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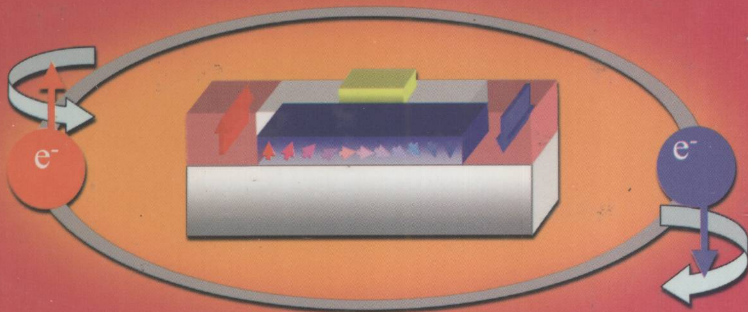

SPINTRONIC MATERIALS AND TECHNOLOGY

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Preface

Spintronics is an exciting and rapidly expanding new field of microelectronics and nanoelectronics, which is based on exploiting the fact that electrons have spin as well as charge. For decades, the information technology (IT) industry has followed Moore's law, that the number of transistors on a chip doubles about every 2 years, but conventional solid state electronics may soon reach a limit due to the increasing heat dissipation challenges of charge current and quantum size effects in small devices. Spintronics, molecular electronics, and carbon-based electronics along with advances in nanotechnology are expected to ensure continued adherence to Moore's law in the future. Within the context of spintronics, the electrons' spins, not just their electrical charge, are manipulated within electronic circuits. These spintronic devices, combining the extra degree of freedom offered by magnetic materials and the versatility of active semiconductor devices, are anticipated to be nonvolatile, versatile, fast, and capable of simultaneous data storage and processing, while consuming less energy. They already play an increasingly significant role in high-density data storage, microelectronics, magnetic sensors, quantum computing, biomedical applications, and so on.

It was the discovery of giant magnetoresistance (GMR) in the early 1980s that initiated spintronic research and resulted in the first generation of a spintronic device in the form of the spin valve. Today, spintronic devices are ubiquitous on the desktop as spin valves play their role as the active element in the read head of most hard disk storage devices. GMR was followed rapidly by the discovery of tunneling magnetoresistance leading to the magnetic tunnel junction that has been utilized in developing the next generation of memory known as magnetic random access memory — an example of another spintronic device. Second-generation spintronic devices will integrate magnetic materials and semiconductor devices to create new flexible devices such as spin transistors and spin logic. These second-generation spintronic devices will not just improve the existing capabilities of electronic transistors, but will have new functionalities enabling future computers to run faster, but consume less power, and have the potential to revolutionize the IT industry as did the development of the transistor 50 years ago.

This book is divided into three parts, covering the main research challenges in spintronics. Part I, "Spintronic Material and Characterization," deals with the properties, desirable features, and the search for new spintronic materials ranging from magnetic oxides and metallic GMR materials to dilute magnetic semiconductors. Their magnetic, structural, and spin-dependent transport properties are characterized using many different conventional laboratory-based techniques and more novel synchrotron radiation-based measurements. In Part II, "Spin Torque and Domain Wall Magnetoresistance," issues concerning the operation of spintronic devices are addressed including the new principle for the operation of future spintronic devices using spin-polarized current rather than conventional applied magnetic fields. This promises to enable the switching of the individual spin components of the device while avoiding cross talk at the nanoscale. In Part III, "Spin Injection and Spin Devices," complete device ideas are explored describing both Si and III-V semiconductor-based spin transistors and the integration of spin technology with photonics.

The book provides background, introduction, the latest research results, and an extensive list of references in each chapter. The textbook style is intended to satisfy the needs of graduate students and young researchers, who have little knowledge of this new area. The collection of this material in one book enables the challenges and progress toward the ultimate goal of spin-controlled devices to be seen in context, and the individual chapters are designed to be self-contained to aid the researcher concerned with one particular area. Due to the multidisciplinary nature of spintronics research, the book covers a wide range of topics in materials science, physics, device fabrication, characterization, and operation. All the authors are active researchers and leading experts in these areas, ensuring that the book provides an excellent insight into the current development and future of spintronics.

The editors wish to thank the authors in writing their chapters so that this very first book in spintronics could be accessible to a general audience. The editors thank Professor Brian Cantor, FREng, for advice in preparing this book. The editors would also like to thank John Navas, Amber Donley, and Gail Renard from the Taylor & Francis Group, LLC.

Yongbing Xu
Sarah Thompson

The Editors

Yongbing Xu is an anniversary reader, which is a senior professorship in nanotechnology at the University of York, UK, and heads the Spintronics Laboratory in Electronics. Before moving to York in 2000, he was a senior research fellow at the Cavendish Laboratory, University of Cambridge. He was awarded Ph.D.s by Nanjing University, China, in 1993, and the University of Leeds, UK, in 1996. His research interests are in the areas of spintronics, magnetic nanomaterial, nanodevices, and nanofabrication. He has published more than 120 refereed papers in leading academic journals and given many invited talks at international conferences. He is the coordinator and chair of the steering committee of the WUN (Worldwide University Network) Grand Challenge Project "Spintronics," which includes 20 partners from 12 leading universities in the UK, USA, and China. He is the section editor in spintronics of the journal *Current Opinion in Solid State and Materials Science* published by Elsevier. In 2000, he was awarded the prestigious EPSRC advanced fellowship. He is the stream leader of the York MEng/BEng program in nanotechnology and teaches introductory nanotechnology, solid state devices, nanoelectronics, and advanced information storage.

Sarah Thompson is a senior lecturer at the University of York, York, UK, and heads the Magnetic Thin Films Research Group in the physics department. She has 15 years' research experience in the fabrication, structural, magnetic, and transport properties of magnetic thin films and multilayers concentrating on spin dependent transport, recently in spin electronics. Since 1999, Dr. Thompson has pioneered the development of infrared spectroscopy in a magnetic field to probe the spin dependent transport in magnetic materials, and combining these two areas of expertise, she is the champion for the spintronics Flagship Project for the Development of the 4GLS at Daresbury Laboratory, UK.

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G.A. Gehring, A.J. Behan, H.J. Blythe, A.M. Fox, R.M. Ibrahim, A. Mokhtari, and J.R. Neal

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