 Oscillatory Interlayer Coupling	159
2.4.5 Giant Magnetoresistance of Cu-Based Multilayers	167
2.4.6 Low Field Giant Magnetoresistance Structures	174
2.4.7 Interfacial Origin of Giant Magnetoresistance	175
2.4.8 Giant Magnetoresistance in Systems Other than Multilayers	180
2.4.9 Conclusions	185
References	186

3. Radio Frequency Techniques

3.1 Ferromagnetic Resonance in Ultrathin Film Structures B. Heinrich (With 14 Figures)	195
3.1.1 Magnetic Properties of Ultrathin Magnetic Layers and the Landau–Lifshitz Equations of Motion	196
3.1.2 FMR Technique and Experimental Procedures	204
3.1.3 Measurements of Magnetic Anisotropies	209
3.1.4 Exchange-Coupled Ferromagnetic Layers	216
3.1.5 Conclusion	222
3.2 Light Scattering from Ultrathin Magnetic Layers and Bilayers J.F. Cochran (With 8 Figures)	222
3.2.1 Introduction	223
3.2.2 The Light Scattering Experiment	224
3.2.3 Light Scattering for a Simple Model	227
3.2.4 The Intensity of the Scattered Light	234
3.2.5 Magnetic Damping	247
3.2.6 Magnetic Bilayers	249

3.2.7 Examples	253
3.2.8 Conclusions	257
Appendix	257
3.3 Brillouin Light Scattering in Magnetic Superlattices	
B. Hillebrands and G. Güntherodt (With 12 Figures)	258
3.3.1 Introduction.	258
3.3.2 Theoretical Background.	259
3.3.3 Dipolar Coupled Collective Spin Waves	262
3.3.4 Interlayer-Exchange Coupled Collective Spin Waves	267
3.3.5 Superlattices with Spatial Inhomogeneities	274
3.3.6 Conclusion and Outlook	277
3.4 Nuclear Magnetic Resonance in Thin Films and Multilayers	
W.J.M. de Jonge, H.A.M. de Gronckel, and K. Kopinga	
(With 7 Figures)	279
3.4.1 Basic Principles.	279
3.4.2 Experimental Results of NMR on Multilayers and Films	283
3.4.3 Conclusion	289
References	290

4. Magneto-Optical Effects in Ultrathin Magnetic Structures

S.D. Bader and J.L. Erskine (With 10 Figures)	297
4.1 Microscopic Basis.	297
4.2 Macroscopic Formulas.	299
4.3 Instrumentation, Techniques, and Sensitivity	303
4.4 Thin Film Phenomena and Applications	306
4.4.1 Monolayer Magnetism	306
4.4.2 Thin Film Anisotropy	309
4.4.3 Critical Phenomena	314
4.4.4 Coupled Layers.	317
4.4.5 Magneto-Optical Media.	319
4.4.6 Magnetic Circular-Dichroism.	320
4.5 Outlook.	322
References	323

5. Mössbauer Spectroscopy as a Means of Characterizing Surfaces, Thin Films, and Superlattices

J.C. Walker (With 8 Figures)	327
5.1 Elements of Mössbauer Spectroscopy	329
5.2 Mössbauer Spectrometers	331
5.3 Information Obtainable from Mössbauer Spectra	333
5.4 Isomer Shift	334
5.5 Conversion Electron Mössbauer Spectroscopy (CEMS).	334
5.6 Magnetic Relaxation in Thin Films and Superlattices.	336

5.7 Examples of Mössbauer Spectroscopy Applied to the Study of Magnetic Thin Films, Surfaces, and Superlattices.	337
5.8 Conclusions	342
References.	343
Subject Index	345