Preface

Papers in a previous issue of this journal [Volume 42, Number 1, 1998] covered advances in metallic magnetic multilayer films, including giant magnetoresistance, oscillatory interlayer exchange, and related effects. To a large extent, those advances made possible significant improvement in read-head sensors for magnetic disk drive systems, leading to a remarkable 60% annual growth rate of areal bit density in magnetic recording systems over the last 15 years!

This group of papers pertain to advances that have occurred over the past decade in related structures that combine magnetic metallic multilayer films with ultra-thin insulating layers (tunnel barriers), semiconducting layers, or both. The structures are being developed for a diverse set of potential applications such as nonvolatile random access memory, improved magnetic sensors, and new rf and microwave frequency oscillators and radiation sources. The first six papers relate to the development of magnetic random access memory (MRAM) technology, based on the use of the magnetic tunnel junction. The next four deal with other aspects of spin transport electronics—spintronics, including especially spin transport in semiconductors.

In the first paper, Gallagher and Parkin review the history of magnetic memory and of the magnetic tunnel junction, with emphasis on developments at IBM over the past decade. The authors frame this work in the context of the historical development of tunneling devices, of spin-polarized tunneling, and of the development of other types of microelectronic memories. The paper also serves to introduce the more specialized MRAM-related papers that follow.

Use of the magnetic tunnel junction to produce a random access memory is described in the paper by Maffitt et al. The paper covers the basics of MRAM read and write principles and array options. It then goes on to describe in detail design considerations that are particularly important for MRAM and that were implemented in a 16-Mb demonstrator chip which was designed in a development partnership with Infineon.

Challenges involved in the fabrication of magnetic tunnel junctions for MRAM are described in the paper by Gaidis et al. The paper illustrates the key process challenges in the context of a shortened fabrication route, focusing on evaluating the magnetic stack structures, the patterning, and the encapsulation process used. The paper by Abraham, Trouilloud, and Worledge discusses novel magnetic tunnel junction characterization methods for the device structures processed, often with just one patterning level. The methods also help speed materials and unit process development, and provide means of monitoring the reproducibility of unique MRAM process steps.

Virtually all other memory technologies make use of at least one transistor per cell as part of the write-selection process. Magnetic memories, by contrast, can work by two-dimensional (x- and y-addressing) magnetic selection, thus not requiring a write transistor at each cell. Magnetic field writing processes in magnetic tunnel junctions are studied using a single-domain magnetic model in the paper by Worledge. In particular, a toggle-mode method of writing bi-layer magnetic bits is analyzed and shown to have better write margins than direct magnetic threshold writing of single-layer bits.

As magnetic bits scale to smaller and smaller sizes, magnetic write selection methods tend to require larger write currents. Fortunately, below about 100 nm in device size, however, it becomes possible to influence the magnetic moment by direct spin injection. The paper by Sun covers the mechanisms of the spin angular momentum transfer effect, the status of associated experimental and theoretical work, and the potential for using spin angular momentum transfer in applications such as writing MRAM bits and as a source of microwave radiation.

The paper by Wolf, Chtchelkanova, and Treger serves to introduce broader spects of spintronics. In fact, the term *spintronics* was coined by the first author of the paper to designate the U.S. Defense Advanced Research Projects Agency (DARPA) funding initiative to advance the use of magnetic devices in electronics. That program partially funded some of the MRAM work described in several papers of this issue. In their paper, Wolf and colleagues review, from their unique perspective, work on spintronic memory and sensors based on magnetic tunnel junctions, as well as promising new materials and associated devices pertaining to spin transport in semiconductors. The review also serves as an introduction to the next three papers, which deal with aspects of spin transport in semiconductors.

A key requirement in semiconductor spintronic devices is that a means be provided for efficient spin injection. In their paper, Jiang et al. review exciting recent progress in spin injection by means of CoFe/MgO(001)/AlGaAs tunnel junctions. The authors were the first to demonstrate highly efficient injection with that approach. Their paper reviews that achievement, as well as interesting magnetic and magneto-optical transport studies carried out using such injectors.

Žutić, Fabian, and Erwin describe a proposal for producing "bipolar" spintronic devices in which both electrons and holes would contribute to spin-charge coupling. The authors predict novel spin-related effects in two- and three-dimensional device structures.

The final paper of the group, by Bernevig and Zhang, explores the idea that dissipationless spin transport in semiconductors could lead to spin-based logic devices that would dissipate much less power than their charge-based equivalents. The basis for this is described, and the conditions for its realization discussed.

In summary, these papers provide a snapshot of the rapidly developing field of spintronics, with exciting scientific breakthroughs showing great potential for both near-term and long-term applications.

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