Effects of Heat Treatment on Microstructure and Magnetic Properties of Electroless CoNiFe-B Thin Film

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Abstract-This paper explains our recent study on fabrication of a uniform and high-performance CoNiFeB soft magnetic thin film for magnetic recording head core applications and the effect of heat treatment on it. Thin film was deposited from borane-based baths on Si. We could synthesize a narrow film with ~45 nm thickness, high saturation magnetic flux density (~2.3 T) and low coercivity (~15.0 Oe). Some new phases created and magnetic properties changed after the heat treatment at 400°C for 60 minutes in Ar.

CoNiFe materials exhibit many of the desirable characteristics for magnetic recording heads because of their low coercivity and their high saturation flux density (B_{sat})[1]. The electroless deposition method is used for fabrication of uniform magnetic films on complex shape of substrate and does not suffer from problems associated with current density distribution [2]. The applied heat treatment in the final stage of EN coating changes its properties such as magnetic properties. We found that the molar ratio of $CoSO_4/NiSO_4$ = 2.647 results in most uniform with smallest particulate size than other bath composition [3]. In this paper, electroless CoNiFe-B soft magnetic thin film will be discussed with emphasis on the effect of heat treatment on its microstructure, morphology and magnetic properties.

Silicon wafer was used as substrate material for the deposition of electroless CoNiFe–B coatings in 30s deposition time. The chemical composition of the electroless deposition bath is as fallows: 0.0255M $CoSO_4.7H_2O$, 0.0085M $NiSO_4.6H_2O$, 0.013M $FeSO_4.7H_2O$, 0.143M lactic acid, 0.07M DMAB. The temperature of the bath was maintained at 70 °C. Heat treatment of electroless CoNiFe-B coatings was performed at 400°C for 60 minutes and in argon atmosphere. XRD and VSM analysis were used to characterize the coatings.

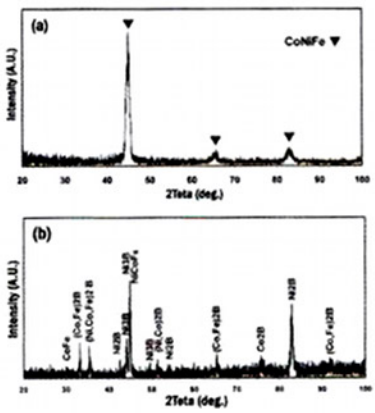

Figure 1. XRD patterns of (a) as-deposited and (b) heat treated electroless CoNiFe-B coatings

Figure 1 presents the XRD patterns of the as-dposited and heat treated electroless CoNiFe–B. Comparison between these XRD pattern concludes that heat treatment not only leads to crystallization of coating, it also change the phase structure and causes formation of some new phases which includes (Co, Ni, Fe)$_2$B and Ni_3B. These new phases are formed by compound of metallic elements with boron which is taken in plated film from DMAB as the reducing agent in the coating bath [4]. The thickness of the as-deposited film measured by a Dektak profilometer and found that it is about 45 nm.

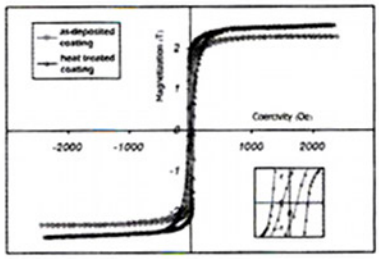

Figure 2. The magnetic hysteresis curves of as-deposits and heat treated coatings

Table. 1. Ms, Mr and Hc of as-deposited and heat treatedcoatings

Sample	As-deposited	Heat treated
M_s (T)	2.30	2.52
M_r (T)	0.95	2.01
H_c (Oe)	15.0	39.1

Magnetization curves of the CoNiFeB films (as-deposited and heat treated) are plotted in Figure 2. The saturation magnetization (M_s), the residual magnetization (M_r) and coercivity (H_c) of the films are tabulated in Table1.

The saturation magnetization and the residual magnetization increase from 2.30 T and 0.95 T to 2.52 T and 2.01 T after heat treatment at 400 °C, respectively. From the XRD results, it is evident that the as-deposit coating was crystallized into new phases after annealing at 400 °C. The formation of the new alloy phases with high magnetization may be the reason of the increase in M_s and M_r. The coercivity (Hc) is pertinent to the structure of material and many factors such as grain size, crystal structure, stress and surface roughness [4]. As is seen in Fig.2 and Table.1 the coercivity has changed with a complex mechanism and moved up from 15.0 to 39.1 after heat treatment at 400 °C.

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