

Contents

1	Introduction	1
1.1	Indium-based spintronics	1
1.2	The structure of this work	4
2	Theoretical concepts	5
2.1	Magnetotransport in two-dimensional systems	5
2.1.1	The two-dimensional carrier gas	5
2.1.2	2D Drude transport in a magnetic field	7
2.1.3	Quantum Hall effect	8
2.1.4	Shubnikov-de Haas effect	10
2.1.5	Quantum interference in diffusive transport	11
2.2	Spin-orbit coupling in two-dimensional systems	12
2.2.1	Energy band structure of III-V semiconductor compounds . .	13
2.2.2	Spin splitting of 2D hole systems	17
2.2.3	Spin relaxation	21
3	Experimental methods	25
3.1	Molecular beam epitaxy	25
3.2	Characterizing the crystal	29
3.3	Low-temperature magnetotransport	30
4	Designing InAlAs/InGaAs/InAs QW heterostructures for 2D magneto-transport	35
4.1	Strain engineering by step-graded $\text{In}_x\text{Al}_{1-x}\text{As}$ buffer layer growth . . .	36
4.2	Heterostructure optimization by 2DEGs in undoped InAs QW systems	40
4.3	2DHG systems from <i>p</i> -type Mn modulation doping	43
5	Magnetotransport in anisotropic 2D carrier systems	47
5.1	Anisotropic scattering of 2DHGs in high-In systems	47
5.2	Hall effect anomalies in anisotropic systems	51
5.2.1	Phenomenology	51
5.2.2	Materials study	54
5.2.3	Drude model of magnetotransport in an anisotropic system . .	60
5.2.4	Overshooting of $\rho_{xy}(B)$ at quantizing fields	63

5.3 Conclusion	67
6 Spin-orbit interaction and quantum interference of 2DHGs in disordered InAs:Mn QW heterostructures	69
6.1 Introduction	69
6.2 Diffusive magnetotransport of high-density 2DHGs	73
6.2.1 Negative correction to the longitudinal magnetoresistivity . . .	75
6.2.2 Temperature damping of SdH oscillations: m_h^* and τ_q	80
6.2.3 Weak antilocalization analysis of SO parameters	83
6.3 Tunability of the spin splitting by SIA-induced Rashba SOI	92
6.3.1 Suppression of weak antilocalization by Rashba SOI	92
6.3.2 Tunability of the Rashba spin splitting	95
6.4 Quantum corrections to the Drude resistivity in low-density disordered systems	100
6.5 Conclusion	106
7 Highly diluted magnetic InAs:Mn QW heterostructures	107
8 Conclusions and perspective	115
A Processing gated Hall bar structures	119
B Van der Pauw characterization of InAs:Mn QW systems	123
C Abbreviations and constants	133
Bibliography	137
Publications	155
Acknowledgements	157