

Preparation and Characterization of MnSi, MnGe and $\text{Mn}_{1-x}\text{Fe}_x\text{Si}$ Thin Films: Magnetic Properties under the Influence of Strain and Finite Size Effects

Von der Fakultät für Elektrotechnik, Informationstechnik, Physik
der Technischen Universität Carolo-Wilhelmina zu Braunschweig
zur Erlangung des Grades einer Doktorin
der Naturwissenschaften (Dr. rer. nat.)
genehmigte

Dissertation

von

Josefin Engelke
aus Hildesheim

Eingereicht am 14.11.2014

Disputation am 13.02.2015

1. Referent: Priv.-Doz. Dr. Dirk Menzel
2. Referent: Prof. Dr. Paul Fumagalli

Druckjahr: 2015

Contents

1	Introduction	1
2	Theoretical Framework	9
2.1	Magnetic Phases in Chiral Systems	9
2.2	The Hall Effect	16
2.3	Non-Fermi Liquid Behavior	21
2.4	Growth of Thin Films by MBE	27
2.5	The MBE System	31
2.5.1	The Effusion Cell	33
2.5.2	The Electron Beam Evaporator	34
2.5.3	The Mini Electron Beam Evaporator	35
2.5.4	The Deposition Rate Controller	35
2.6	Reflection High Energy Electron Diffraction	37
2.6.1	Diffraction Theory	37
2.6.2	Kikuchi Lines	41
2.6.3	The Coherence Length	42
2.7	Surface Reconstruction	44
3	MnSi Thin Films	47
3.1	Properties of Bulk MnSi	47
3.2	Preparation of MnSi Thin Films	53
3.2.1	Characteristics and Treatment of the Si Substrate	53
3.2.2	The Growth of MnSi Thin Films on Si(111)	54
3.3	Morphological and Structural Characterization	64
3.3.1	Atomic Force Microscopy	64
3.3.2	Transmission Electron Microscopy	66
3.3.3	RHEED	67
3.4	Magnetic Characterization	69
3.4.1	Dimensionality of MnSi Thin Films	69
3.4.2	Susceptibility Measurements	70
3.4.3	Field Dependence of the Magnetization	76
3.5	Resistivity and Magnetoresistance Measurements	81
3.5.1	The van-der-Pauw Method	81

3.5.2	The Measurement Setup	82
3.5.3	Resistivity Measurements	83
3.5.4	Magnetoresistivity	88
3.6	Hall Effect Measurements	94
3.7	The Magnetic Phase Diagram of MnSi Thin Films	101
3.8	Resistance Measurements under Hydrostatic Pressure	109
3.8.1	Experimental Setup for High Pressure Experiments	110
3.8.2	Resistance Measurements	111
3.8.3	NFL Behavior in MnSi Thin Films	115
4	MnGe Thin Films	121
4.1	Properties of Bulk MnGe	122
4.2	Preparation of MnGe Thin Films	123
4.3	Characterization of MnGe Films by RHEED	124
4.4	AFM Investigations	126
4.5	XRD Measurements	126
4.6	Magnetic Measurements	127
4.7	Resistivity and Magnetoresistivity	131
4.8	Discussion	134
5	Mn_{1-x}Fe_xSi Thin Films	137
5.1	Properties of Bulk Mn _{1-x} Fe _x Si	137
5.2	Preparation of Mn _{1-x} Fe _x Si Thin Films	139
5.3	Structure and Morphology	140
5.4	Magnetic Characterization	142
5.4.1	Susceptibility	142
5.4.2	Field Dependence of the Magnetization	146
5.5	Resistivity Measurements	147
5.6	Discussion	151
6	Summary	155
A	Supplemental Data	159
A.1	Calibration of the Ceramic Heater	159
A.2	Calibration of the Tantalum Substrate Heater	161
A.3	Resistivity Data	162
A.4	Hall Effect Data	166
	Acknowledgments	171
	References	173