

# Spin dependent transport in magnetic nanostructure

Soumik Mukhopadhyay

*Experimental Condensed Matter Physics Division,  
Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700064*



Thesis submitted for the Degree of  
Doctor of Philosophy in Science (Physics)  
Jadavpur University, Jadavpur, Kolkata, India

# Contents

<b>Acknowledgments</b>	<b>vi</b>
<b>List of Publications</b>	<b>viii</b>
<b>Preface</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Spin polarized tunneling . . . . .	1
1.1.1 Tunneling of charge . . . . .	2
1.1.2 Tunneling: a many body effect . . . . .	5
1.2 Spin-polarized tunneling — earlier studies . . . . .	8
1.2.1 Tunneling from a normal metal to a Zeeman split superconductor . . . . .	9
1.2.2 Zeeman split superconductor-ferromagnet tunneling . . . . .	10
1.3 Transport in magnetic tunnel junction . . . . .	12
1.3.1 Julliere model . . . . .	13
1.3.2 Stearns model . . . . .	16
1.3.3 Slonczewski’s model . . . . .	16
1.3.4 What is meant by tunneling spin polarization ? . . . . .	19
1.3.5 A recapitulation of the major advances in the field of magnetic tunnel junctions . . . . .	22
1.4 What is a half metal ? . . . . .	24
1.5 Electrical transport in nano-scale systems . . . . .	25
1.5.1 Ideal quantum wire — Landauer approach . . . . .	27

1.5.2	Quantized conductance by Landauer formalism: where is the dissipation ?!	30
1.6	Ballistic magnetoresistance	32
1.7	Spin dependent transport in granular ferromagnets : a brief chronological survey	33
1.8	Physics of manganites	38
1.9	Experimental methods	43
1.9.1	Pulsed Laser Deposition	43
1.9.2	Sample preparation using sol-gel route	47
1.9.3	Seeing is believing: Microscopic imaging tools	47
1.9.4	X-ray Diffraction	52
1.9.5	SQUID Magnetometer	53
1.9.6	Transport property measurement set-up	55
<b>Bibliography</b>		<b>61</b>
<b>2</b>	<b>Spin polarized transport in magnetic tunnel junction</b>	<b>62</b>
2.1	Transport in magnetic tunnel junction without pinhole short	62
2.1.1	Zero bias anomaly in the bias dependence of Tunnel magnetoresistance	64
2.2	Influence of ballistic spin polarized transport on tunnel magnetoresistance	70
2.2.1	Inverse Tunnel Magnetoresistance	70
2.2.2	Ballistic channels in magnetic tunnel junction	72
2.2.3	Experimental results and discussions	72
2.3	Summary	86
<b>Bibliography</b>		<b>90</b>
<b>3</b>	<b>Spin dependent transport in nano-granular ferromagnets and manganite thin films</b>	<b>91</b>
3.1	Low temperature resistivity minima in ferromagnetic manganites	91
3.2	Unified description of spin dependent transport in granular ferromagnetic manganites	93

3.2.1	Magnetotransport properties at low temperature in $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$ nanoparticles and nano-composites . . . . .	93
3.2.2	Magnetotransport at low temperature in ferromagnetic manganite thick films . . . . .	96
3.2.3	Discussions . . . . .	101
3.3	Transport in ferromagnetic manganite thin films at low temperature: quantum corrections and the effect of grain boundaries . . .	110
3.4	Enhanced magnetoresistance in LSMO thin films: evidence of electronic phase separation in a canonical double exchange system . .	120
3.5	Summary . . . . .	130
<b>Bibliography</b>		<b>134</b>
<b>4</b>	<b>Spin dependent transport in manganite multilayers</b>	<b>135</b>
4.1	Giant enhancement of room temperature magnetoresistance in LSMO/NSMO multilayer . . . . .	136
4.2	Colossal enhancement of magnetoresistance in $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$ / $\text{Pr}_{0.67}\text{Ca}_{0.33}\text{MnO}_3$ multilayers: reproducing the phase-separation scenario . . . . .	142
4.2.1	Experimental results and discussion . . . . .	143
4.3	Summary . . . . .	152
<b>Bibliography</b>		<b>155</b>
<b>5</b>	<b>Conclusions and future prospects</b>	<b>156</b>
5.1	Conclusions . . . . .	156
5.2	Future prospects . . . . .	159
<b>Bibliography</b>		<b>159</b>