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The Effect of Milling and Thermal Annealing on Microstructural and Magnetic Properties of Nanocrystalline Fe and Fe-35 wt% Co Alloys

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Nanocrystalline Fe and Fe-35 wt% Co alloys were prepared using a high-energy ball mill and then annealed under vacuum. The effect of milling and thermal annealing on microstructural and magnetic properties were investigated using XRD, SEM and VSM. A body-centered cubic nanocrystalline Fe-Co alloy resulted after 8 h of the milling process with an average grain size of about 12 nm. Figure 1 depicts the coercivity versus milling time for pure Fe and Fe-35 wt% Co before and after thermal annealing. Before annealing, the coercivity increased from 43 to 60 Oe, by milling for 3 h, followed by a reduction to 31 Oe on milling for longer periods. This latter effect attributed to the effect of the very fine crystallite size associated with prolonged milling. In addition, the samples, which experienced annealing process, showed lower coercivity due to the reduction of imperfections and defects [1, 2].

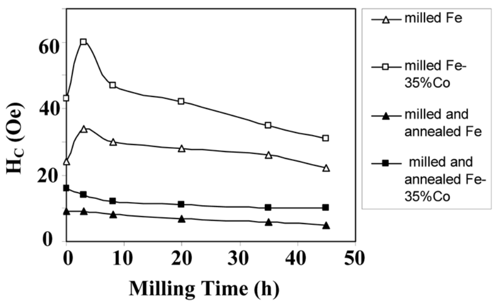

Fig. 1. H_C versus milling time for Fe and Fe-35 wt.% Co before and after annealing at 550 °C for 1 h.

The saturation magnetization increased during milling caused by the completion of alloying and the diminution in magnetocrystalline anisotropy due to the grain refinement, which leads to an easier rotation of the magnetic moment.

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Surface Magnetic Properties of the Rapid Annealed $Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$ Alloy Ribbons

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The Nanocrystalline FINEMET ($Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$) alloys obtained by partial devitrification of amorphous alloys are very attractive for application due to their excellent soft magnetic properties [1].

The Nanocrystalline FINEMET ($Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$) alloys have been studied in the field of homogenous annealing technique, but very little attention has been devoted in rapid annealing.

In this study, The near surface magnetic properties of rapid annealed $Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$ amorphous ribbons were investigated the effect of the halogen light annealing system, intensively the influence of annealing temperature, time of annealing, heating rate and cooling rate.

Alloy	Structure	Bs (T)	μ_e (at 1kHz)	Hc (A/m)	Pc (kW/m³)	λs (x10⁻⁶)
$Fe_{91}Zr_7B_2$(N)	bcc	1.70	14000	7.2	-	-
$Fe_{89}Zr_7B_4$(N)	bcc	1.65	15000	7.4	-	-
$Fe_{89}Zr_5B_6$(N)	bcc	1.70	13000	8.3	-	-
$Fe_{91}Hf_7B_2$(N)	bcc	1.60	18000	4.1	-	-
Fe-6.5wt%Si	Ordered bcc	1.80	2400	9.6	-	≅ 0
Fe-Si-B	Amorphous	1.41	6000	6.9	460	+ 20
Co-Fe-Si-B	Amorphous	0.53	80000	0.32	300	≅ 0
MnZn ferrite		0.43	2300	14.3	600	-
Fe-Nb-Cu-Si-B(N)	bcc	1.25	100000	0.53	280	+2.1

N : nanocrystalline　　Pc : Core loss(f= 100 kHz, Bm=0.2 T)

Table 1. Magnetic properties of nanocrystalline other soft magnetic materials 1 [2].

The amorphous ribbons with the nominal atomic composition $Fe_{73.5}Si_{13.5}B_9Nb_3Cu_1$ were fabricated by single-roll melt-spun method under argon atmosphere. The quartz nozzle shape was circular/rectangular and the surface speed of Cu wheel was 25~30 m/sec. The prepared ribbons were about 15/20 μm in thickness and 3/5 mm in width. The ribbons were pasted on the Si wafer/glass and then put into the rapid-annealing chamber. The halogen light irradiates the wheel side of the ribbons directly. The temperature of the samples increases from room temperature to 300 °C and keep 10 and 30 second at high vacuum condition (higher than 10^{-6} torr).

The prepared samples' near surface and volume magnetic properties were measured by Kerr effect (MOKE) magnetometer and vibrating sample magnetometer (VSM), respectively. The microstructure of the rapid-annealed ribbons are examined by the X-ray diffraction (XRD). The cross sectional phase of ribbons were observed by scanning electron microscopy (SEM).

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