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Fabrication and Structural Properties of Al-N-Co-Fe/Zr Thin Film†

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Al-N-Co-(Zr/Fe/Zr-Fe) films were prepared by using a two-facing target type dc sputtering (TFTS) system. The deposited films were annealed isothermally at 773 K and their magnetic properties and resistivity were investigated. This TFTS method is suitable for preparing Al-N-Co-(Zr/Fe/Zr-Fe) films. The X-ray diffraction profile for Al-N-Co-Zr film shows that it crystallized into the phases of AlN and β-Co, while the profiles for Al-N-Co-Fe and Al-N-Co-Zr-Fe films show that they crystallize into three phases of AlN, β-Co and α-Co. Resistivity shows monotonous increase with increasing annealing time for all kinds of films. The highest resistivity was found for Al-N-Co-Fe-Zr film while lowest was obtained for Al-N-Co-Zr films.

Keywords: Thin films, Sputtering, Crystallization, X-ray diffraction, Magnetic properties, Resistivity.

INTRODUCTION

Much attention in recent years has focused on the design, synthesis and properties of nanostructured materials since they exhibit unique properties that are potentially attractive for technological applications. However, the tendency of the nano-structured materials to aggregate in order to reduce the high energy associated with a large surface to volume ratio presents a critical obstacle in fabricating and exploiting the potential of these materials. There is increasing interest to overcome these difficulties by adopting innovative synthesis procedures that are economically feasible for technological applications. One of the major challenges facing the recording industry is that of minimizing particle size so that a high recording density can be realized. And also to obtained soft magnetic properties by optimizing particle size. However, as the particle size decreases, superparamagnetism will begin to occur. The goal is thus to keep the particle size small while at the same time achieving acceptable magnetic stability. The addition of third elements or other additives improves the soft magnetic properties and thermal stability of the films. In this respect, Fe based Fe-Si-B-M (M: additives Cu, Nb, Mo, W, Ta, *etc.*) film[1], Fe-M-N film (M: Ta, Zr, Hf, Nb, *etc.*)[2-4], Fe-M-O (M: Hf, Zr, rare earth metals)[5] and Co based CoFeNiNbSiB film[6] have been reported.

Therefore, the purpose of this work is to examine the effect of addition of Fe, Zr element on the microstructure and properties of Al-N-Co film.

EXPERIMENTAL

Al-N-Co-(Fe/Zr/Fe-Zr) films were prepared by the method described in the previous work[7] only by placing 4 pieces of 10 mm × 10 mm × 0.5 mm Zr or Fe or a combination of Fe and Zr (2+2) chips at the center of lower composite target. The prepared films were annealed isothermally in a coil furnace vacuum annealing system. Their microstructure and property changes caused by annealing were investigated. Microstructural changes were evaluated by XRD while magnetic and electrical property changes were determined by VSM and four-probe method, respectively.

RESULTS AND DISCUSSION

Structural evaluation of Al-N-Co-(Zr/Fe/Zr-Fe) films: The structure of as-deposited film depends on fourth element in Al-N-Co films. The structure of Al-N-Co-Zr as-deposited films was found to be amorphous. This is clearly seen from the X-ray diffraction results shown in Fig. 1(a). The X-ray diffraction profile shows only two very broad peaks covering a wide angular range where several diffraction peaks of AlN

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and Co are expected to appear. Fig. 1(b) and 1(c) show the diffraction profiles for Al-N-Co-Fe and Al-N-Co-Zr-Fe film. The results illustrate that for these two profiles, there is a relatively strong wide peak around the angular position of AlN. As-deposited films crystallized after heat treatment. Fig. 2 shows the X-ray diffraction profiles of three types of films annealed at 773 K for 118.8 ks. The profile for Al-N-Co-Zr film shows that it crystallized into the phases of AlN and β-Co, while the profiles for Al-N-Co-Fe and Al-N-Co-Zr-Fe film show that they crystallize into three phases of AlN, β-Co and α-Co.

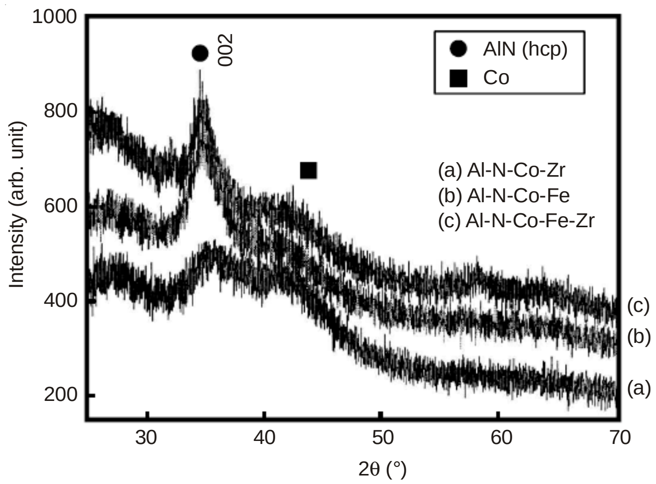

Fig. 1. Typical XRD profiles of as-deposited Al-N-Co-(Zr/Fe/Zr-Fe) films

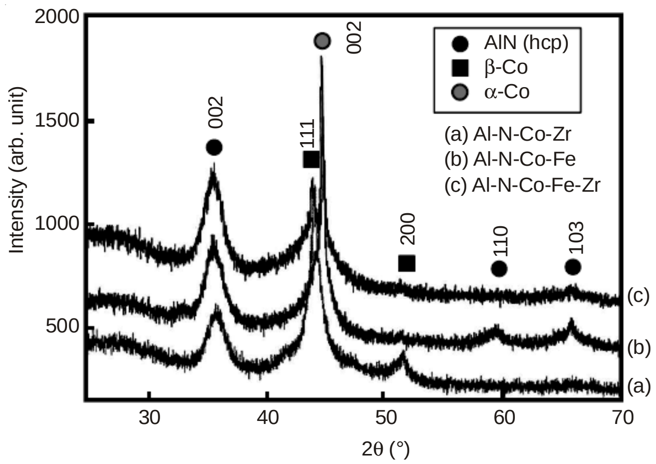

Fig. 2. Typical XRD profiles of Al-N-Co-(Zr/Fe/Zr-Fe) films annealed at 773 K for 118.8 ks

Magnetic and electrical properties: All types of as-deposited films show a very small magnetization. Fig. 3 shows the variation of saturation magnetization as a function of annealing time for different types of film annealed at 773 K for 118.8 ks. All kinds of film show almost the same tendency of monotonous increment of magnetization with annealing time. The magnetization increases rapidly for 10.8 ks annealing and then a slight increase with annealing time was observed. This is due to the fact that as-deposited amorphous-like films crystallize into the magnetic and insulating phases caused by annealing. And with increasing annealing time phase separation becomes more and more complete. Therefore, magnetic

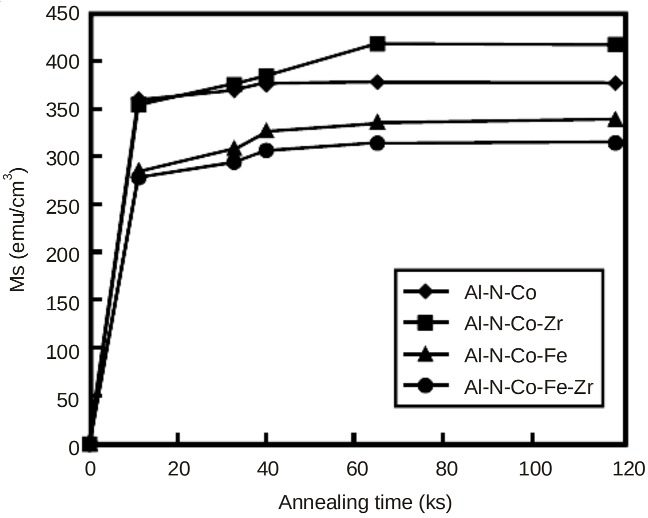

Fig. 3. Variations of saturation magnetization as a function of annealing time for Al-N-Co-(Zr/Fe/Zr-Fe) films annealed at 773 K for 118.8 ks

phases dispersed in the AlN matrix caused the increase of saturation magnetization. The highest saturation magnetization was obtained for Al-N-Co-Zr films while the lowest was shown by Al-N-Co-Fe-Zr film. The reason is not clear yet. However, it is probably due to the changes in plasma conditions as well as sputtering yield with different kinds of chip caused by the changes of distance between upper and lower targets.

Different resistivity was obtained for different types of as-deposited film. The lowest resistivity was obtained for Al-N-Co-Zr films while the highest resistivity for Al-N-Co-Zr-Fe film. From the results, it is predictable that the first type of film has a larger amount of conducting component than the second type. XRD profiles of Fig. 1 also support this assumption. The profile for the first type of film shows amorphous criteria attributed to large amounts of conducting elements while the profile for the second type of film shows a relatively high intensity broad peak of AlN ascribed to larger amounts of nitrogen in the film. Fig. 4 shows variations of resistivity with annealing time for different kinds of films. Resistivity also shows monotonous increase with increasing

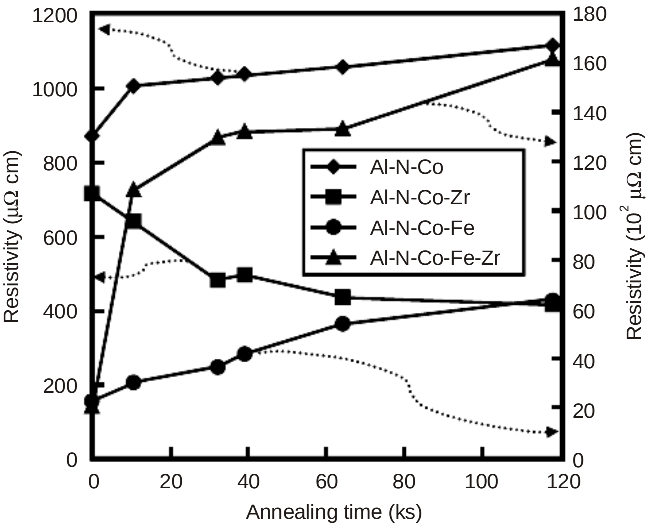

Fig. 4. Variations of resistivity as a function of annealing time for Al-N-Co-(Zr/Fe/Zr-Fe) films annealed at 773 K for 118.8 ks

TABLE-1
PROPERTIES OF DIFFERENT TYPES OF FILM

Kinds of film	As-deposited		Annealed	
	Magnetization (emu/cm^3)	Resistivity (μΩ-cm)	Magnetization (emu/cm^3)	Resistivity (μΩ-cm)
Al-N-Co-Zr	~4.4	~720	~520	~410
Al-N-Co-Fe	~4.5	~2100	~345	~6500
Al-N-Co-Zr-Fe	~2.5	~2200	~320	~16200

annealing time for all kinds of films. This can be explained in terms of microstructural changes caused by annealing as discussed above. Magnetic/conducting phases dispersed in the insulator AlN matrix increase the resistivity of the films. The highest resistivity was found for Al-N-Co-Fe-Zr film while lowest was obtained for Al-N-Co-Zr films. These results are exactly inverses to the results of saturation magnetization. Therefore, it can be concluded that the cause is due to the relative differences in the magnetic/conductive component in the films. Resistivity and magnetization of these films are tabulated in Table-1.

Conclusion

The differences in saturation magnetization and resistivity are probably due to the differences of the magnetic/conductive components in the respective films. This is also suggests that the resistivity as well as magnetization is adjustable by adding the third elements to the base Al-N-Co films.

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