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EFFECTS OF SURFACE CRYSTALLINE MODIFICATION ON GIANT MAGNETO-IMPEDANCE IN Co-BASED AMORPHOUS RIBBON

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I. INTRODUCTION

The asymmetric GMI profile, showing GMI-valve phenomenon with a high field sensitivity and linearity, has been realized by field-annealing of Co-based amorphous ribbon in open air [1]. The asymmetric GMI profile has been qualitatively associated with the role of bias field developed on a surface crystalline layer on the permeability [2]. However, there is no detail analysis for the microcrystalline structures of surface and bulk materials. In this work, microstructural analysis have been made on the amorphous $Co_{66}Fe_4B_{15}Si_{15}$ ribbons annealed at the temperature of 380 °C for various annealing time in vacuum and in open air.

II. EXPERIMENTAL

Amorphous ribbons $Co_{66}Fe_4B_{15}Si_{15}$ were annealed at temperature T_a=380 °C in various annealing time (t_a) in vacuum (A-batch), and in open air (B-batch). The field of 3 Oe was applied during the annealing of both A- and B-batch samples, where the direction of annealing field was regarded as positive. X-ray diffraction experiment was done by GID method (grazing incidence diffraction) with Cu-anode (λ_{Cu} = 0.154184 nm). In order to check the surface crystallisation 2θ–scans were provided.

III. RESULTS AND DISCUSSION

Microstructural analysis

Figures 1(a)-1(c) present the 2θ-scan diffraction spectra (with incidence angle $\omega=1^0$) of the as-quenched, A- and B-batch samples with t_a = 480 min, respectively. The penetration depth estimated from absorption law is about 300 nm. The diffraction spectrum is typical for amorphous state with two wide maxima for 2θ=45.67° and 80.4°, respectively, as in Fig.1(a). Samples of shorter annealing time than 60 min show no distinctive changes between amorphous and annealed samples. However, the diffraction spectra, around the first maximum of amorphous state, of A-batch samples with t_a = 480 min (Fig.1(b)) could be decomposed into three wide peaks centred around crystalline positions of fcc-Co, and around the amorphous phase. The peak positions for crystalline Co-phases are collected in Table I. The main peak $2\theta_1$ is related to the amorphous phase. The peaks $2\theta_2$ is the main positions of initial nucleation of crystallisation to hcp-Co (101) phases, and $2\theta_3$ position is probably related to the nucleation of hcp-Co (200).

Table I. Peak positions for annealed samples in vacuum (A-batch).

Annealing Parameters	Peak positions		
	$2\theta_1$	$2\theta_2$	$2\theta_3$
As-quenched	a-45.67	-	-
T_a=380 °C, t_a= 300 min	45.05	46.9	50.96
T_a=380 °C, t_a = 480 min	44.75	46.93	51.82

a- denotes the value of the position of amorphous peak.

The diffraction spectra in B-batch samples for the short annealing time of t_a = 20 and 40 min could be decomposed into five and nine, respectively, wide peaks centred around amorphous and crystalline positions of hcp- and fcc-Co, as summarized in table II. Samples annealed during long time of t_a = 300 and 480 min (Fig.1(c)) show very sharp peaks evidently connected with fcc-Co, hcp-Co and Co_2Si crystalline phases (see Table III). For the annealed samples in air, the B and Si atoms diffuse to the surface and oxidize after 20 min annealing, and Co-atoms also diffuse to the surface and simultaneously start to nucleate fcc- and hcp-Co crystallites [3].

Table II. Peak positions for annealed samples in air (B-batch).

Peak positions	$2\theta_1$	$2\theta_2$							
As-quenched	a-45.67	a-80.40	$2\theta_3$	$2\theta_4$	$2\theta_5$				
T_a=380°C, t_a= 20min	41.46	44.07	a-45.85	51.86	a-80.89	$2\theta_6$	$2\theta_7$	$2\theta_8$	$2\theta_9$
T_a=380°C, t_a= 40min	41.76	a-45.17	a-45.28	48.16	51.04	60.58	76.38	a-83.92	92.24

Table III. Peak positions for annealed samples in air (B-batch).

Peak positions	$2\theta_1$	$2\theta_2$									
As-quenched	a-45.67	a-80.40	$2\theta_3$	$2\theta_4$	$2\theta_5$	$2\theta_6$	$2\theta_7$	$2\theta_8$	$2\theta_9$	$2\theta_{10}$	$2\theta_{11}$
T_a=380°C, t_a=300 min	41.77	44.48	45.46	a-45.93	46.53	51.18	59.98	75.87	a-82.48	84.25	92.56
T_a=380°C, t_a=480 min	41.85	44.42	45.52	a-45.81	47.55	51.31	60.74	75.93	a-82.65	84.39	92.49

In order to check how amorphous and crystalline phases are distributed in the depth of the ribbon, the incident beam angle of X-ray was changed from ω=1° to ω=5°. In this new measurement geometry the structural information comes from the about 1.5 μm thickness of the ribbon surface. The spectrum was changed drastically with the angle and the sharp crystalline peaks of surface have been dominated by greater amorphous fraction at ω=5°. This effect of course is much stronger when the spectrum from scan θ–2θ is taken for the analysis. In this case the structural information comes from whole volume of the sample and contribution of amorphous fraction evidently dominates over surface crystalline phases fraction.

IV. CONCLUSION

The XRD spectra in annealed amorphous $Co_{66}Fe_4B_{15}Si_{15}$ samples in vacuum indicate atomic arrangements with initial nucleation of hcp-Co crystallite at 380° annealing temperature. The samples annealed in open air during short time for $t_a \leq 40$ min show the formation of the initial surface nuclei of fcc- and hcp-Co crystalline phases. However the XRD spectra in samples for long annealed time of $t_a \geq 300$ min show a sharp and good developed surface crystalline hcp-, fcc- Co and Co_2Si phases

References

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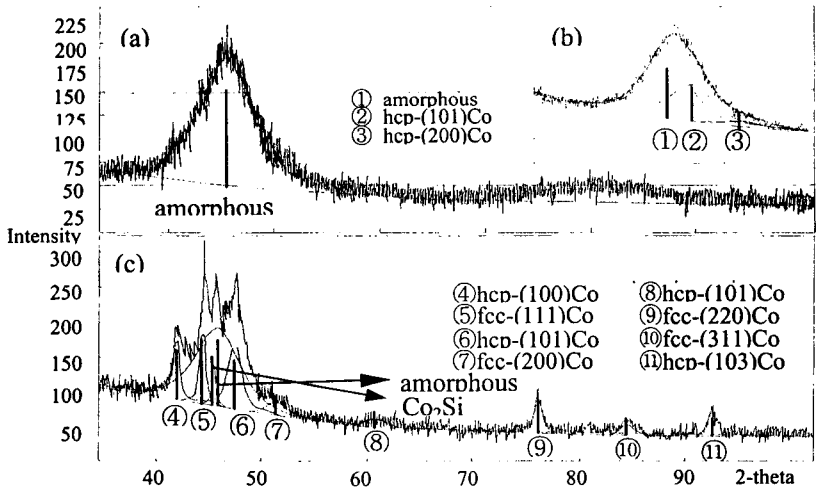

Fig1. GID-spectrum (ω=1°)
(a) as-quenched sample
(b) annealed sample in vacuum (A-batch)
(c) in air (B-batch) for 480 min annealing time.
Solid line denotes the best fitting profiles.