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Electrochemical formation of intermediate layer for Co/Pd multilayered media

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Abstract

Pd nanocluster seeds were formed on a soft magnetic underlayer (SUL) using an electrochemical substitution reaction, and were utilized as an intermediate layer for a Co/Pd multilayered ($[Co/Pd]_n$) perpendicular magnetic recording medium. A CoNiFeB film prepared with electroless deposition was used as SUL, which was immersed into a $PdCl_2$ solution for the formation of Pd seeds. The Pd seeds were found to effectively reduce the size of magnetic domains in the $[Co/Pd]_n$ film deposited on them. The optimization of the concentration of the $PdCl_2$ solution and the use of the pretreatment process with a $SnCl_2$ solution were effective to obtain the smooth SUL surface with fine Pd seeds as small as 5 nm. The 20 nm-thick $[Co/Pd]_n$ film deposited on the optimized Pd seeds/CoNiFeB SUL exhibited a high coercivity of 7.8 kOe and a small magnetic domain size of 69 nm. These results indicated that the combination of the Pd seeds and the electroless-deposited SUL was desirable in terms of the improvement not only in the magnetic properties of $[Co/Pd]_n$ media but also in the mass productivity of the underlayer.

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1. Introduction

A Co/Pd multilayered ($[Co/Pd]_n$) film is a promissing candidate for a recording layer in a perpendicular magnetic recording medium because of its strong magnetic anisotropy in the perpendicular direction [1]. For improving the recording performance of the medium, fine and well-separated $[Co/Pd]_n$ grains are required to be formed, which decreases the size of magnetic domains in the recording layer. The grain growth of $[Co/Pd]_n$ film strongly depends on the physical and/or chemical suface state of an intermediate layer [2–4], which is located between the recording layer and a soft magnetic underlayer (SUL) in a double-layered medium. The sputter-deposited composite intermediate layers such as Pt–B/Pd/MgO [2], Pd/In–Sn–(O) [3], and Pd/Si [4] were reported to be suitable for improving the magnetic properties and for reducing the magnetic domain size. On the other hand, we have succeeded in forming Pd seeds on a sputter-deposited CoZrNb SUL by utilizing an electrochemical substitution reaction [5], and the seeds were found to play a significant role as the intermediate layer to enhance the physical isolation of the $[Co/Pd]_n$ grains, leading to fine magnetic domains [6,7]. An advantage of the process is that the deposition morphology of Pd seeds can be varied by adjusting the treatment conditions, and our recent study clarified that the size and nucleation density of the Pd seeds were controlled by applying a pretreatment with a $SnCl_2$ solution [8]. The other advantage is the superior mass productivity, which is a characteristic feature of

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electrochemical process. Recently, the development of SUL using an electroless deposition has started [9,10]. The combination of the Pd formation process and the electroless deposition process of SUL is considered to be significant, because the combination process means total preparation of intermediate layer/SUL with the electrochemical processes showing a high mass productivity.

In this study, the $PdCl_2$ treatment was applied to an electroless-deposited CoNiFeB SUL [9], and the control of surface roughness of the $[Co/Pd]_{20}$/Pd seeds/CoNiFeB SUL medium was attempted by adjusting the treatment conditions. Magnetic properties of the $[Co/Pd]_n$ media with the Pd seeds were also studied.

2. Experimental

A CoNiFeB film electroless-deposited onto a Si (1 0 0) disk substrate [9] was used as the SUL of the $[Co/Pd]_n$ medium. The preparation process of the CoNiFeB SUL was summarized in the following: First, Ni seed layer was electrochemically deposited on a properly treated Si substrate [11], and the specimen was immersed into an electroless CoNiFeB bath [9]. The composition of the deposited film was Co:Ni:Fe = 72:13:15 in atomic % (excluding boron content), which was determined by an X-ray fluorescence analysis [9]. After the electroless deposition, the surface of CoNiFeB film was flattened with a chemical mechanical polishing (CMP) process, and the average surface roughness (R_a) of the polished SUL was less than 0.5 nm [9]. On the other hand, a $Co_{91}Zr_5Nb_4$ (300 nm) film sputter-deposited on a glass disk substrate was also used as SUL for comparison. The CoNiFeB SUL was cleaned with ultrapure water, and then immersed into the aqueous $PdCl_2$ solution. When necessary, some specimens were pretreated with the $SnCl_2$ solution prior to the $PdCl_2$ treatment. Table 1 summarizes the concentration and treatment time for the $SnCl_2$ pretreatment and the $PdCl_2$ treatment, where process A is the same as that in the previous study for the Pd seeds on CoZrNb SUL [6,7]. Then, [Co (0.2 nm)/Pd (0.8 nm)]$_{20}$ films were deposited on treated SULs with DC-magnetron sputtering, where two kinds of sputtering apparatuses, named as sputter-I and -II, were used. These sputtering conditions are summarized in Table 2. In this paper, sputter-I was used unless otherwise noted. The perpendicular coercivities of the $[Co/Pd]_{20}$/Pd(5 nm)/SUL media prepared using sputter-I and sputter-II were 2.6 and 5.3 kOe, respectively. On the other hand, these films both exhibited maze-like magnetic domain patterns with a few hundred nanometres in width in magnetic force microscope (MFM) images, and the effects of the Pd seeds on the magnetic properties for $[Co/Pd]_{20}$ films deposited by sputter-I and sputter-II were qualitatively similar, which were independent of the sputtering conditions. Magnetic properties of the $[Co/Pd]_{20}$ films were measured using a polar Kerr effect magnetometer. From Kerr hysteresis loops, the loop slope parameter, α [12], was obtained by using the following equation;

$$\alpha = 4\pi\left(\mathrm{d}M/\mathrm{d}H\right)_{H=H_c} = 4\pi\left(\mathrm{d}\theta_k/\mathrm{d}H\right)_{H=H_c} \times M_s/\theta_{k\,\max}, \quad (1)$$

where θ_k, $\theta_{k\max}$ are Kerr rotation angle and its maximum values, and saturation magnetization, M_s, was assumed to be the same as that of $[Co/Pd]_n$ film without SUL. Magnetic domain size was defined as the correlation length where the autocorrelation function for the MFM images at AC-demagnetized state was equal to zero. Surface morphology of the $[Co/Pd]_{20}$ medium was evaluated by using a scanning electron microscope (SEM) and an atomic force microscope (AFM).

3. Results and discussion

Fig. 1(a) and (b) show SEM images of CoNiFeB surfaces before and after process A using the $PdCl_2$ treatment (treatment time, $t = 40$ s), and those of CoZrNb surfaces are also shown in Fig. 1(c) and (d). In both cases, the Pd metal seeds were formed on the SUL surfaces after the $PdCl_2$ treatment.

Fig. 2 shows the treatment time dependences of perpendicular coercivity (H_c) and loop slope parameter (α) of the $[Co/Pd]_{20}$ films on the CoNiFeB and CoZrNb

Table 2
Sputtering conditions for $[Co/Pd]_n$ deposition

Sputter	Background pressure (Torr)	Target-Substrate distance (mm)	Ar gas pressure (mTorr)
I	$<3\times10^{-7}$	50	20
II	$<4\times10^{-9}$	300	7.5

Table 1
Treatment conditions for Pd seeds formation

Process	$SnCl_2$ pretreatment		$PdCl_2$ treatment	
	Concentration (g/L)	Treatment time, t (s)	Concentration (g/L)	Treatment time, t (s)
A	–	–	0.10	0–90
B	–	–	0.30	5
C	1.0	10	0.30	5