Effects of Tb content on the microstructure and magnetic properties of Co$_{85-x}$Tb$_x$Dy$_{15}$ films

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Abstract

The Co$_{85-x}$Tb$_x$Dy$_{15}$ films ($x = 0$–24 at%) were prepared at room temperature by DC magnetron sputtering. Transmission electron microscopy analysis indicated that all the films were amorphous. The magnetization measurement revealed that increasing Tb content would reduce the saturation magnetization $M_s$ of the film but the out-plane coercivity $H_{c\perp}$ was increased. The $M_s$ and $H_{c\perp}$ values of the Co$_{85}$Dy$_{15}$ film ($x = 0$) were about 640 emu/cm$^3$ and 50 Oe, respectively. However, the $M_s$ and $H_{c\perp}$ values of the Co$_{61}$Tb$_{24}$Dy$_{15}$ film ($x = 24$ at%) were about 20 emu/cm$^3$ and $10 \times 10^3$ Oe, respectively.

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Co subnetwork is antiparallel to that of Dy subnetwork. Net magnetization of Co85Dy15 alloy is parallel to that of Co subnetwork. The decrease of $M_s$ of the Co85/C0X/TbX/Dy15 film with increasing Tb content is due to the fact that the direction of net moment of the Tb atoms is opposite to that of Co atoms. The variation of $H_c$ with Tb content is small but the $H_c$ value is increased rapidly with increasing Tb content as $x > 11$. The $H_c$ value increases from about 1.5 kOe for $x = 11$ to about 10 kOe for $x = 24$. Magnetic easy direction of the film is changed from isotropy to perpendicular gradually as the Tb content is increased, because Tb atoms have large out-plane magnetic anisotropy constant $K_{u\perp}$ [5].

Fig. 3 shows the variations of out-plane squareness $S_\perp$ and in-plane squareness $S_\parallel$ with Tb content of the Co85$_{\ldots}$Tb$_x$Dy$_{15}$ film, where $S_\perp = M_\perp/M_s$ and $S_\parallel = S_\parallel/M_s$. $M_\perp$ and $M_\parallel$ are the out-plane and in-plane remanent magnetization, respectively. The $S_\perp$ of CoTb-Dy film is increased with increasing Tb content. $S_\perp$ increases from 0.07 to about 1 as $x$ increases from 0 to 24. This is due to the fact that Tb has large $K_{u\perp}$. The $S_\perp$ was larger than 0.85 as $x > 14$ at%. The curve of $S_\parallel$ versus Tb content is like the peak behavior. The peak of $S_\parallel$ occurs at $x \approx 11$ that is about 0.45. When Tb content is more than 18 at%, $S_\parallel$ is increased with increasing Tb content. As $x > 11$ at%, $S_\perp$ of the Co85$_{\ldots}$Tb$_x$Dy$_{15}$ film is larger than $S_\parallel$. The curve of $S_\parallel$ versus Tb content is like the peak behavior. The peak of $S_\parallel$ occurs at $x_B \approx 11$ that is about 0.45. When Tb content is more than 18 at%, $S_\parallel$ is increased with increasing Tb content. As $x > 11$ at%, $S_\perp$ of the Co85$_{\ldots}$Tb$_x$Dy$_{15}$ film is larger than $S_\parallel$. The curve of $S_\parallel$ versus Tb content is like the peak behavior. The peak of $S_\parallel$ occurs at $x_B \approx 11$ that is about 0.45. When Tb content is more than 18 at%, $S_\parallel$ is increased with increasing Tb content. As $x > 11$ at%, $S_\perp$ of the Co85$_ {\ldots}$Tb$_x$Dy$_{15}$ film is larger than $S_\parallel$.

We have investigated the effects of Tb content on the magnetic properties and microstructure of the Co85$_{\ldots}$Tb$_x$Dy$_{15}$ films ($x = 0–24$ at%). TEM analysis indicated that all the films were amorphous. The magnetization measurement revealed that the addition of Tb would reduce the $M_s$ value of the Co85Dy$_{15}$ film but $H_c$ was increased. $S_\perp$ was about 1 and $H_c \perp \approx 10$ kOe as the Tb content increased to 24 at%.

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References