Spin Hall Effect And Spin Orbit Torques

Novel magnetotransport phenomena appear when magnet sizes become nanoscale. Typical examples of such phenomena are giant magnetoresistance (GMR) in magnetic multilayers, tunnel magnetoresistance (TMR) in ferromagnetic tunnel junctions, and ballistic magnetoresistance (BMR) in magnetic nanocontacts. In this chapter, we first briefly review the relationship between spin-dependent resistivity and electronic structures in metals and alloys, and describe microscopic methods for investigating electrical transport. We then review the essential aspects of GMR, TMR, and BMR, emphasizing the role of the electronic structures of the constituent metals of these junctions and the effects of roughness on the electrical resistivity (or resistance). The important factors that control GMR are shown to be the spin-dependent random potential at interfaces and band matching/mismatching between magnetic and nonmagnetic layers. For TMR, several factors are shown to be important in determining the MR ratio, including the shape of the Fermi surface of the electrodes, the symmetry of the wave functions, electron scattering at interfaces, and spin-slip tunneling. An interpretation of TMR in Fe/MgO/Fe and of an oscillation of TMR is presented. TMR in granular films and in the Coulomb-blockade regime is also described. We also provide a brief explanation for other MR effects, such as normal MR, anisotropic MR (AMR) and colossal MR (CMR) in order to clarify the essential difference between these MRs and GMR, TMR, and BMR. These MR effects are attributed to the spin-dependent electrical currents produced in metallic ferromagnets. After the discovery of these different MR effects, the role of spin current was proposed, for example, spin Hall effect and the effects of spin transfer torque, which will be briefly explained in this chapter. The former orginates from the spin–orbit interaction, and can be observed even in nonmagnetic metals and semiconductors. It is closely related to the anomalous Hall effect observed in ferromagnetic metals. The spin transfer torque is an inverse effect of the MR. The MR is the resistivity change produced by magnetization rotation in ferromagnetic junctions, while the spin transfer torque is an effect in which spin-polarized current makes the magnetization rotate. Finally, we briefly introduce the coupled effects of spin, charge, and heat transport, which are called spin caloritronics.

Recently, a new branch of physics and nanotechnology called spin electronics has emerged, which aims at simultaneously exploiting the charge and spin of electrons in the same device. The aim of this book is to present new directions in the development of spin electronics in both the basic physics and the technology which will become the foundation of future electronics.

This book comprises the first systematic exposition of various physical aspects of the orientation of electron and nuclear spins in semiconductors by optical means.

There are only few discoveries and new technologies in physical sciences that have the potential to dramatically alter and revolutionize our electronic world. Topological insulators are one of them. The present book for the first time provides a full overview and in-depth knowledge about this hot topic in materials science and condensed matter physics. Techniques such as angle-resolved photoemission spectrometry (ARPES), advanced solid-state Nuclear Magnetic Resonance (NMR) or scanning-tunnel microscopy (STM) together with key principles of topological insulators such as spin-locked electronic states, the Dirac point, quantum Hall effects and Majorana fermions are illuminated in individual chapters and are described in a clear and logical form. Written by an international team of experts, many of them directly involved in the very first discovery of topological insulators, the book provides the readers with the knowledge they need to understand the electronic behavior of these unique materials. Being more than a reference work, this book is essential for newcomers and advanced researchers working in the field of topological insulators.

The first part provides a general introduction to the electronic structure of quasi-two-dimensional systems with a particular focus on group-theoretical methods. The main part of the monograph is devoted to spin-orbit coupling phenomena at zero and nonzero magnetic fields. Throughout the book, the main focus is on a thorough discussion of the physical ideas and a detailed interpretation of the results. Accurate numerical calculations are complemented by simple and transparent analytical models that capture the important physics.

This book provides a comprehensive introduction to spintronics-based computing for the next generation of ultra-low power/highly reliable logic. It will cover aspects from device to system-level, including magnetic memory cells, device modeling, hybrid circuit structure, design methodology, CAD tools, and technological integration methods. This book is accessible to a variety of readers and little or no background in magnetism and spin electronics are required to understand its content. The multidisciplinary team of expert authors from circuits, devices, computer architecture, CAD and system design reveal to readers the potential of spintronics nanodevices to reduce power consumption, improve reliability and enable new functionality.

Spintronics (short for spin electronics, or spin transport electronics) exploits both the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices. Controlling the spin of electrons within a device can produce surprising and substantial changes in its properties. Drawing from many cutting edge fields, including physics, materials science, and electronics device technology, spintronics has provided the key concepts for many next generation information processing and transmitting technologies. This book discusses all aspects of spintronics from basic science to applications and covers: • magnetic semiconductors • topological insulators • spin current science • spin caloritronics • ultrafast magnetization reversal • magneto-resistance effects and devices • spin transistors • quantum information devices This book provides a comprehensive introduction to Spintronics for researchers and students in academia and industry.

We study theoretically the electronic states in a 5d transition metal oxide Na2I{sub r}O3, in which both the spin-orbit interaction and the electron correlation play crucial roles. Tight-binding model analysis together with the fisrt-principles band structure calculation predicts that this material is a layered quantum spin Hall system. Due to the electron correlation, an antiferromagnetic order first develops at the edge, and later inside the bulk at low temperatures.

This book presents both experimental and theoretical aspects of topology in magnetism. It first discusses how the topology in real space is relevant for a variety of magnetic spin structures, including domain walls, vortices, skyrmions, and dynamic excitations, and then focuses on the phenomena that are driven by distinct topology in reciprocal momentum space, such as anomalous and spin Hall effects, topological insulators, and Weyl semimetals. Lastly, it examines how topology influences dynamic phenomena and excitations (such as spin waves, magnons, localized dynamic solitons, and Majorana fermions). The book also shows how these developments promise to lead the transformative revolution of information technology.

Electrical generation of spin polarization by the spin Hall effect is imaged with both spatial and temporal resolution using Kerr rotation microscopy in bulk zincblende semiconductors. The spin Hall effect, which arises due to the spin-orbit coupling, refers to the generation of a pure spin current transverse to a charge current driven by an electric field which causes a spontaneous quasi-equilibrium spin accumulation near sample boundaries without the need for magnetic fields or magnetic materials. Bulk current-induced in-plane spin polarization and out-of-plane spin accumulation from the spin Hall effect are observed in the II-VI semiconductor ZnSe despite no evidence for a spin-orbit induced internal magnetic field, which are only observed sub-critical thickness ZnSe with enhanced k-linear Hamiltonian terms due to biaxial strain. The wide band gap of ZnSe enables the first observation of electrical spin generation at room temperature. The spatial dependence of steady-state spin accumulation from the spin Hall effect is addressed in channels made of the III-V semiconductor GaAs. One- and two-dimensional spatially-resolved diffusion modeling clarifies the important role of drift and diffusion in transporting spin generated at sample boundaries to the interior of the device. Driving spin accumulation with an electrical pulse and probing with a frequency-synchronized ultrafast laser enables time-resolved measurement of the spin Hall effect. Probing the dynamical processes of spin accumulation and diffusion reveals spatially-dependent nanosecond timescales comparable to the electric-field dependent spin coherence time. Prospects are considered for an all-electrical measurement of the spin Hall effect which should enable more accurate determination of the magnitude of the spin Hall conductivity and illuminate the microscopic mechanisms governing the spin Hall effect in GaAs.

Since the discovery of the giant magnetoresistance (GMR) effect in magnetic multilayers in 1988, a new branch of physics and technology, called spin-electronics or spintronics, has emerged, where the flow of electrical charge as well as the flow of electron spin, the so-called "spin current," are manipulated and controlled together. Recent progress in the physics of magnetism and the application of spin current has progressed in tandem with the nanofabrication technology of magnets and the engineering of interfaces and thin films. This book is intended to provide an introduction and guide to the new physics and applications of spin current. The emphasis is placed on the interaction between spin and charge currents in magnetic nanostructures.

In the past several decades, the research on spin transport and magnetism has led to remarkable scientific and technological breakthroughs, including Albert Fert and Peter Grunberg's Nobel Prize-winning discovery of giant magnetoresistance (GMR) in magnetic metallic multilayers. Handbook of Spin Transport and Magnetism provides a comprehensive, bal

This book focuses on an increasingly important area of materials science and technology, namely, the fabrication and properties of artificial materials where slabs of magnetized materials are sandwiched between slabs of nonmagnetized materials. It includes reviews by experts on the theory and descriptions of the various experimental techniques such as those using nuclear or electron spin probes, as well as optical, X-ray or neutron probes. It also reviews potential applications such as the giant magnetoresistance, and one specialized preparation technique, the electrodeposition. The various chapters are tutorial in nature, making the subject accessible to nonspecialists, as well as useful to researchers in the field. Contents: Application of Magnetic Multilayers (M Pardavi-Horvath)Magnetic Coupling in Metallic Multilayers (Y Yafet)First-Principles Calculations of Magnetic Interfaces and Multilayers (M Weinert ' S Blügel)Influence of Imperfections on the Magnetic Properties of Fe/Ag Films and Multilayers (J Pirnay et al.)NMR Studies on Magnetic Multilayers (H A M de Gronckel ' W J M de Jonge)Conversion Electron Mössbauer Spectroscopy of Magnetic Multilayers (Ch Sauer ' W Zinn)Resonance in Coupled Ferromagnetic Layer Structures (P E Wigen)Magnetic Circular X-Ray Dichroism (F Baudelet et al.)Magneto-Optical Spectra in Multilayers (K Sato)Neutron and X-Ray Diffraction Studies of Magnetic Multilayers (C F Majkrzak et al.)Giant Magnetoresistance (GMR) in Multilayers (M Pardavi-Horvath)Electrodeposited Magnetic Multilayers (M P Dariel et al.) Readership: Graduate students, professional researchers and well-educated others (eg. contract officers). keywords:Magnetic Multilayers;Circular Dichroism;Giant Magnetoresistance;Magnetic Interfaces;Magnetic Multilayers: Effect of Imperfections;Conversion Electron Mossbauer Spectroscopy;Multilayer Magnetic Coupling;Magneto-Optical Spectroscopy;Neutron Diffraction;Magnetic Xray Diffraction;Magnetic Multilayer Fabrication;Supermirrors;Magnetic Recording;RKKY Coupling;Nuclear Magnetic Resonance;Ferromagnetic Resonance

This chapter will focus on the experimental properties of the quantum spin Hall effect in HgTe quantum well structures. HgTe quantum wells above a critical thickness are 2-dimensional topological insulators. The most prominent signature of the non-trivial topology in these systems is the occurrence of the quantum spin Hall effect when the Fermi energy is located inside the bulk band gap. We will present the main experimental results we obtained for transport in the quantum spin Hall regime and discuss how they confirm the prediction of the quantum spin Hall effect as a helical edge state system consisting of two counterpropagating oppositely spin polarized edge states.

STAY UP TO DATE ON THE STATE OF MRAM TECHNOLOGY AND ITS APPLICATIONS WITH THIS COMPREHENSIVE RESOURCE Magnetic Memory Technology: Spin-Transfer-Torque MRAM and Beyond delivers a combination of foundational and advanced treatments of the subjects necessary for students and professionals to fully understand MRAM and other non-volatile memories, like PCM, and ReRAM. The authors offer readers a thorough introduction to the fundamentals of magnetism and electron spin, as well as a comprehensive analysis of the physics of magnetic tunnel junction (MTJ) devices as it relates to memory applications. This book explores MRAM's unique ability to provide memory without requiring the atoms inside the device to move when switching states. The resulting power savings and reliability are what give MRAM its extraordinary potential. The authors describe the current state of academic research in MRAM technology, which focuses on the reduction of the amount of energy needed to reorient magnetization. Among other topics, readers will benefit from the book's discussions of: An introduction to basic electromagnetism, including the fundamentals of magnetic force and other concepts An thorough description of magnetism and magnetic materials, including the classification and properties of magnetic thin film properties and their material preparation and characterization A comprehensive description of Giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR) devices and their equivalent electrical model Spin current and spin dynamics, including the properties of spin current, the Ordinary Hall Effect, the Anomalous Hall Effect, and the spin Hall effect Different categories of magnetic random-access memory, including field-write mode MRAM, Spin-Torque-Transfer (STT) MRAM, Spin-Orbit Torque (SOT) MRAM, and others Perfect for senior undergraduate and graduate students studying electrical engineering, similar programs, or courses on topics like spintronics, Magnetic Memory Technology: Spin-Transfer-Torque MRAM and Beyond also belongs on the bookshelves of engineers and other professionals involved in the design, development, and manufacture of MRAM technologies.

The quantum Hall liquid is a novel state of matter with profound emergent properties such as fractional charge and statistics. Existence of the quantum Hall effect requires breaking of the time reversal symmetry caused by an external magnetic field. In this work, we predict a quantized spin Hall effect in the absence of any magnetic field, where the intrinsic spin Hall conductance is quantized in units of 2 e/4[pi]. The degenerate quantum Landau levels are created by the spin-orbit coupling in conventional semiconductors in the presence of a strain gradient. This new state of matter has many profound correlated properties described by a topological field theory.

This book is a collection of lecture notes which were presented by invited speakers at the Eleventh School on Theoretical Physics "Symmetry and Structural Properties of Condensed Matter SSPCM 2014" in Rzeszów (Poland) in September 2014. The main challenge for the lecturers was the objective to present their subject as a review as well as in the form of introduction for beginners. Topics considered in the volume concentrate on: spin dynamics and spin transport in magnetic and non-magnetic structures, spin-orbit interaction in two-dimensional systems and graphene, and new mathematical method used in the condensed matter physics. Contents: Lectures on Non-Abelian Bosonization (A M Tsvelick)Electrical and Thermal Control of Magnetic Moments (J Barna?, P Balaz, A Dyrda? and V K Dugaevk)Rigged String Configurations, Bethe Ansatz Qubits, and Conservation of Parity (T Lulek)Nonequilibrium Spin Dynamics: From Protons in Water to a Gauge Theory of Spin-Orbit Coupling (I V Tokatly and E Ya Sherman)Non-Markovian Effects in the Lindblad Master Equation Approach to Electronic Transport (P Ribeiro and V R Vieira)Quantum Transport in Hybrid Nanostructures (K I Wysoki?ski, T Doma?ski and B Szukiewicz)Resonant Scattering Off Magnetic Impurities in Graphene: Mechanism For Ultrafast Spin Relaxation (D Kochan, M Gmitra and J Fabian)Spin-Orbit Interaction and Related Transport Phenomena in 2D Electron and Hole Systems (A Khaetskii)Landau Weak Crystallization Theory and Its Applications (E I Kats)Coupled Polarization/Magnetization Dynamics in Composite Multiferroics: An Overview (A Sukhov, L Chotorlishvili, C L Jia and J Berakdar)Reservoir Approach to Two-Dimensional Electron Gas in a Magnetic Field (W Zawadzki, A Raymond and M Kubisa)From Graphene and Topological Insulators to Weyl Semimetals (R D Y Hills, M Brada, Yang Liu, M Pierpont, M B Sobnack, W M Wu and F V Kusmartsev) Readership: For graduate students and junior condensed matter theorists. Key Features:Intermediate level between students textbook and monographProminent contributorsVarious modern aspects of condensed matter theoryKeywords:Symmetry;Spin Dynamics;Graphene;Topological Insulators;Nanostructures

This dissertation focuses on the study of spin-dependent transport in systems with strong spin-orbit coupling within their band structure. In particular we focus on the anomalous Hall effect, the spin Hall effect, and the Aharonov-Casher effect whose origins, are linked to the presence of spin-orbit coupling. Given the theoretical controversy surrounding these effects we further simplify our studies to semiconductor systems where the band structure is much simpler than in metallic systems with heavy elements. To obtain finite analytical results we focus on reduced dimensions (two and one dimensions) which can be explored experimentally. To set the stage, we discuss the origins of the strong spin-orbit coupling in semiconductors deriving the effective interaction from the Dirac equation. We discuss in detail the skew scattering contribution to the anomalous Hall effect in two-dimensional systems, which is dominant for systems with low impurity concentrations, and find that it is reduced when the two chiral subbands are partially occupied in an electron gas and vanishes for a hole gas, regardless of the band filling. We also present calculations for all contributing mechanisms. We propose a device to test this prediction and study the crossover from the intrinsic to the extrinsic anomalous Hall effect. We calculate all contributions to the anomalous Hall effect in electron systems using the Kubo-Streda formalism. We find that all contributions vanish when both subbands are occupied and that the skew scattering contribution dominates when only the majority subband is occupied. We calculate the interference effects due to spin-orbit interaction in mesoscopic ring structures patterned from HgTe quantum wells related to the Aharonov-Casher effect and the spin Hall effect. We find that the transport properties are affected by the carrier density as well as the spin orbit interaction. We find that the conductivity is larger in hole gas systems. We also show that devices with inhomogenous spin orbit interaction exhibit an electrically controlled spin-flipping mechanism.

"This series summarizes the field of Organic Spintronics up to 2017. It contains four volumes dedicated to spin injection, spin transport, spin pumping, organic magnetic field effect, and molecular spintronics. The field of Organic Spintronics has accelerated and matured in the last dozen years with the realization of an organic spin-valve (in 2004) and magneto-resistance and magneto-electroluminescence in organic optoelectronic devices (2006). The book series is comprehensive in that it summarizes all aspects of Organic Spintronics to date. The first two volumes deal with spin injection, spin transport, spin manipulation and spin pumping into organic semiconductors. The main device that is thoroughly discussed here is the organic spin-valve, where spinterface states at the interface between the organic semiconductor and the ferromagnetic (FM) electrode has been the focus of many chapters. An interesting emerging subject is the role of chirality in the organic layer of the device. A relatively new method of achieving spin aligned carriers in organic semiconductors is spin pumping, where magnons in the FM substrate generate spin aligned carriers in the organic layer at the FM/organic interface. The third volume deals mainly with magnetic field effect in organic devices. Several spin-mixture processes that lead to magnetic field effect in devices and films are thoroughly discussed, such as hyperfine interaction, direct spin-orbit coupling, indirect spin-orbit coupling via [delta]g, triplet-triplet annihilation, and thermal spin alignment. The similarity between the magnetic field effect obtained in optoelectronic devices based on organic semiconductors and the novel hybrid organic-inorganic semiconductors is also a subject of intense interest. The fourth volume deals with spin in molecular films and devices. It includes thorough discussion of spin exchange interaction that leads to organic ferromagnets, as well as manifestation of various spin interactions in thin molecular films and devices."--

The spin Hall effect (SHE) induced spin current in some certain heavy transition metals has been shown to impose spin transfer torque (STT) upon an adjacent magnetic layer strong enough to excite magnetization switching and/or magnetic oscillation therein. The similarities and differences between this new paradigm and the traditional route of spin generation will be the main focus of this dissertation. Firstly, these phenomena stemming from the SHE can be viewed as a reminiscent of the traditional spin-torque generation from a ferromagnetic layer in spin-valve-like devices, except that now the source of the STT is coming from the normal metal (NM) layer instead of the ferromagnetic (FM) spin-polarizer in those traditional devices with sandwich structures (FM/NM/FM or FM/Insulator/FM). In this fashion, essentially only one layer of ferromagnetic layer is required as the read-out means. In the first part of this dissertation, I will show that this detection of the spin-Hall response can be done either via anisotropic magnetoresistance (AMR), anomalous Hall effect (AHE), or planar Hall effect (PHE) in a simple NM/FM bilayer structure. By analyzing the data from both high and low frequency measurements, the spin Hall angle, which represents the strength of the SHE, from various transition metals are estimated. Secondly, the symmetry of the SHE, from which the resulting spin current is transverse to the applied charge current, allows us to design STT devices using in-plane charge current (CIP) instead of the traditional utilization of current-perpendicular-toplane (CPP) architecture. This facilitates the realization of a new three-terminal

device, which eventually leads us to a prototype of magnetic cross-point nonvolatile memory. By studying the SHE-STT switching from beta-Ta and beta-W-based three-terminal devices, I will confirm that the spin Hall angle of [beta]-Ta and [beta]-W are respectively [ALMOST EQUAL TO]-0.15 and [ALMOST EQUAL TO]-0.30, which are consistent with the results from the first part of this work. The strong SHE from these transition metals can also be adopted to modulate spin-waves and will be shown at the end of this section. Lastly, the adaptation of a CIP architecture means that the spin-charge transport properties in the spin Hall devices are, per se, more complicated than that in their CPP counterparts. The interface(s) as well as the bulk properties in these magnetic heterostructures both play important roles in determining the final spin transport properties, thereby the effective spin Hall efficiency. In this final section, I will present the variation of the current induced damping-like torque and field-like torque in NM/(spacer)/FM heterostructures, from which the possible interplay between interface(s) and bulk, as well as their relative contributions, can be estimated.
This thesis presents an in-depth theoretical analysis of charge and spin transport properties in complex forms of disordered graphene. It relies on innovative real space computational methods of the time-dependent spreading of electronic wave packets. First a universal scaling law of the elastic mean free path versus the average grain size is predicted for polycrystalline morphologies, and charge mobilities of up to 300.000 cm2/V.s are determined for 1 micron grain size, while amorphous graphene membranes are shown to behave as Anderson insulators. An unprecedented spin relaxation mechanism, unique to graphene and driven by spin/pseudospin entanglement is then reported in the presence of weak spin-orbit interaction (gold ad-atom impurities) together with the prediction of a crossover from a quantum spin Hall Effect to spin Hall effect (for thallium ad-atoms), depending on the degree of surface ad-atom segregation and the resulting island diameter.
Spintronics is an emerging technology that exploits the intrinsic spin of the electron and its associated magnetic moment in addition to its fundamental electronic charge. The central issue of this multidisciplinary field is the manipulation of the spin degree of freedom in solid-state systems. Discoveries in recent years have inspired a new route in spintronic research which needs no ferromagnetic components. The research field "spintronic without magnetism" is based on the possibility to manipulate electric currents via spin-orbit coupling only. The spin Hall effect (SHE) is one of the most promising effects for the generation of spin polarized currents which is even present in non-magnetic materials. The SHE appears when an electric current flows through a medium with spin-orbit coupling present, leading to a spin-current perpendicular to the charge current. In this work the SHE as well as the anomalous Hall effect (AHE) are investigated on a first principles level using the spin-polarized fully relativistic Korringa-Kohn-Rostoker Green's function method (SPR-KKR-GF) in conjunction with the linear response Kubo-Streda formalism. Intrinsic as well as extrinsic contributions to the SHE/AHE are treated on equal footing. This opened up for the first time the possibility to reliably decompose the SHE/AHE into skew and side-jump scattering as well as intrinsic contributions in a quantitative manner.
Present worldwide funding in organic electronics is poised to stimulate major research and development efforts in organic materials research for lighting, photovoltaic, and other optoelectronic applications. The field of organic spintronics, in particular, has flourished in the area of organic magneto-transport. Reflecting the main avenues of substantial advances in this arena, Organic Spintronics is an up-to-date summary of the experimental and theoretical aspects of the field. With contributions by a panel of international experts on the cutting edge of research, this volume explores: Spin injection and manipulation in organic spin valves The magnetic field effect in organic light-emitting diodes (OLEDs) The spin transport effect in relation to spin manipulation Organic magnets as spin injection electrodes in organic spintronics devices The coherent control of spins in organic devices using the technique of electronically detected magnetic resonance The possibility of using organic spin valves as sensors Balancing practical experimentation with analytical constructs, the book covers both the theoretical aspects of spin injection, transport, and detection in organic spin valves as well as the underlying mechanism of the magnetoresistance and magneto-electroluminescence in OLEDs. The first book of its kind on this specialized area, this volume is destined to provide researchers and students with the impetus to develop new channels of inquiry in an area that has almost limitless potential.
As the first comprehensive introduction into the rapidly evolving field of spintronics, this textbook covers ferromagnetism in nano-electrodes, spin injection, spin manipulation, and the practical use of these effects in next-generation electronics. Based on foundations in quantum mechanics and solid state physics this textbook guides the reader to the forefront of research and development in the field, based on repeated lectures given by the author. From the content: Low-dimensional semiconductor structures Magnetism in solids Diluted magnetic semiconductors Magnetic electrodes Spin injection Spin transistor Spin interference Spin Hall effect Quantum spin Hall effect Topological insulators Quantum computation with electron spins
The purpose of this collective book is to present a non-exhaustive survey of sp- related phenomena in semiconductors with a focus on recent research. In some sense it may be regarded as an updated version of theOpticalOrientation book, which was entirely devoted to spin physics in bulk semiconductors. During the 24 years that have elapsed, we have witnessed, on the one hand, an extraordinary development in the wonderful semiconductor physics in two dim- sions with the accompanying revolutionary applications. On the other hand, during the last maybe 15 years there was a strong revival in the interest in spin phen- ena, in particular in low-dimensional semiconductor structures. While in the 1970s and 1980s the entire world population of researchers in the ?eld never exceeded 20 persons, now it can be counted by the hundreds and the number of publications by the thousands. This explosive growth is stimulated, to a large extent, by the hopes that the electron and/or nuclear spins in a semiconductor will help to accomplish the dream of factorizing large numbers by quantum computing and eventually to develop a new spin-based electronics, or “spintronics”. Whether any of this will happen or not, still remains to be seen. Anyway, these ideas have resulted in a large body of interesting and exciting research, which is a good thing by itself. The ?eld of spin physics in semiconductors is extremely rich and interesting with many spectacular effects in optics and transport.
Spin CurrentOUP Oxford

Since the discovery of the giant magnetoresistance (GMR) effect in magnetic multilayers in 1988, a new branch of physics and technology, called spin-electronics or spintronics, has emerged, where the flow of electrical charge as well as the flow of electron spin, the so-called "spin current", are manipulated and controlled together. Recent progress in the physics of magnetism and the application of spin current has progressed in tandem with the nanofabrication technology of magnets and the engineering of interfaces and thin films. This book is intended to provide an introduction and guide to the new physics and applications of spin current. The emphasis is placed on the interaction between spin and charge currents in magnetic nanostructures.

The first part of this state-of-the-art book conveys the fundamentals of magnetism for atoms and bulk-like solid-state systems, providing a basis for understanding new phenomena which exclusively occur in low-dimensional systems as the giant magneto resistance. This wide field is discussed in the second part. Suitable for graduate students in physical and materials sciences, the book includes numerous examples, exercises, and references.

For 50 years conventional electronics has ignored the electron spin. The manipulation and utilisation of the electron spin heralds an exciting and rapidly changing era in electronics, combining the disciplines of magnetism and traditional electronics. The first generation of "spintronic" devices (such as read heads based on giant magnetoresistance or non-volatile magnetic random access memories) have already gained dominant positions in the market place. This volume, the first of its kind on spin electronics describes all the essential topics for new researchers entering the field. It covers magnetism and semiconductor basics, micromagnetism, experimental techniques, materials science, device fabrication and new developments in spin-dependent processes. At the end of most chapters are a number of exercises and worked problems to aid the reader in understanding this fascinating new field.

We show that the bulk Dresselhauss (k3) spin-orbit coupling term leads to an intrinsic spin-Hall effect in n-doped bulk GaAs, but without the appearance of uniform magnetization. The spin-Hall effect in strained and unstrained bulk GaAs has been recently observed experimentally by Kato et. al. [1]. We show that the experimental result is quantitatively consistent with the intrinsic spin-Hall effect due to the Dresselhauss term, when lifetime broadening is taken into account. On the other hand, extrinsic contribution to the spin-Hall effect is several orders of magnitude smaller than the observed effect.

Topological insulators are insulating in the bulk, but process metallic states present around its boundary owing to the topological origin of the band structure. The metallic edge or surface states are immune to weak disorder or impurities, and robust against the deformation of the system geometry. This book, the first of its kind on topological insulators, presents a unified description of topological insulators from one to three dimensions based on the modified Dirac equation. A series of solutions of the bound states near the boundary are derived, and the existing conditions of these solutions are described. Topological invariants and their applications to a variety of systems from one-dimensional polyacetalene, to two-dimensional quantum spin Hall effect and p-wave superconductors, and three-dimensional topological insulators and superconductors or superfluids are introduced, helping readers to better understand this fascinating new field. This book is intended for researchers and graduate students working in the field of topological insulators and related areas. Shun-Qing Shen is a Professor at the Department of Physics, the University of Hong Kong, China.