Invited Paper

Magnetic Thin Films for Recording Industry
ฟิล์มบางสารแม่เหล็กสำหรับอุตสาหกรรมบันทึกข้อมูล

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Abstract

Fabrication of magnetic thin films always has a big part in recording industry. The change in electrical resistance of the thin films in magnetic field, referred to as magnetoresistance (MR), has revolutionized the read head technology. Anisotropic magnetoresistance (AMR), giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR) have successively been implemented in commercial hard disks. Recently, a new design of a read head based on magneto-electric effect in ferroic thin film has been proposed. Furthermore, high capacity hard disk drives using magnetic layers with perpendicular magnetization are commercially available. These magnetic thin films can be prepared by techniques such as sputtering and evaporation. In the characterization stage, patterns of magnetic domain are visualized by magnetic force microscopy (MFM) and hysteresis loops are usually obtained by magneto-optic Kerr effect.

บทคัดย่อ

การสังเคราะห์ฟิล์มบางสารแม่เหล็ก เป็นส่วนสำคัญของอุตสาหกรรมบันทึกข้อมูล แมกนีโตรีซิสแทนซ์ (MR) หรือ การเปลี่ยนแปลงความต้านทานไฟฟ้าของฟิล์มบางในสนามแม่เหล็กได้ปฏิวัติเทคโนโลยีการผลิตหัวอ่าน แอนไอโซโทรปิกแมกนีโตรีซิสแทนซ์ (AMR), ไจแอนท์แมกนีโตรีซิสแทนซ์ (GMR) และ ทันเนลลิงแมกนีโตรีซิสแทนซ์ (TMR) ได้รับการนำมาใช้ในฮาร์ดดิสก์ เป็นลำดับ จนกระทั่งเร็ว ๆนี้ มีการเสนอหัวอ่านแบบใหม่ที่ใช้ฟิล์มบางที่แสดงปรากฏการณ์เฟอร์โรอิก นอกจากนี้ฮาร์ดดิสก์ไดร์ฟความจุสูงที่ใช้ชั้นบันทึกข้อมูลที่มีแมกนีไตเซชันตั้งฉากได้มีจำหน่ายแล้ว ฟิล์มบางสารแม่เหล็กเหล่านี้สามารถสังเคราะห์ได้โดยเทคนิคเช่น การสปัตเตอริง และ การระเหย ในขั้นตอนการวิเคราะห์ รูปแบบของโดเมนแม่เหล็กสามารถแสดงให้เห็นได้ด้วยกล้องจุลทรรศน์แบบ MFM และฮิสเทอริซีสลูปนิยมวัดโดยใช้ ปรากฏการณ์แมกนีโตออปติกของเคอร์

Keywords: magnetic thin films, storage layer, read heads, sputtering, evaporation, characterization techniques
คำสำคัญ: ฟิล์มบางสารแม่เหล็ก, ชั้นบันทึกข้อมูล, หัวอ่าน, การสปัตเตอริง, การระเหย, เทคนิควิเคราะห์

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Introduction

Magnetic materials have been used in recording technology for more than one hundred years and the overviews of magnetic recording are presented in many articles and textbooks (Jiles, 1991). For hard disk drives, data are coded in forms of the magnetization of magnetic thin films. To increase the recording capacity, hard disks using storage layers with perpendicular magnetization have been developed and are commercially available (Richter, 2007). To read the data from the hard disk, thin films with anisotropic magnetoresistance (AMR), giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR) have successively been implemented in the read heads (Xu and Thompson, 2007). Recently, a new design of a read head based on magneto-electric effect in multiferroic thin film has been proposed (Vopsaroiu et al., 2007).

In this paper, fabrication and characteri - zation techniques for magnetic thin films are summarized. Recent developments in Thailand and trends are also outlined.

Fabrication techniques

Magnetic thin films for recording industry are primarily prepared by either evaporation or sputtering techniques. In the evaporation technique, bulk magnetic materials are heated beyond their boiling point and the atoms in the gas phase are then collected to form a film on the substrate. Heating of magnetic materials can be done by supplying a high current in a thermal evaporator or bombarding with an electron beam in an electron beam evaporator. Examples of such films are cobalt films on silicon prepared by thermal evaporation (Pansong and Sirisathitkul, 2005) and cobalt films on platinum by electron beam evaporation (Samenram et al., 2008).

The sputtering technique has a rather different approach. A piece of magnetic material is installed as a target in a plasma chamber. Under the influence of an electric field, the ionized gas bombards the magnetic target. As a result, atoms are ejected from the target and deposited onto a substrate. There are large variations of sputtering systems (Ohring, 1992). The DC sputtering may be the simplest kind but the RF sputtering possess several advantages especially its ability to grow insulator films. A higher sputtering rate and a lower heating can be obtained in either DC or RF magnetron sputtering by installing a permanent magnet behind a target. All kinds of sputtering systems are increasingly used in Thailand and they can be easily adapted for fabrication of magnetic thin films (Aiempanakit et al., 2008; Klaitabtim et al., 2007).

Both evaporation and sputtering described above may be similar to deposition techniques for generic thin films. However, some treatments may be applied exclusively to magnetic films. For example, an application of magnetic field to the substrate during a deposition induces magnetic anisotropy and dictates the magnetization orientation in the films (Ohring, 1992). Furthermore, the implementation of magnetic thin film almost always requires multilayer deposition. For GMR and TMR read heads, nonmagnetic spacer layers are needed (Xu and Thompson, 2007). In the perpendicular recording, it is necessary to have a soft magnetic underlayer inducing the perpendicular magnetization in the storage layer (Richter, 2007).

Characterization techniques

Like other thin films, several techniques are applied to characterize the film after the deposition (Brundle et al., 1992). Phases are usually identified by X-ray diffraction (XRD) while electron diffraction techniques including LEED and RHEED are exceptionally useful for surface studies. Impurities and surface cleanliness are often studied by Auger electron spectroscopy (AES). Morphology of thin films can be visualized by scanning electron microscopy (SEM) and atomic force microscopy (AFM). All techniques are available in Thailand and are employed in several recent research papers (Arthibenyakul et al., 2008; Samenram et al., 2008; Aiempanakit et al., 2008; Klaitabtim et al., 2007).

For magnetic thin films, not only the surface imaging but also the domain imaging is important. The magnetic domain structure can be visualized by dropping ferrofluid on magnetic films. In the similar way to the traditional Bitter method, the magnetic particles from the fluid are accumulated by the stray field over the domain wall region and the contrast reveals the orientation of magnetization (Piromrak et al., 2007). However, there are many limitations in the application of this ferrofluid and its resolution is somewhat lower than that of magnetic force microscopy (MFM). In the MFM, a magnetic tip probes the surface of a magnet thin film revealing the domain structure (Szmaja, 2006).

Magnetic parameters of thin films such as saturation magnetization, remanent magnetization and coercive field are obtained from hysteresis loops. There are several kinds of magnetometer for measuring the hysteresis loops but the widely-used technique for thin films is the magneto-optic Kerr effect (MOKE). As demonstrated by some research groups in Thailand, such magnetometer can be set-up using He-Ne laser and photodetector (Rattanasakulthong, 1999; Rattanasuporn et al., 2008). Since the magnetic film can rotate the polarization of the incident light beam, the analysis of the reflected light give rise to the magnetization of the film (Jiles, 1991).

All types of MR can be measured by the same system consisting of an electromagnet, a constant current source and a voltmeter. The resistance of magnetic thin film can be measured as a function of varying magnetic field of the electromagnet (Pansong and Sirisathitkul, 2005).

Conclusions

The hard disk drive is already considered as a triumph in combining several disciplines of science and engineering. Every year, the recording density has been increased at a phenomenal rate with the reduction of size and cost. With the going-on research works on the perpendicular recording and new types of read head, the astonishing progresses in science and technology are set to continue. Magnetic thin films have been and will always be an integral part of these phenomenal advancements.

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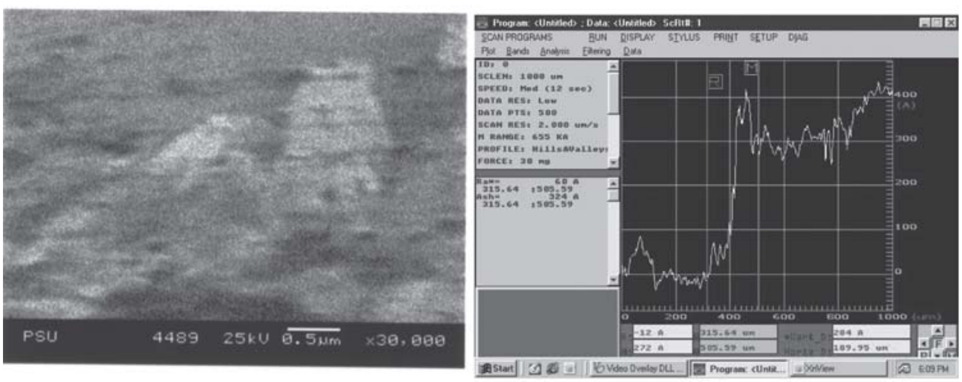
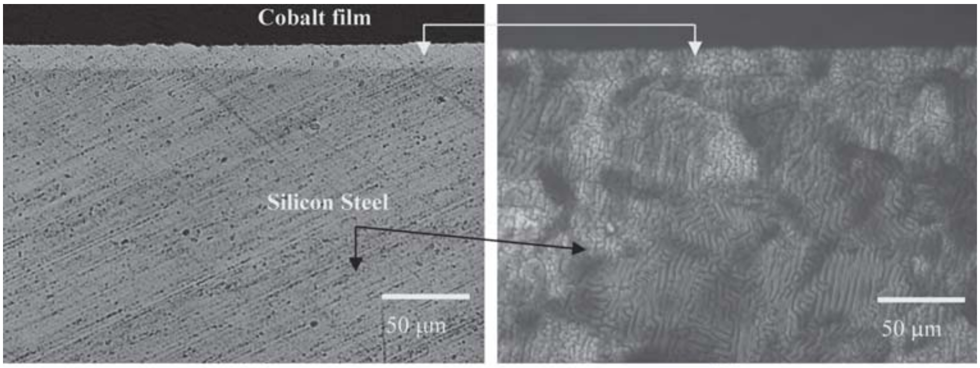
(a) (b)

Figure 1. Photographs of (a) a sputtering plant and (b) a thermal evaporator at Walailak University.



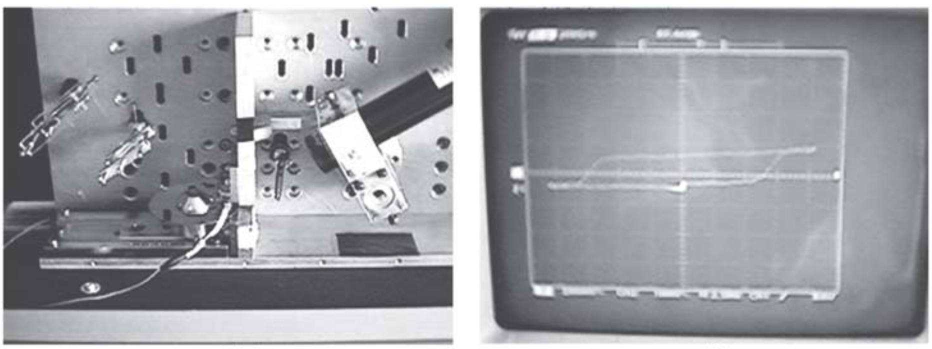
(a) (b)

Figure 2. Examples of characterization of cobalt thin films prepared by thermal evaporation (a) SEM micrograph and (b) thickness profile (Pansong and Sirisathitkul, 2005).



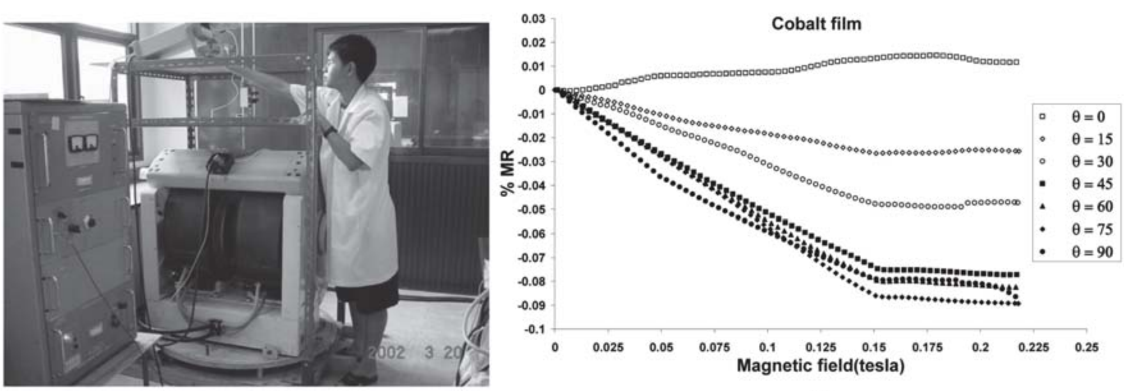
(a) (b)

Figure 3. Micrographs of (a) cross sectional view of cobalt on silicon steel and (b) its Bitter pattern image (Piromrak et al., 2007).



(a) (b)

Figure 4. (a) Photograph of MOKE setup and (b) an example of hysteresis loop of a magnetic layer of a hard disk (Rattanasakulthong et al., 1999).



(a) (b)

Figure 5. (a) Photograph of MR measurement setup and (b) an example of AMR curves of cobalt thin film at varying angle between current and magnetic field (Pansong and Sirisathitkul, 2005).