



High-energy high-momentum surface spin waves of ultrathin epitaxial 3d transition metal films

Rajeswari Jayaraman

Forschungszentrum Jülich GmbH
Peter Grünberg Institute (PGI)
Electronic Properties (PGI-6)

High-energy high-momentum surface spin waves of ultrathin epitaxial 3d transition metal films

Rajeswari Jayaraman

Schriften des Forschungszentrums Jülich
Reihe Schlüsseltechnologien / Key Technologies

Band / Volume 68

ISSN 1866-1807

ISBN 978-3-89336-890-7

Contents

1	Introduction	1
2	Magnetic excitations in solids	7
2.1	Magnetic interactions	7
2.2	Spin waves versus Stoner excitations	8
2.3	Spin waves in the Heisenberg model	11
2.3.1	Spin waves in the $\bar{\Gamma}\bar{X}$ -direction of an fcc(100) surface	14
2.3.2	Spin waves in the $\bar{\Gamma}\bar{M}$ -direction of an fcc(100) surface	16
2.3.3	Dispersion of an eight layer slab	16
2.3.4	Analytical solution for surface spin waves	17
2.4	Experimental probes to study spin waves	19
3	Electron energy loss spectroscopy	23
3.1	Basic principles	23
3.2	The spectrometer	25
3.2.1	New operation mode of the lens system	27
3.2.2	Relation between experimental intensity and scattering probability	29
3.3	Solid angle and lens transmission	29
3.4	Calculation of the incident electron energy	31
4	Spin waves in fcc Co layers grown on Cu(100)	35
4.1	Introduction	35
4.2	The Co/Cu(100) system	36
4.2.1	Preparation	37
4.2.2	Definition of scattering geometry	38
4.2.3	Data evaluation procedure	40
4.3	Results of spin wave measurements	44
4.3.1	Experimental data	44
4.3.2	Dispersion	48
4.3.3	Energy width of spin waves	50
4.3.4	Intensity of spin waves	51

CONTENTS

4.4	Discussion	53
4.4.1	Spin waves in the Heisenberg model	54
4.4.2	Stiffness of spin waves	55
4.4.3	Qualitative discussion of the width of spin waves	56
4.4.4	Spin waves in itinerant electron theory	57
4.5	Summary	60
5	Search for spin waves on fcc Ni layers grown on Cu(100)	63
5.1	Introduction	63
5.2	Preparation and characterization	63
5.3	Electron energy loss spectra	65
5.4	Summary	67
6	Spin waves at interfaces	69
6.1	Introduction	69
6.2	Data evaluation procedure	70
6.3	The Ni/Co(100) interface	71
6.3.1	Experimental details	71
6.3.2	Spin wave spectra	72
6.3.3	Dispersion of Ni/Co interface spin waves	77
6.3.4	Widths of the Ni/Co interface spin waves	78
6.3.5	Electronic and magnetic structure of the Ni/Co interface	79
6.4	The Cu/Co(100) interface	80
6.4.1	Experimental details	80
6.4.2	Spin wave spectra	82
6.4.3	Dispersion of Cu/Co interface spin waves	83
6.4.4	Width of Cu/Co(100) interface spin waves	84
6.4.5	Effect of interface magnetic moment	86
6.5	Summary	87
7	Surface spin waves of ultrathin iron layers	89
7.1	Introduction	89
7.2	The Fe/Cu(100) system	90
7.2.1	Structure and magnetic properties	90
7.2.2	Preparation	93
7.2.3	Spin waves of the 4 ML Fe/Cu(100) system	95
7.2.4	Spin waves of the 3 ML Fe and 5 ML Fe on Cu(100)	100
7.3	The Fe/Co(100) system	102
7.3.1	Structure and magnetic properties	102
7.3.2	Preparation	103
7.3.3	Spin waves of the 4 ML Fe/8 ML Co/Cu(100) system	104
7.4	Iron clusters on 8 ML Co/Cu(100)	104

CONTENTS

7.4.1 Preparation	105
7.4.2 Energy loss spectra	106
7.5 Discussion	109
7.5.1 Spin waves in a 4 ML Fe film	110
7.5.2 Spin waves in 3 ML and 5 ML Fe films on Cu(100)	113
7.6 Summary	115
8 Conclusions and outlook	117
Bibliography	119
List of Own Publications	131
Acknowledgements	133
Curriculum Vitae	135



Schlüsseltechnologien / Key Technologies
Band / Volume 68
ISBN 978-3-89336-890-7

 **JÜLICH**
FORSCHUNGSZENTRUM