



Glassy alloy composites for bit-patterned-media

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ABSTRACT

With the aim of developing a novel perpendicular bit-patterned-media, combined process of thermal imprinting of glassy alloy thin film and embedding Co/Pd multilayer was developed. Nano hole array with a hole diameter of 30 nm was successfully formed onto Pd-based glassy alloy thin film by thermal imprinting. Co/Pd multilayer was overlaid on a textured Pd-based glassy alloy thin film. After finishing by sputter etching, prototype bit-patterned-media was prepared. Switching behavior examined under magnetic field of ± 10 kOe reveals that the isolated magnetic dots began to switch at 10 kOe. These results suggest that the prototype composite has a strong possibility for the realization of next generation bit-patterned-media with high data density.

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1. Introduction

Owing to dense and random atomic configuration, glassy alloys (GAs) exhibit excellent properties [1]. By utilizing the properties of GAs, several innovative products have been successfully developed and commercialized [2]. In addition, GAs exhibit good sub-micro imprintability in their supercooled liquid (SCL) region [3–5]. By the glassy nature of such atomic configuration, GAs are expected to be candidate materials for nano-imprinting. By combining a surface nano-texture of GAs by imprinting with other materials, so-called GA-nano-composites, innovative nano-structured devices with high functionality will be developed.

In the case of magnetic recording media for hard disk drive (HDD), magnetic domains are drastically miniaturized as according to requirement for higher data density and plane data density is reaching about several hundreds of Gbit/in.² at present. However, a thermal demagnetization [6] will be caused at when a certain miniaturization of magnetic domains. To overcome the limitation and achieve higher data density, precisely aligned and isolated magnetic recoding dots (MRDs) so-called bit-patterned-media (BPM) [7] is expected to adopt for the next generation media. We have already reported about the applicability of GA-nano-composites to BPM for HDD with a plane data density of about 20 Gbit/in.² [8]. By utilizing the imprinted nano

hole array with a hole diameter of 90 nm on the surface of Pd-based glassy alloy [9] thin film (GA-TF) and embedding Co/Pd multilayer with perpendicular magnetism, prototype nano-composite for BPM was prepared. Consequently, it was found that the isolated Co/Pd MRDs act as single magnetic domains and magnetization-switching behavior was confirmed under magnetic fields of ± 20 kOe. However, the plane data density of the prototype BPM media is still small and finer pattern should be required.

In this paper, we intend to present the fabrication result of Pd-based GA-TF with a finer surface texture of 30 nm hole by thermal imprinting. By overlaying the Co/Pd multilayer and surface sputtering etching for flattening and isolation of MRDs, prototype BPM with a plane data density of about 180 Gbit/in.² was prepared. Magnetization-switching behavior was also examined.

2. Experimental procedures

In the present study, expected composite construction for BPM of high data density HDD system has already reported [8]. A Pd-based GA-TF was deposited on water-cooled Si substrate using a DC magnetron sputtering method. Detailed sputtering condition was described in elsewhere [10]. The compositions of the obtained films were analyzed by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Phase identification and thermal characteristic of the films were examined by X-ray diffractometry (XRD) and differential scanning calorimetry (DSC), respectively. For imprinting, an EB lithographed Si mold having a dot array pattern with a dot diameter of 30 nm, a pitch of 60 nm and a dot height of 30 nm was used in the present study. Using the Pd-based GA-TF and the Si mold, nano-texture was fabricated by thermal imprinting. The imprinted morphology was examined using an atomic force microscope (AFM) and a field-emission scanning electron microscopy (FE-SEM).

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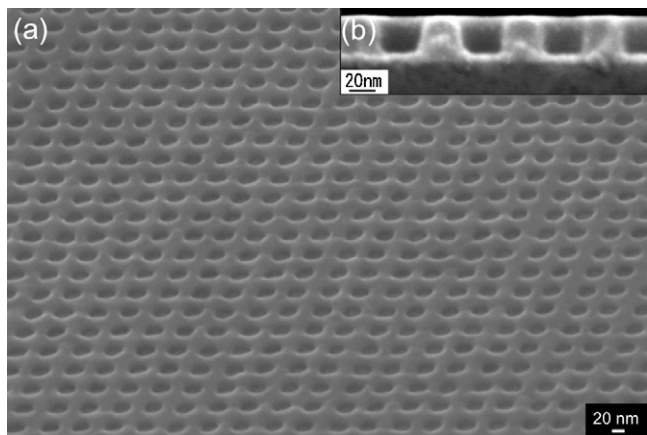


Fig. 1. (a) the SEM slantview and (b) cross-sectional images of the nano hole array with a hole diameter of 30 nm imprinted on the Pd-based GA-TF.

For the magnetic recording layer, a Co/Pd multilayer was overlaid onto nano-textured Pd-based GA-TF. High saturation magnetization of the MRDs is favorable from the point of thermal demagnetization [6]. On the other hand, magnetic field generated by read/write head will be limited in actual use. It is therefore a Co/Pd multilayer with controllable magnetic properties by changing the thickness of Co and Pd layer was employed for fabricating MRDs. Sputtering atmosphere and DC power for preparation of Co/Pd multilayer was 0.2 Pa of high purity argon gas and 20 W for Co and 40 W for Pd, respectively. Finally, argon ion sputter etching was carried out for surface flattening and isolating the MRDs of the prototype BPM. Switching behavior of the prototype BPM was examined using an in situ magnetic force microscope (MFM) [11] under typical magnetization field ranging between ± 10 kOe.

3. Results and discussion

For the fabrication of nano-template, non-magnetic Pd-based GA-TF with a chemical composition of $\text{Pd}_{39}\text{Cu}_{29}\text{Ni}_{13}\text{P}_{19}$ was selected. Glass transition temperature (T_g), onset of crystallization temperature (T_x) is evaluated to be 575 K and 658 K, respectively. Resulting SCL region of 83 K will be much suitable for thermal nano-imprinting. The details of structures and thermal characteristics were reported in Ref. [10]. Nano-imprinting for the Pd-based GA-TF with a thickness of 20 nm was carried out. The Pd-based GA-TF was initially heated at a rate of 1.67 K/s in an argon atmosphere. Then the mold was pressed to the GA-TF at 615 K with an applied stress of 60 MPa. To avoid surface roughening due to crystallization, pressing time of 40 s was chosen. Fig. 1(a and b) shows the SEM slantview and cross-sectional SEM images of the imprinted nano hole array with a hole diameter of 30 nm. As seen in the slantview image, homogeneous and periodic holes are formed on the Pd-based GA-TF. It is also found that the hole shape is trapezoid and bottom is flat as shown in the cross-sectional image. This flat bottom morphology is quite important for perpendicular magnetization of overlying the Co/Pd multilayer because the large anisotropy field (H_k) of the Co/Pd multilayer is originated from interface flatness between Co and Pd [12].

To add a magnetic recording layer, Co/Pd multilayer was overlaid onto textured Pd-based GA-TF. The construction of the multilayer was seven times periodically stacking of Co and Pd with a thickness of 0.43 and 1.0 nm, respectively. Fig. 2 shows the in-plane and perpendicular magnetization curves of the Co/Pd multilayered thin film. The curves show perpendicular magnetization behavior. Saturation magnetization (M_s) and H_k of the Co/Pd multilayered thin film in the as-deposited plane form is evaluated to be 600 emu/cc and 2.2 kOe, respectively. The value of H_k may be not enough for high resistivity against thermal demagnetization [6]. However, the H_k will be increased by sectioned high aspect magnetic dot due to nano-texture. Finishing by argon ion sputter etching for the overlaid Co/Pd multilayer was carried out for

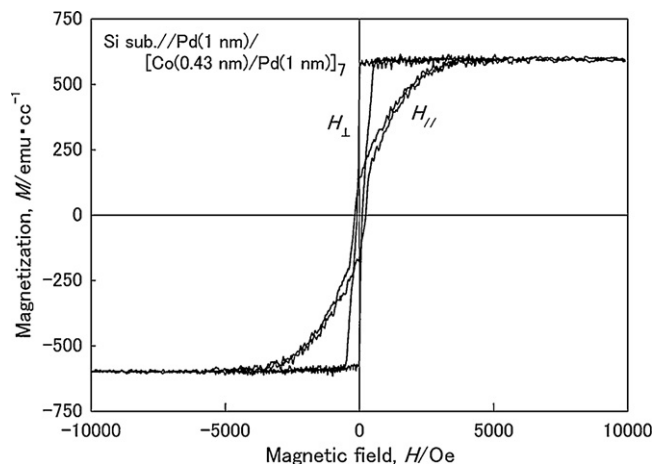


Fig. 2. In-plane and perpendicular magnetization curves of the Co/Pd multilayered thin film with a total thickness of about 10 nm.

isolation of MRD embedded into nano-hole and flattening of the surface.

Fig. 3a and b shows the back scattering SEM overview and AFM profile of the finished surface, respectively. As seen in the SEM image, Co/Pd multilayered MRDs having uniform circular shape are isolated with each other. These properties will be an advantage to practical use for BPM with high plane data density. In addition, result of AFM profile reveals that the super-smooth surface with a maximum roughness (R_y) of less than 3.8 nm will also be another advantage for flying read/write magnetic head.

To confirm the most important property, switching behavior for prototype BPM was investigated under continuous sweeping magnetic field ranging from +10 kOe to -10 kOe.

Fig. 4 shows the MFM images of BPM surface using GA-composite under +10, -1 , -3 , -4 , -6 and -10 kOe, respectively. All the MRDs under +10 kOe exhibit white color, revealing the same magnetization direction. No directional change can be seen up to -6 kOe. Under -10 kOe, just one dot turned the color to black,

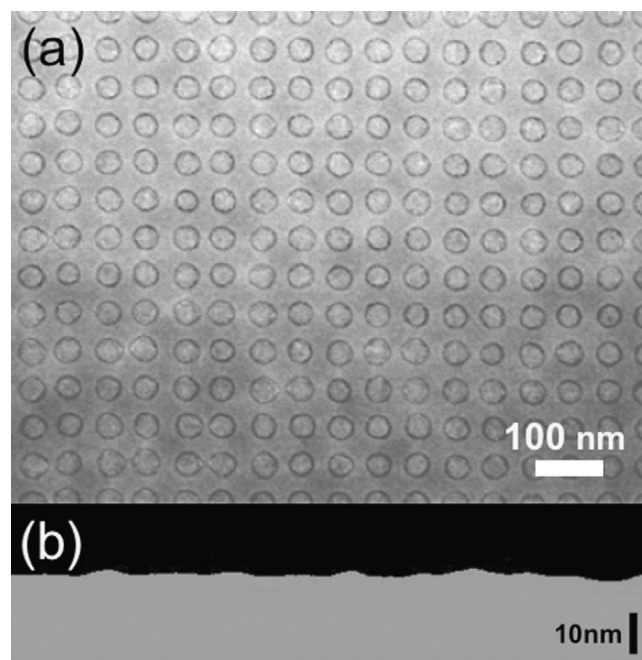


Fig. 3. (a) the back scattering SEM overview and (b) AFM profile of finished prototype BPM surface flattened by an argon ion sputter etching.

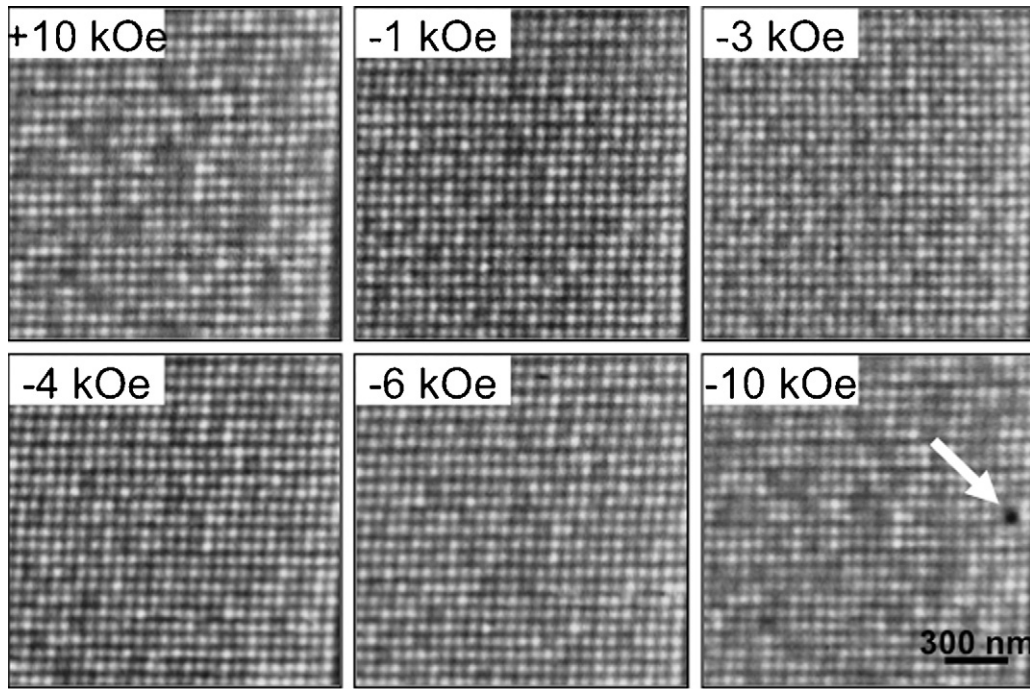


Fig. 4. MFM images of prototype BPM surface using glassy alloy composite under +10, -1, -3, -4, -6 and -10 kOe, respectively.

suggesting an occurrence of switching. This result suggests that the isolated MRDs are independently magnetized and each dot will act as single magnetic domain. In addition, it is worthy note that the switching field is much larger than H_k of the Co/Pd multilayer (2.2 kOe) in the as-deposited plane form. Not surprisingly, this large difference between switching field of the dot and H_k is attributed to the shape dominated magnetic anisotropy or an effect of demagnetizing field. However, relationship between size of dot and switching field should be clarified because the switching field of dots will be optimized as according to field by recording head. Anyway, these results suggest that the nano-composite using Pd-based GA-TF is preferable material for the constituent of BPM with high data density HDD. It is therefore concluded that this production method is a candidate process for preparing BPM of high data density HDD.

4. Conclusions

With the aim of developing a BPM with high data density, prototype GA-composite was prepared using nano-imprinting of GA-TF and embedding of Co/Pd multilayer. The obtained results are summarized as follows;

- 1) Nano-imprinting for Pd-based GA-TF was carried out. As a result, periodic nano hole array with a hole diameter of 30 nm could be formed on the surface of the Pd-based GA-TF.
- 2) By overlaying Co/Pd multilayer onto textured Pd-based GA-TF and finishing by an argon ion sputter etching, uniform and isolated MRDs were formed. Magnetic switching behavior for the prototype BPM was investigated. As a result, the switching of

isolated MRDs began to occur at an opposite magnetic field of 10 kOe.

These obtained results suggest that the production process using a nano-imprinting of GA-TF and overlaying of Co/Pd multilayer is suitable for the realization of next generation BPM with high data density.

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