

Contents

Preface to the second edition — V

Preface to the first edition — VII

1 Introduction — 1

- 1.1 What is a spin? — 1
- 1.2 Single spin algebra — 2
- 1.3 A spin in a real material — 4
- 1.4 The 3d electrons in ferromagnetic atoms — 5
- 1.5 An electron in a phase space: the density of states — 8
- 1.6 Full quantum perspective for the electron spin description: the second quantization — 10
- 1.7 Spin transport and random-walk — 13
- 1.8 Magnetization and micromagnetism — 16

2 Physical effects in spintronic structures — 20

- 2.1 Classical dipole interactions versus quantum exchange interaction — 20
- 2.2 Double-exchange interaction — 21
- 2.3 The RKKY interaction — 23
- 2.4 Examples of anisotropy effects in low-dimensional objects — 24
 - 2.4.1 Dots (0D) — 26
 - 2.4.2 Wires (1D) — 35
 - 2.4.3 Layers (2D) and spatial systems (3D) — 39
- 2.5 Magnetization dynamics in low-dimensional magnetic systems — 41

3 Micromagnetic equations in magnetization dynamic studies — 49

- 3.1 Magnetization dynamics in materials with strong spin-orbit coupling: the Dzyaloshinskii-Moriya interaction — 60
- 3.2 Skyrmions — 68
- 3.3 Hopfions — 73
- 3.4 Magnetization dynamics for temperatures above 0 K — 81

4 Sensing magnetization dynamics — 96

5 Contact effects in layered structures — 123

- 5.1 Boundary conditions and magnetic interface effects — 123
- 5.2 Ferromagnetic-antiferromagnetic junction: EB and 90° coupling — 125
- 5.3 Superconductor-normal conductor junction: Andreev reflection — 130

6	Transport in spintronic structures — 133
6.1	Diffusion and Drift of Spins — 133
6.2	Tunnel effect — 136
6.2.1	The single tunnel junction — 140
6.2.2	The lead–island–lead basic three-component system — 146
6.3	Coulomb blockade — 153
6.4	Kondo effect — 156
6.5	Reflection and scattering of carriers — 160
6.6	Spin injection and spin accumulation — 161
6.7	Spin-transfer torque — 165
7	Spintronics devices — 169
7.1	Electronic parameters of spintronic devices — 169
7.2	Spin valve — 169
7.3	Magnetic tunnel junctions — 174
7.4	Magnetic diode — 177
7.5	Magnetic electroluminescent diode — 180
7.6	Single-electron transistor — 181
7.7	Bipolar magnetic transistor — 186
7.8	Magnetic NOT logic gate — 187
7.9	Other magnetic logic gates and devices — 189
7.10	From magnetic tape storage systems to hard disk read/write heads and beyond — 191
7.11	Magnetic memory cell: MRAM — 200
7.12	Beyond von Neumann architecture: neuromorphic computing — 202
7.13	CMOS-compatible spintronics and hybrid solutions — 211
7.14	Quantum interferometers, Aharonov–Bohm, and Fano effects — 215
7.15	Magnetic markers and biochips — 217
8	Influence of external factors and physical fields onto spintronic devices work — 219
8.1	Temperature-supported switching of elements — 219
8.2	Spin caloritronics — 221
8.3	Pressure — 224
8.4	Strain — 225
8.5	Electric field — 226
8.6	Light — 227
8.7	Electric current and switching of spintronic devices — 228
9	Materials in commercial applications — 229
9.1	Metals and half-metals — 229
9.2	Diluted magnetic semiconductors — 230

9.3	Multiferroics —	230
9.4	Antiferromagnets —	231
9.5	Organic spintronics —	231
9.6	Other materials in layered systems —	232

Bibliography — 233

Index — 287