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Morphological Study of CoNiFe-B Thin Film Fabricated on Si Substrate by Electroless Method

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Abstract: The influence of coating bath composition on CoNiFe-B magnetic thin film was investigated. Electroless method with different substrate of Si wafer and brass were used. AFM, SEM and EDX analysis were carried out to characterize the CoNiFe-B thin films. According to the results, Addition of the Ni^{2+} to electroless coating bath, not only changes the coating composition, but it also influences the morphology of the coatings and their particulate size.

Keywords: Magnetic Thin Film; Electroless; AFM; Bath Composition.

Introduction

Recently, the areal recording density has been increasing dramatically in magnetic recording systems, especially in the hard disk drive (HDD). The development of a new magnetic recording head with better recording performances and smaller dimensions is one of the key requirements for realizing a high-density magnetic recording device. Soft magnetic thin films with low coercivity, high saturation, and high permeability have been in use as the writing-head core material of the merged type magnetoresistive (MR) head. Many soft magnetic thin films with high saturation have been reported recently, such as Co-Fe, Co-Ni, Ni-Fe, Co-B, Co-Ni-P [1-2].

NiFe [3] materials exhibit many of the desirable characteristics because of their low coercivity (<2 Oe) and their high saturation flux density (B_{sat}) to facilitate the use of thin films and high resistivities to reduce eddy current losses in the magnetic material and improve the overall efficiency of the device [4]. More recently Co containing alloys (CoNiFe [5-6] and CoFe [7]) have been investigated as these materials exhibit larger saturation magnetisation values [4].

The writing head cores are now being fabricated by the electrodeposition method because it is the most desirable technique for the fabrication of micro-devices with a high aspect ratio such as magnetic recording head cores. In the near future, recording heads and their components will be miniaturized to write the recording media with a very high recording density. It will become difficult for the electrodeposition method to produce films with uniform thickness and composition in the sub-micrometer scale. On the other hand, the electroless deposition method does not suffer from problems associated with current density distribution, and hence it should be more suitable for depositing uniform films on substrates with fine and complex geometries [1]. Since CoNiFe is Co-based, it can be produced by the electroless deposition method [5]. Different investigation on electroless magnetic alloys shown that higher B_{sat} values can be obtained from deposits using dimethylamine borane (DMAB) rather than hypophosphite as the reducing agent [4].

In this paper, new electroless CoNiFeB soft magnetic thin films will be discussed with emphasis on the effect of coating bath compositions on their morphology and chemical composition.

Experiment

Silicon wafer and Brass were used as substrate materials for the deposition of electroless CoNiFe–B coatings. Silicon wafer substrate was used to prepare thin films of electroless CoNiFe–B coating in low time of 30s for evaluating the coating characteristics (such as particulate size, chemical composition, and magnetic properties), whereas brass substrate was employed to prepare coatings in higher time (6 min) to study the coating morphology.

Prior to the electroless deposition, the silicon wafer substrates had been etched using the 10% hydrofluoric acid solution for 10min. After this process, the silicon substrates were coated by Au using sputtering method because the CoNiFe alloy SUL deposited by the electroless deposition method does not have enough adhesiveness with the glass substrate [5].

The brass substrates were degreased with acetone, cleaned using HNO_3 solution and washed thoroughly with DI water. After this process, the brass substrates were sensitized by immersing in an aqueous mixture of $19gl^{-1}$ $SnCl_2$ and $50gl^{-1}$ HCl for 10 min and washing with DI water solution, followed by immersion in an aqueous mixture of $1gl^{-1}$ $PdCl_2$ and $12gl^{-1}$ HCl for 2min. Subsequently, the substrates were rinsed with DI water several times.

An alkaline bath having nickel sulphate, cobalt sulphate and iron sulphate as the sources of metallic elements of coatings and dimethylamine borane (DMAB) as the reducing agent was used to prepare the electroless CoNiFe–B deposits. The temperature of the bath was maintained at 70 °C. During plating, the bath solution was agitated using a magnetic stirrer at 250 rpm.

The chemical composition of the electroless deposition bath is as fallows:

0.034M ($NiSO_4.6H_2O+CoSO_4.7H_2O$), 0.013M $FeSO_4.7H_2O$, 0.143M lactic acid, 0.07M DMAB.
The electroless CoNiFe coatings obtained from different bath composition with various molar ratios of $X=NiSO_4.6H_2O/(NiSO_4.6H_2O+CoSO_4.7H_2O)$ in order to study the effect of bath composition on coating properties. The surface morphology of the films was imaged using the scanning electron microscope (SEM) and atomic force microscopy (AFM) measurements. Energy dispersive X-ray analysis (EDX) was carried out to obtain the composition of the films. The AFM and EDX experiments were performed for the films deposited on Si wafer. Besides, the coatings deposited on brass substrate were investigated by SEM.

Results and Discussion

Fig.1 shows the AFM images of the electroless CoNiFe-B coatings on silicon wafer substrate obtained from baths with different molar ratio of X. Variation of the particulate size and the composition of the CoNiFe coatings by changing in coating bath composition are presented in Fig. 2. The particulate size of the coatings was found by 2D AFM image analyses of each coating. The boron content of the coatings is taken in plated film from reducing agent of dimethylamine borane (DMAB).

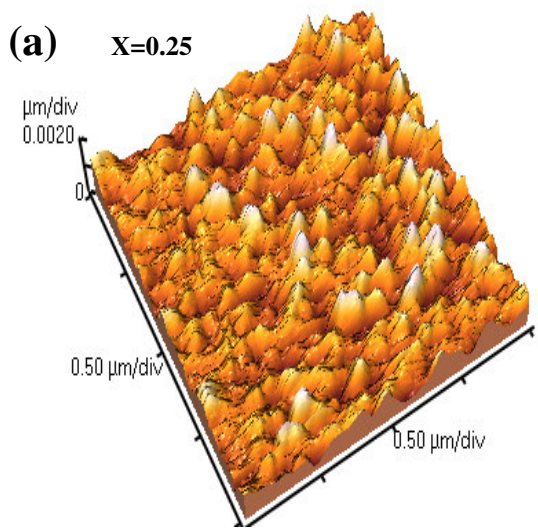
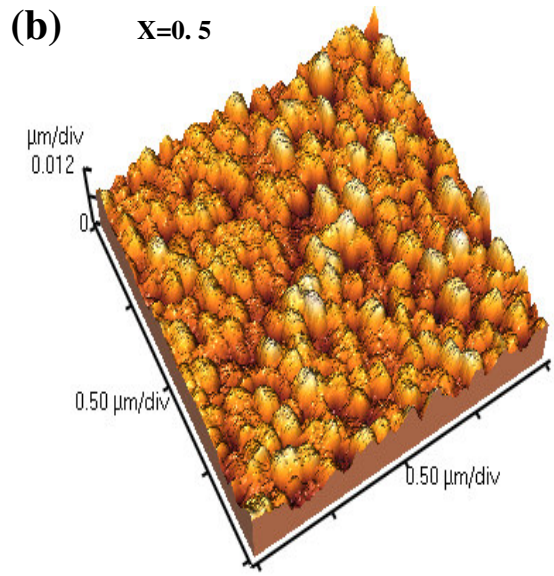


Fig 1. AFM images of CoNiFe-B coatings on Si a) x=0.25, b) x=0.5 and c) x=0.75



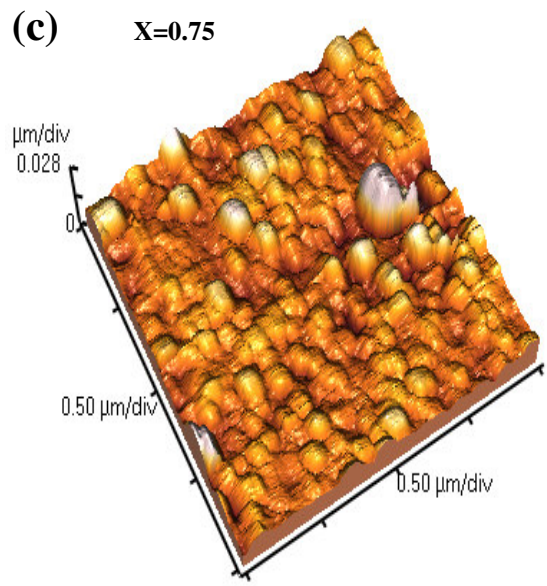


Fig 1. (continued)

Although existence of boron in the coating is not unavoidable, but because it is a light element, can not be detected by EDX analyses.
EDX results indicate that Ni content of coating increased with nickel ion concentration in the coating bath. Fe content of the coatings was not changed by alteration in the bath composition. Therefore, increase in Ni wt.% of the coatings is equal with decrease in Co wt.% of coatings. The AFM images of the coatings (Fig. 1) indicate that change in bath composition not only affects on the coating composition, it also changes the surface topography and the particulate size of the coating. While the CoNiFe-B film obtained from

coating bath with molar ratio of 0.25 (Fig. 1a) shows the particulates about 80 nm, the particulate size of CoNiFe-B film with molar ratio of 0.5 (Fig. 1b) and 0.75 (Fig. 1c) are about 150 nm and 200 nm respectively.

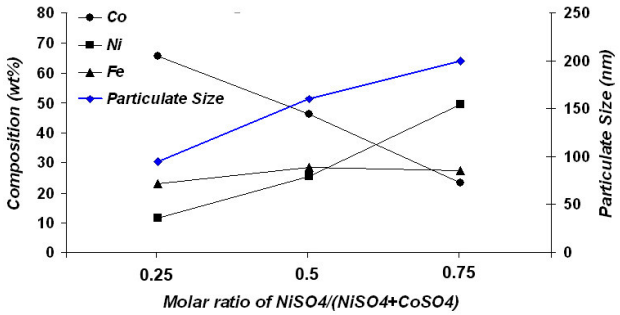


Fig 2. particulate size and composition of CoNiFe coatings

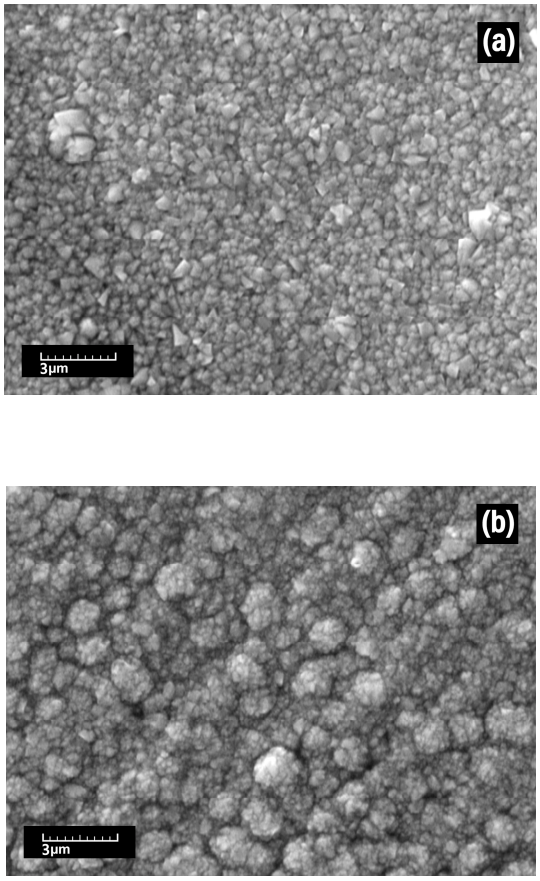


Fig 3. SEM image of CoNiFe-B coatings on brass a) x=0.25, b) x=0.5 and c) x=0.75

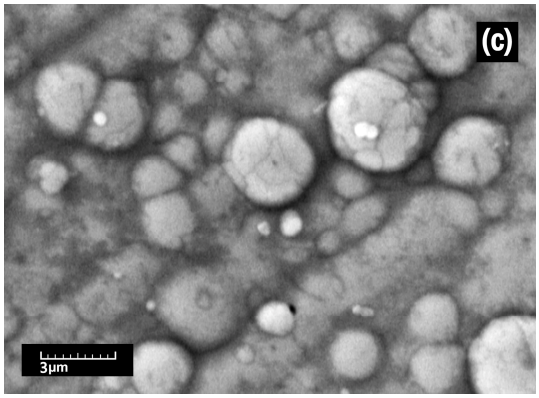


Fig 3. (continued)

The AFM images of the coatings (Fig. 1) indicate that change in bath composition not only affects on the coating composition, it also changes the surface topography and the particulate size of the coating.
Fig.3 shows the morphological images (SEM) of the CoNiFe-B films deposited on brass substrate from different bath composition in time of 6min. As mentioned before, the activation of brass carried out in two steps. In first one, the stannous ion (Sn^{2+}) was adsorbed onto the brass surface. In the second step, when substrate with the stannous ion was immersed in $PdCl_2$ soloution, Pd^{2+} ions are reduced to atomic Pd according to the following reaction:

$$Sn^{2+} + Pd^{2+} \rightarrow Sn^{4+} + Pd \qquad (1)$$

The SEM images of the CoNiFe-B coated brass (Fig.3) agree with the AFM results of the coatings on Si wafer. Fig.3 indicates that CoNiFe-B coatings obtained from bath with the molar ratio of 0.5 and 0.75 have cauliflower-shape and globular morphologies, respectively.
Although the particulate size of these films is different from that of deposited on Si which is due to deposition growth, they confirm the variation of the particulate size with change in X value.

Conclusion

The effect of coating bath composition on electroless CoNiFe-B magnetic thin film using different substrate of Si wafer and brass was investigated. Different composition of these coatings successfully deposited on Au spattered silicon wafer. Adding of the Ni^{2+} to electroless coating bath leads to change in composition and the size of the particulates. The particulate size of the CoNiFe-B film deposited on Si wafer from coating bath with molar ratio of 0.25, is less than 100nm. Furthermore, increase in molar ratio of $Ni^{2+}/(Ni^{2+}+Co^{2+})$ in the coating bath culminates in enlargement of the particulate size of the coatings.

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