Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Magnetism and Magnetic Materials 272–276 (2004) e353–e355
Journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Microstructure and magnetic properties of $Co_{70.5-x}Tb_{29.5}Pd_x$ films

C.T. Lie[a,*], P.C. Kuo[a], C.Y. Chou[a], S.C. Chen[b], T.H. Wu[a], A.C. Sun[a]

[a] *Institute of Materials Science and Engineering and Center for Nanostorage Research, National Taiwan University, Taipei 106, Taiwan*
[b] *Department of Mechanical Engineering, De Lin Institute of Technology, Taipei 236, Taiwan*

Abstract

The $Co_{70.5-x}Tb_{29.5}Pd_x$ films ($x=0\sim22.5$ at%) were prepared at room temperature. Transmission electron microscopy diffraction patterns revealed that all the films are amorphous. The saturation magnetization is decreased and the perpendicular coercivity is increased with increasing Pd content as $x<5$ at%. But the perpendicular coercivity is decreased rapidly with increasing Pd content as $x>5$ at%. Compensation temperature of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is decreased with increasing Pd content. Compensation composition of the film occurs at $x\sim5$ at%.

PACS: 75.50.Kj; 75.70.-i

Keywords: $Co_{70.5-x}Tb_{29.5}Pd_x$ film; Compensation temperature

Amorphous films of rare earth-transition metal (RE-TM) alloys such as Co–Tb are of interest in the basic research and their application. They have been widely studied by many investigators [1,2]. Previously, we had shown that the magnetic properties of amorphous CoTb film are sensitive to the composition of the film and the process parameters [3]. In this work, we investigated the effects of Pd content on the microstructure and magnetic properties of the CoTbPd film.

The $Co_{70.5-x}Tb_{29.5}Pd_x$ films ($x=0\sim22.5$ at%) were prepared on glass and natural-oxidized silicon wafer substrates at room temperature by DC magnetic sputtering of the composite target which made by over-laying Tb and Pd chips on the Co target. The CoTbPd magnetic film was sandwiched between the SiNx protective layers to prevent oxidization. Thicknesses of the CoTbPd magnetic layer and the SiNx protective layer were 75 and 30 nm, respectively. Structure of the film was examined by transmission electron microscopy (TEM). Composition and homogeneity of the film were determined by energy dispersive spectroscopy (EDS). The film thickness was measured by atomic force microscope (AFM). Magnetic properties of the film were measured by using vibrating sample magnetometer (VSM) at room temperature and superconducting quantum interference device (SQUID) at temperatures between 25 and 400 K.

TEM analysis shows that the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is amorphous structure as Pd content is less than 22.5 at%. Fig. 1 is a typical example; Fig. 1(a) is the TEM image of the $Co_{63.5}Tb_{29.5}Pd_7$ film. No crystal grains and grain boundaries are observed in Fig. 1(a). Fig. 1(b) is the electron diffraction pattern of Fig. 1(a). The broad halo diffraction pattern indicates that this film is an amorphous structure.

Fig. 2 shows the variations of saturation magnetization Ms and perpendicular coercivity Hc with Pd content of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film at room temperature. The Ms value of pure $Co_{70.5}Tb_{29.5}$ film ($x=0$ at%) is about 130 emu/cm^3. It is found that the Ms value decreases with increasing Pd content and approaches 0 at $x\sim5$ at% then increases as $x>5$ at%. CoTb alloy is sperimagnetic. The magnetization of the Co subnetwork is antiparallel to that of the Tb subnetwork. $Co_{70.5}Tb_{29.5}$ is RE-rich because its compensation temperature (T_{comp}) is higher than room temperature [4]. The net

*Corresponding author. Tel.: +886-2-2364-8881; fax: 886-2-2363-4562.
E-mail address: f86542011@ntu.edu.tw (C.T. Lie).

0304-8853/$ - see front matter © 2004 Published by Elsevier B.V.
doi:10.1016/j.jmmm.2003.11.369

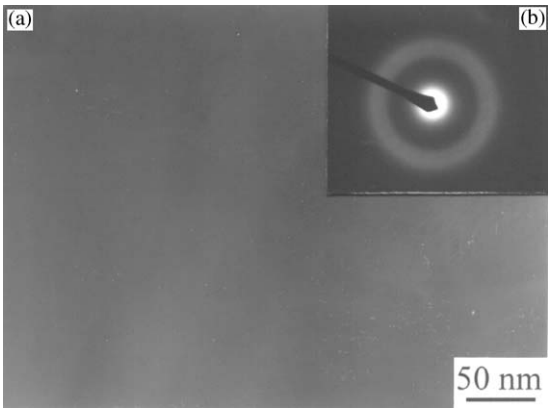

Fig. 1. (a) TEM bright-field image and (b) electron diffraction pattern of the $Co_{63.5}Tb_{29.5}Pd_7$ film.

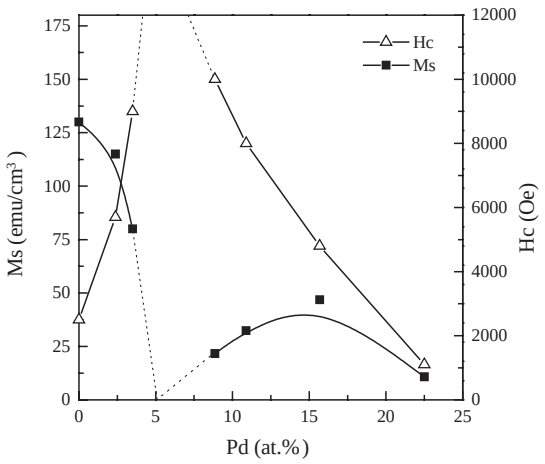

Fig. 2. Variations of Ms and Hc with the Pd content of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film.

magnetization of the $Co_{70.5}Tb_{29.5}$ alloy is parallel to the direction of Tb magnetization. When some Co atoms are substituted for the non-magnetic Pd atoms, the net magnetization of the $Co_{70.5-x}Tb_{29.5}Pd_x$ alloy will be increased. So, Ms value of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film will increase with Pd content. However, as shown in Fig. 2, Ms value of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is decreased with increasing Pd content as $x<5$ at%. This is due to the effect of Co–Pd interface on the magnetization of $Co_{70.5-x}Tb_{29.5}Pd_x$. It had been shown that the saturation magnetization of Co/Pd multilayers exceed than that of pure Co, owing to the spin polarization of non-magnetic Pd [5]. The magnetization of TM subnetwork is increased in RE-rich CoTbPd alloy due to the polarization of the Pd atoms. This results in reducing the Ms value of $Co_{70.5-x}Tb_{29.5}Pd_x$ film as Pd content is less than 5 at%. The $Co_{70.5-x}Tb_{29.5}Pd_x$ alloy becomes TM-rich as $x>5$ at%, as shown in Fig. 3.

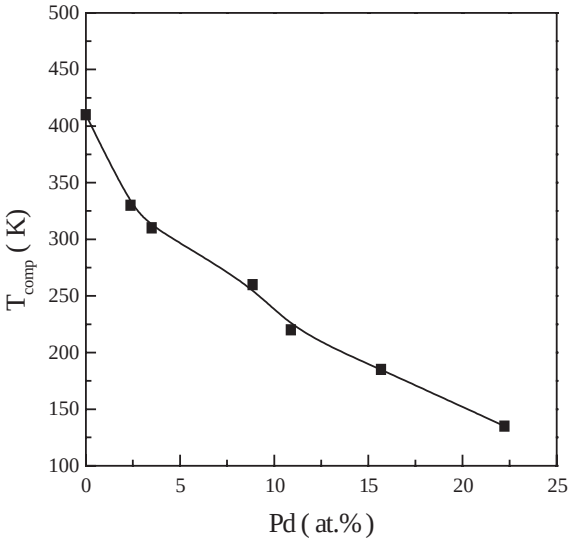

Fig. 3. Relationship between T_{comp} and Pd content of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film.

The Hc value of pure $Co_{70.5}Tb_{29.5}$ film ($x=0$ at%) is about 2500 Oe as shown in Fig. 2. The Hc value increases rapidly from 2500 to 8000 Oe when Pd content increases from 0 to 3.5 at%. Hc decreases rapidly as x larger than about 5 at%. The compensation temperature T_{comp} of RE-TM alloy is very sensitive to the composition of the alloy [4]. At room temperature, the Ms value is zero and Hc value is infinite at the compensation composition. In the RE-rich region, Ms decreases but Hc increases as T_{comp} is decreased. In the TM-rich region, Hc decreases as T_{comp} is decreased. In Fig. 2, we can see that the $Co_{70.5-x}Tb_{29.5}Pd_x$ alloy is transform from RE-rich to TM-rich when $x>5$ at% at room temperature.

Fig. 3 shows the variation of T_{comp} with Pd content of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film. The $Co_{70.5}Tb_{29.5}$ film is RE-rich because T_{comp} of the $Co_{70.5}Tb_{29.5}$ film is about 410 K which is higher than room temperature. T_{comp} of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is decreased from 410 to 130 K as Pd content is increased from 0 to 22 at%. The compensation composition of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is about at $x=5$ at%, as shown in Fig. 3. T_{comp} of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film is lower than room temperature as $x>5$ at%.

The effects of Pd content on the microstructure and magnetic properties of the $Co_{70.5-x}Tb_{29.5}Pd_x$ films with $x=0\sim22.5$ at% have been investigated. TEM analysis indicated that all these films are amorphous. Substituting Co for the non-magnetic Pd will decrease the compensation temperature of the $Co_{70.5-x}Tb_{29.5}Pd_x$ film. The compensation composition of the film occurs at $x\sim5$ at%.

This work was supported by the National Science Council and Ministry of Economic Affairs of R.O.C.

through Grant No. NSC 90-2216-E 002-036 and 92-EC-17-A-08-S1-0006, respectively.

References

[1] H. Katayama, et al., Appl. Phys. Lett. 81 (2002) 4994.
[2] R. Carey, et al., Thin Solid Films 259 (1995) 75.
[3] P.C. Kuo, et al., J. Appl. Phys. 84 (1998) 3317.
[4] P. Hansen, et al., J. Appl. Phys. 69 (1991) 3194.
[5] K. Miura, et al., J. Appl. Phys. 72 (1992) 4826.