Magnetic Memory

If you are a semiconductor engineer or a magnetics physicist developing magnetic memory, get the information you need with this, the first book on magnetic memory.

From magnetics to the engineering design of memory, this practical book explains key magnetic properties and how they are related to memory performance, characterization methods of magnetic films, and tunneling magnetoresistance effect devices. It also covers memory cell options, array architecture, circuit models, and read-write engineering issues.

You'll understand the soft-fail nature of magnetic memory, which is very different from that of semiconductor memory, as well as methods to deal with the issue. You'll also get invaluable problem-solving insights from real-world memory case studies.

This is an essential book, both for semiconductor engineers who need to understand magnetics, and for magnetics physicists who work with MRAM. It is also a valuable reference for graduate students working in electronic/magnetic device research.

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Magnetic Memory
Fundamentals and Technology

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The advent of semiconductor technology has impacted the lives of many of us since the 1970s. Silicon CMOS (complementary metal-oxide-semiconductor) devices are practically ubiquitous, and by the year 2000, the value of the semiconductor industry exceeded that of the automobile industry. The magnetic industry, on the other hand, is much smaller than the semiconductor industry. Engineering schools of universities rarely cover any courses in this discipline. Nonetheless, a tiny magnetic recording device is in the hard disk of every computer. Like CMOS devices, magnetic recording technology is being scaled down from generation to generation. At the time of writing, the physical size of the magnetic bit remains smaller than a DRAM bit on silicon chips.

Researchers working in these two communities had little in common until the development of the modern magnetic random access memory, or MRAM. A MRAM chip is built by integrating magnetic tunneling junction (MTJ) devices onto the silicon CMOS circuits. The research activity of MTJs in academia and industry, both hard disk and semiconductor, has been very active since it first showed signs of technology implication in the mid 1990s. That effort led to the mass production of the MTJ recording head in hard disk in 2006. In the same year, the semiconductor industry announced the first successful introduction of an MTJ memory product. The viability of MTJ technology is proven. It is expected that research activities will develop further, which will increase cooperation between these two research communities. The purpose of this book is to facilitate the dialog and to bridge the gap. Each simple homework problem and answer is designed to help readers to link the magnetics to the memory performance. Thus, the book is suitable for those with discipline of semiconductor devices and wish to "fine-tune" magnetics for MRAM chips.

The book is organized into seven chapters. Chapter 1 reviews the electric current, as most electrical engineering students learn, in their sophomore and junior years, that magnetism results from an electric current. This chapter introduces readers to the unit conversion ready for the discussion in Chapter 2, which deals with the origin of magnetism in materials and introduces the concepts of electron spin, magnetic moments and its dynamics. It covers the microscopic view of the magnetic moment of an electron and an atom, and investigates its relationship with the macroscopic properties of magnetic thin film materials. Once the
film is patterned to make devices, it behaves very differently from a full film. Chapter 3 covers the properties of the patterned thin magnetic films. This leads to the discussion of magnetization switching properties of many modern magnetic RAM devices. Chapter 4 introduces the magnetoresistance effect in thin film stacks, covering AMR (anisotropy magneto-resistance), GMR (giant magneto-resistance) and TMR (tunnel magneto-resistance) effects. The magneto-resistance effect is the operational principle of all modern non-volatile magnetic memories. A thorough discussion of the magnetic tunnel junction is presented. A detailed description of the properties and the design of field-write modes magnetic memory device are given in Chapter 5 and that of spin-torque transfer mode in Chapter 6. The discussion also covers circuit aspects of the memory cell and memory array, and the circuit model of the magnetic tunnel junction device, so that one can gain a better perspective of the merits in the design of the magnetic tunnel junction for memory. Chapter 7 covers the present memory market and the position of the magnetic memory in this market. New applications of this technology will also be discussed.

This is a very active field. Papers and patent applications of the related subject appear continuously and in large quantities. This book aims to provide the reader with a sufficient understanding of the fundamental physics of magnetics, the properties of magnetic thin film materials, device properties, design, memory operation and many other aspects of engineering. It also aims to give those working with semiconductors a head start so that they may bring in more fruitful results to this relatively new field.

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