"Developments in Data Storage: Materials Perspective"

Edited by S. N. Piramanayagam (Data Storage Institute, A*STAR (Agency for Science, Technology and Research), Singapore) and Tow C. Chong (Singapore University of Technology and Design, Singapore), Wiley-IEEE Press, Hoboken/Piscataway, New Jersey, USA, 2012, 352 pages, ISBN: 978-0-470-50100-9, £80.50, €96.60, US$120.00

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Introduction

"Developments in Data Storage" is intended to provide the reader with a well-structured and concise overview of the data storage market from a materials viewpoint. Edited by S. N. Piramanayagam and Tow C. Chong, the chapters are written by a series of experts from both academia and industry including some of the world's largest data storage companies (HGST, Seagate Technology and Western Digital to name just a few). Aimed at university level students, the book provides sufficient variety to satisfy a range of technical backgrounds and knowledge, from physics and chemistry to materials science and electronics. This book provides an excellent introduction to the field of data storage, beginning with the basics of magnetism before guiding the reader through the latest developments in data storage, which may well be used in your computer over the next few years.

Consisting of fourteen chapters, the authors take the reader logically from the general concepts of recording and magnetism, through the disk and head technologies, explaining the all-important interface between the two before moving on to the emerging technologies in the fields of magnetic recording and solid state memory.

Data Storage

The first chapter begins by neatly introducing the concept of data storage through some interesting references to the earliest methods of preserving data such as stone carvings or early cave paintings. A brief history of more recent data storage technologies ensues, from punch cards and magnetic tapes (many people will not realise that magnetic recording is well over 100 years old, having first been demonstrated by Valdemar Poulsen in 1898 (1)) through to the ubiquitous hard disk drives that we are so dependent upon today.

The key concept of areal storage density – the amount of data that can be stored on a given area – is explained, as well as the issue of the 'media trilemma'. Ever increasing requirements for greater data storage mean that this 'trilemma' is of central importance to new developments in hard disk technology. At the core of the issue are three aspects:

(a) obtaining an acceptable signal-to-noise ratio (SNR);
(b) maintaining thermal stability of the data bits; and
(c) allowing data to be successfully written to the storage medium in ever decreasing bit sizes.

The remainder of the chapter deals with the fundamentals of data storage, which are presented in an easy to understand manner. The basics of hard disk technology are described, accompanied by some useful photographs of the internal workings of the disk drive (**Figure 1**). Brief sections on recording media, heads and the head-disk interface lead nicely into a swift examination of future hard disk and other storage technologies such as flash memory.

Fundamentals of Magnetism

After the relatively gentle introductory chapter, the next instalment is somewhat more academically focused, as the fundamentals of magnetism are introduced. Taking the reader from the most basic of magnets, such as those used in a navigational compass, and through the world of quantum mechanics before explaining the various types of magnetic anisotropy is clearly no easy task, but one that the author does very elegantly. The succinct explanations of often complex principles are aided by a combination of diagrams, equations and the occasional microscopy image, which by the end of the chapter gives the reader the necessary understanding to fully appreciate how magnetic recording is achieved.

Fig. 1. Hard disk drive with cover removed, showing the pgm-containing disk in which information is stored

Longitudinal and Perpendicular Magnetic Recording

Chapters 3 and 4 are of particular relevance to platinum group metals (pgms) as they are key to achieving the required properties to meet all three aspects of the 'media trilemma' described earlier. These chapters are where the book really starts to delve into the detail of hard disk drive recording. The two most recent hard disk recording technologies, longitudinal magnetic recording (LMR) and perpendicular magnetic recording (PMR), are discussed in Chapters 3 and 4, respectively, and the differences in layer composition of the disk media that allowed a step change improvement in areal density to be achieved are described in detail. LMR had existed for around 50 years before being superseded by PMR technology in 2005–2006.

In Chapter 3, the simplified representation of the basics of magnetic recording given in the introductory chapter is expanded upon as each bit cell is described as being effectively a small magnet. In real magnetic media a collection of grains makes up one bit cell. In the older LMR technology multiple grains were required to provide the necessary voltage for the information to be read effectively by the head. The possibility of using only one grain per bit is alluded to, and is followed up in a later chapter regarding future technology. The LMR chapter, as well as providing a historical perspective, is used by the author to introduce concepts applicable outside of LMR such as magnetism at the nanoscale, how to measure recording performance, types of noise and how to minimise it, and the important issue of thermal stability.

The chapter concludes with an excellent section on the production of hard disk media by the sputtering process, in which the various different layers are applied from a series of different targets. Argon ions are fired at the target, and the energised Ar atoms displace atoms from the target surface which are then deposited on the substrate.

PMR, the current technology of choice for all hard disk producers is the topic of Chapter 4. The first section provides an introduction to the key issues involved in moving from storing data parallel to the disk surface to aligning the magnetisations perpendicular to the surface. Again a combination of diagrams and images

are used to help illustrate the key points, such as how the data is written and how it differs from the LMR technology.

A description and illustration of the various layers that make up a PMR disk follows, with a lengthy section describing the soft magnetic underlayer (SUL), whose presence is one of the key differences between PMR and LMR technologies (**Figure 2**). After an explanation of the key layers attention turns to the composition of current PMR media, where the use of Pt is discussed as a key alloy component in the magnetic storage layer.

Role of Ruthenium

The use of Ru in hard disk technology is discussed in the section of Chapter 4 regarding improvements in the SNR. Maintaining a good SNR, while simultaneously ensuring thermal stability and writeability, is part of the trilemma which the authors continually refer back to throughout the text. There is considerable discussion of the use of Ru in the intermediate layer between the SUL and the recording layer, again highlighting the vital role pgms play in the data storage industry.

The Ru performs two key functions: primarily it is used to break the coupling between the SUL and the recording layer, thus reducing noise, but it also has a secondary use whereby it induces perpendicular orientation of the magnetic alloy. Mention is made of the 2006 price spike (2), during which the Ru price increased by close to 400% as hard disk companies moved to the new technology, with the effect of dramatically increasing global Ru demand in a short time frame.

The chapter, which is one of the most relevant to pgm usage, concludes with a discussion of recent developments and future trends. This concentrates mainly on changes to the magnetic and soft underlayers and gives brief mention to some experimental work using an iridium-manganese (IrMn) layer to replace the thick Ru-containing interlayers.

Read-Write Technology

Chapters 5–9 are of less relevance to pgms and so will not be covered in detail in this review. Suffice it to say that the chapters on write head fundamentals, magnetoresistive read heads, read sensors, thin film

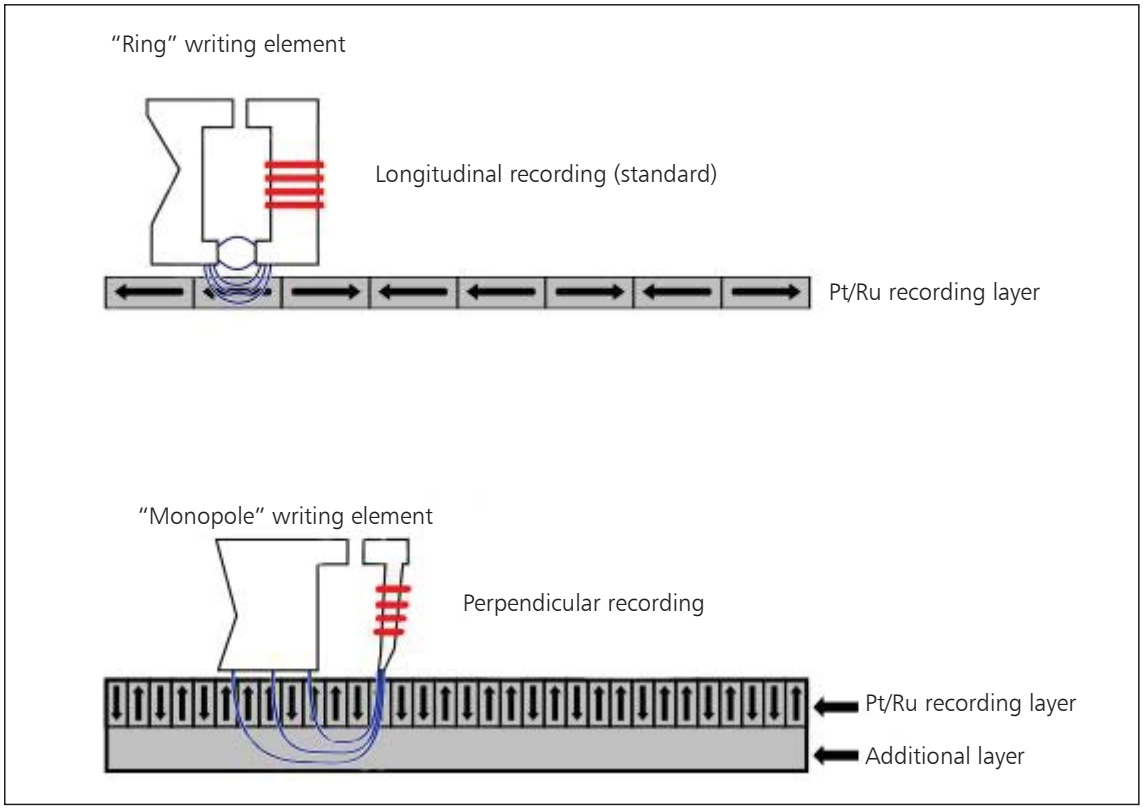

Fig. 2. Basic concept of longitudinal magnetic recording (LMR) and perpendicular magnetic recording (PMR) designs

media lubricants and overcoat materials provide the reader with a comprehensive and well explained background to the subjects. Chapters 5, 6 and 7 discuss how data is written and then read from the recording disk and the technology improvements that have maintained hard disk recording devices at the forefront of data storage over the years. Chapters 8 and 9 explain the role of the protective lubricant layer and overcoat which maintain the integrity of both the surface and the read-write head. This is explained with the aid of some excellent schematics, illustrating the complex chemistry occurring at the surface interface. As throughout the book, text is interspersed with a refreshing mixture of graphs, photographs, microscope images and diagrams to assist in understanding often complex ideas and technology.

The Future of Data Storage

The remaining five chapters look to the future of data storage and the next generation of storage media. The technology of heat assisted magnetic recording (HAMR) is discussed in detail in Chapter 10, with the key concepts, issues and benefits being well illustrated. HAMR is particularly relevant to Pt demand as the media will require a new FePt alloy for the magnetic recording layer, which can produce smaller grain sizes to increase the areal density limits beyond that of PMR. This is done by thermally heating the disk surface with a laser before data is written and then 'locked in' by rapid cooling of the surface.

This chapter introduces the concept of HAMR and discusses the possible layer combinations that will make up the disk. The key difference between HAMR and other existing technologies is the localised heating of the disk media (**Figure 3**), which is given excellent coverage in sections on thermal design and characterisation. Again, this section of the book is well illustrated with diagrams showing the relevant equipment as well as results from thermal mapping experiments. The summary and outlook section leaves the reader in no doubt of the technological challenges facing hard disk manufacturers, but also the significant benefits in terms of data storage improvements if these hurdles can be overcome.

Pt is of key importance in this next generation of data storage media as a component of the magnetic alloy material, so much so that Chapter 11 is entirely devoted to the FePt alloy which is the current standout material for data recording using HAMR technology. This chapter includes much detailed discussion on alloy structures, chemical ordering and microstructure control and will be of particular interest to materials scientists and chemists. With Pt mentioned on every page, this chapter really drives home the vital role pgms play in the recording of information.

HAMR is certainly not the only option available for increasing the areal density limits of hard disk devices and the last three chapters recognise the alternatives being pursued by both academia and industry. Patterned recording is widely considered

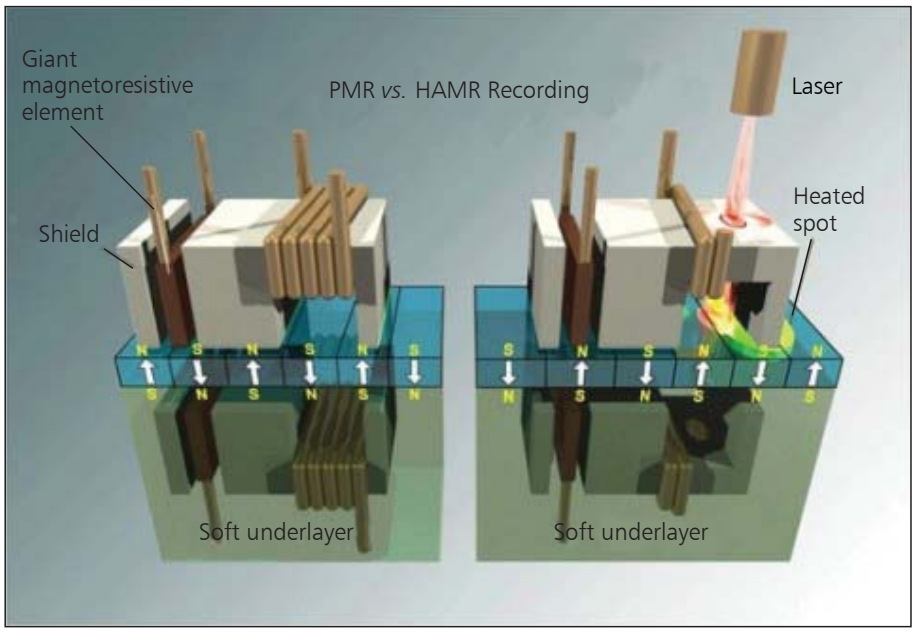

Fig. 3. Schematic image showing the difference between HAMR and PMR technology (Courtesy of Seagate Technology)

the main alternative to HAMR for future generations of disk media. Chapter 12 describes the two forms of patterned media currently under investigation. These are discrete track media and bit patterned media, both of which use lithographic techniques to physically separate recording grains and allow them to be placed in closer proximity without interfering with each other. The complex fabrication of patterned media is explained with the help of a series of schematics and electron microscope images which again highlights both the benefits and many issues still to be overcome in order for this technology to become commercially viable.

The final two chapters move away from hard disk technology for the first time and introduce solid state memory devices. There are certainly benefits of this technology over hard disks, most notably faster speeds and smaller more compact sizes. Flash memory, for instance, has already found use in a variety of small mobile devices such as cameras and mobile phones. However there are concerns regarding the number of times data can be re-written, security and overall durability. The most important issue is that the price per gigabyte is still substantially higher than the hard disk drive at the time of writing. These final chapters round off nicely the latest developments in data storage and complete the reader's journey through this rapidly changing industry.

Conclusions

This book provides a fascinating examination of the rapidly changing field of data storage, taking the reader on a logical journey from the earliest storage devices, through current perpendicular magnetic recording hard disk drives, and finishing with a look at what the future may hold, whether that be heat assisted recording, patterned media, solid state semiconductor devices or a combination of the three. The book will appeal to a wide audience, particularly to university level students with an interest in physics, chemistry, materials science and electronics. The chapters are well laid out, do not overwhelm the reader with too much complex information and are nicely illustrated with a combination of diagrams, photographs, graphs, tables and microscope imagery. It is clear that the editors and contributing authors are passionate about this particular subject and that enthusiasm can be felt throughout the book, especially in chapters concerning the exciting new technology on the horizon for data storage.

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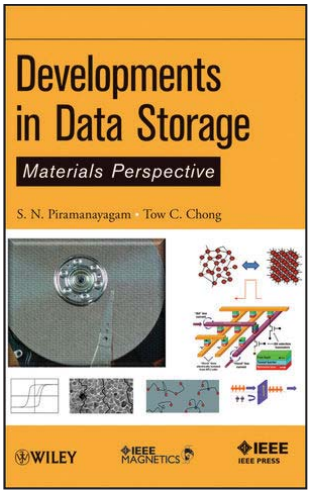

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