# Effects of a Pt Underlayer and Interlayer on the Growth Texture of Strontium Ferrite Thin Films

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***Abstract*—The effects of a Pt underlayer and a Pt interlayer on the textured growth of the sputtered strontium ferrite (SrM) films were investigated. The structural and magnetic properties of SrM films on the Pt underlayers were compared with SrM films on thermally oxidized Si substrates. It was found that much better $(00l)$ texture was obtained on the films with Pt underlayers, as indicated by the strong (006), (008) and (0014) reflections from X-ray diffraction (XRD) measurement. A Pt interlayer was also found to further improve the $(00l)$ texture.**

***Index Terms*—Strontium ferrite, SrM, Pt underlayer, Pt interlayer, textured growth.**

## I. Introduction

Strontium hexagonal ferrite (SrM) thin films which have the same crystal structure as barium hexagonal ferrite thin films are attractive candidates for overcoat free magnetic recording due to their large uniaxial anisotropy, high chemical stability, and corrosion resistance [1]–[4]. The $c$-axis orientation needs to be controlled to be perpendicular to the film plane for perpendicular recording applications, or needs to be controlled to be either in-plane or randomly oriented for longitudinal recording applications. It was shown that the $c$-axis orientation of SrM films can be made either perpendicularly or randomly orientated by changing the process parameters and choice of different substrates [5]–[7]. It was also found that Pt is effective in controlling the $c$-axis orientation for barium ferrite films [8], [9]. In this study, we focus on the effects of Pt underlayers and Pt interlayers on the textured growth for the sputtered strontium ferrite films.

## II. Experimental

The strontium ferrite films were prepared by rf diode sputtering in a Leybold Z400 sputtering system, using a strontium ferrite target of stoichiometric composition. The sputtering gas is a mixture of argon and oxygen gas. The total pressure was fixed at 5.7 mTorr with the oxygen to argon ratio of $0.7/5$. The Pt layer was prepared by rf diode sputtering in the Leybold Z400 system with an argon pressure of 5 mTorr. The target power was fixed 100 W for all the films. Thermally oxidized silicon ($SiO_2$) substrates were used for all the films. The as-deposited films were amorphous, and the annealing was carried out for about 20 min at 800°C using a furnace oven.

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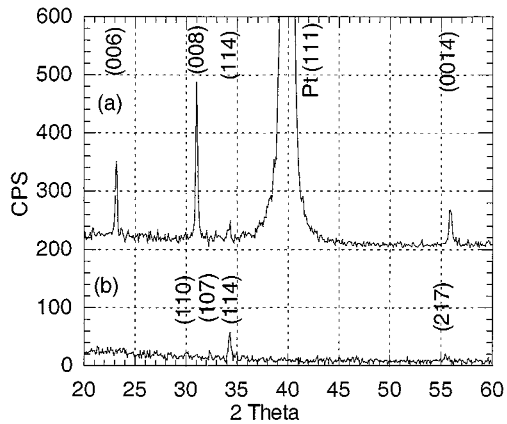


Fig. 1. XRD curves for 900 Å-thick SrM films (a) on the 500 Å-thick Pt underlayer; (b) on the $SiO_2$ substrate.

The magnetic properties of the films were studied using either an alternating gradient magnetometer (AGM) or a vibrating sample magnetometer (VSM). The crystal structures and textures of the films were characterized by X-ray diffraction (XRD) using Cu $K_\alpha$ radiation. A Philip EM420T transmission electron microscope (TEM) was used to characterize the grain size and grain orientation.

## III. Results and Discussion

### A. The Effect of a Pt Underlayer

The X-ray diffraction (XRD) patterns for the post annealed 900 Å-thick SrM films are shown in Fig. 1. The samples prepared on the $SiO_2$ substrate show (110), (107), (114), and (217) reflections, indicating a random orientation of the $c$-axis for the films, that is, there is not dominant texture in the films. The samples with a 500 Å-thick Pt underlayer show (006), (008) and (0014) reflections, indicating a strong perpendicular $c$-axis orientation in the films. There is also (114) reflection for films with the Pt underlayer, indicating a tilt angle of about 60° for the $c$-axis with respect to normal to the plane. The films on the $SiO_2$ substrate thus have a random texture, while the films with the Pt underlayer have a dominant $(00l)$ texture. The Pt underlayer shows a strong (111) texture, as indicated by the strong (111) reflections shown in Fig. 1. These results show that the films with the Pt underlayers have much improved perpendicular $c$-axis orientation compared to the films on the $SiO_2$ substrate with same deposition conditions. Thus, the Pt underlayer is very effective in promoting perpendicular $(00l)$ texture for SrM films.

(a)

(b)

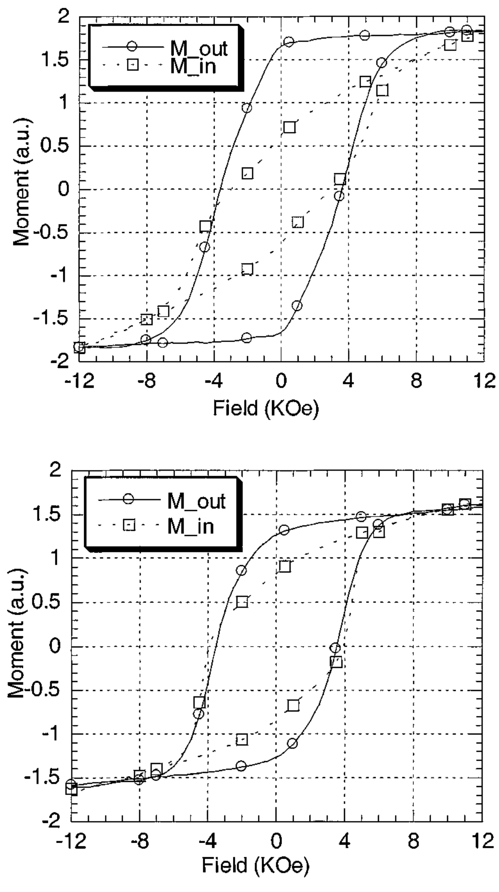


Fig. 2. In-plane ($M$_in) and perpendicular ($M$_out) $MH$ loops for SrM films: (a) on the 500 Å-thick Pt underlayer (b) on the $SiO_2$ substrate.

The perpendicular and in-plane $M$-$H$ loops for the above films are shown in Fig. 2. The films with the Pt underlayer have a perpendicular remnant squareness of about 0.91 and in-plane squareness of about 0.35. The perpendicular and in-plane coercivity is about 3600 Oe and 3000 Oe respectively. The higher perpendicular squareness agrees well with XRD results, indicating $c$-axis (easy axis) normal to the film plane for most grains. An in-plane squareness of about 0.35 indicates there are still some grains with axis in-plane or randomly oriented, consistent with the (114) reflections shown in Fig. 1(a). The films without the Pt underlayer have perpendicular and in-plane squareness of about 0.8 and 0.6, which indicates there is little preferential orientation for the films. The perpendicular and in-plane coercivity is about 4000 Oe and 3500 Oe respectively for the films without Pt underlayer. The magnetic properties for the films with and without the Pt underlayer are summarized in Table I.

Plan-view bright field (BF) images for above films are shown in Fig. 3. For the films with the Pt underlayer, most grains are platelet-like grains whose $c$-axes are perpendicular to the film plane, while there is still some needle-like grains with $c$-axes either in-plane or at angle oriented with normal to the plane. For the films without Pt underlayer, the grains are a combination of needle-like and platelet-like grains, indicating no preferred $c$-axis orientation. Electron diffraction patterns for the films are shown on the top right corner of Fig. 3(a) and (b), showing the grains with perpendicular $c$-axes for the films with the Pt underlayer, and the grains with in-plane $c$-axes for the films without the Pt underlayer.

TABLE I

MAGNETIC PROPERTIES OF SrM THIN FILMS ON THE $SiO_2$ SUBSTRATE AND THE 500 Å-THICK Pt UNDERLAYER. $S$_out AND $S$_in STAND FOR PERPENDICULAR SQUARENESS AND IN-PLANE SQUARENESS, RESPECTIVELY; $Hc$_out AND $Hc$_in STAND FOR PERPENDICULAR COERCIVITY AND IN-PLANE COERCIVITY, RESPECTIVELY

| Sample | Ms emu/cc | S_out | S_in | H_out Oe | Hc_in Oe |
|---|---|---|---|---|---|
| on $SiO_2$ | 258 | 0.61 | 0.53 | 4200 | 4000 |
| on Pt | 270 | 0.91 | 0.35 | 3600 | 3100 |

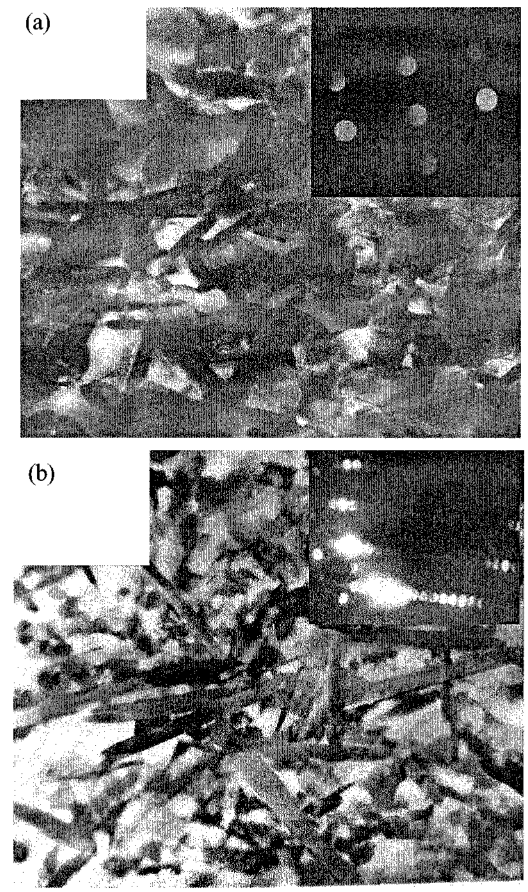

Fig. 3. TEM BF images and electron diffraction patterns for 900 Å thick SrM: (a) on a 500 Å-thick Pt underlayer (b) on $SiO_2$ substrate. The electron diffraction pattern from one plate-like is shown on the top right corner of (a). The electron diffraction pattern from one needle-like grain is shown on the top right corner of (b).

The experimental results from XRD, $MH$ loop and TEM all suggest that the Pt underlayer promotes the growth of platelet-like grains, and suppresses the growth of needle-like grains. Thus better $(00l)$ texture was developed on the Pt underlayer.

### B. The Effect of a Pt Interlayer

With a Pt underlayer, it was found that there is still a gradual deterioration of perpendicular $c$-axis orientation. The

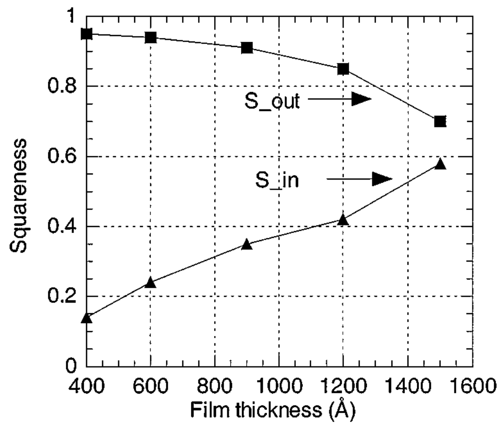


Fig. 4. The thickness dependence of in-plane squareness ($S$_in) and perpendicular squareness ($S$_out) on the film thickness for SrM films on the 500 Å-thick Pt underlayer.

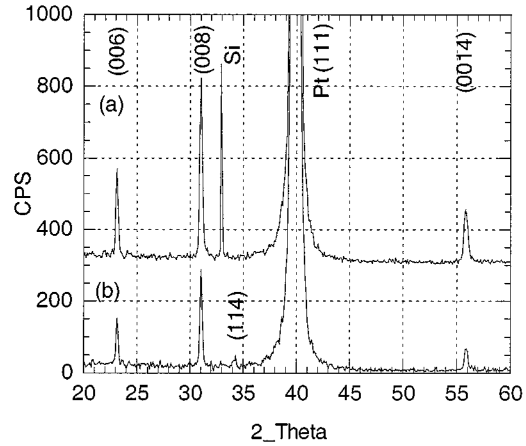


Fig. 5. XRD curves for 900 Å-thick SrM films on the 500 Å-thick Pt underlayer: (a) with a 150 Å-thick interlayer (b) without a interlayer.

dependence of in-plane and perpendicular remanent squareness on the film thickness for SrM films with the 500 Å-thick Pt underlayer is shown in Fig. 4. Perpendicular remanent squareness decreases gradually from about 0.95 to about 0.7 with an increase in film thickness from 400 Å to 1500 Å, while in-plane remanent squareness increases gradually from 0.14 to 0.58. To further improve the perpendicular orientation, a Pt interlayer can be used. Several 900 Å-thick SrM samples with a 150 Å-thick Pt interlayer sandwiched between two 450 Å-thick SrM layers were made and characterized. 500 Å-thick Pt underlayers was used for all the samples. It was shown that an Pt interlayer is very effective to promote the perpendicular axis orientation by promoting more perpendicular nucleation sites at the interface for barium ferrite films [9]. Our data on SrM films show that the mechanism holds true for SrM films. The 900 Å-thick SrM films without a Pt interlayer has a perpendicular squareness of 0.91 and in-plane squareness of 0.35, as shown in Fig. 4, while the 900 Å-thick SrM films with a 150 Å-thick Pt interlayer have a perpendicular squareness of 0.95 and in-plane squareness of 0.13. Thus there are more perpendicular oriented grains and less in-plane or randomly oriented grains for the films with a Pt interlayer. XRD results agree well with the magnetic measurements as shown in Fig. 5. The $(00l)$ texture becomes stronger for SrM films with a Pt interlayer, as indicated by the stronger (006), (008) and (0014) reflections. There is a weak (114) reflection for films without the Pt interlayer, while there is no (114) reflections observed for films with the Pt interlayer, which also suggests better $(00l)$ texture for SrM films with a Pt interlayer.

## IV. Conclusion

Pt underlayers were found to be very effective in controlling the $(00l)$ textured growth for the sputtered strontium ferrite (SrM) films. A Pt interlayer was also found to further promote the growth of $(00l)$ texture.

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