

THE EFFECT OF LOCAL LASER ANNEALING ON THE MAGNETIC PROPERTIES OF AMORPHOUS RIBBONS

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Abstract. - Ferromagnetic amorphous ribbons has been locally laser annealed, with different geometrical arrays of annealed zones being the density of irradiated areas constant (100 spots of 10 μm of diameter by square centimeter). It has been studied the influence of these heat treatments in the induced anisotropy and magnetic losses.

The magnetic behavior of amorphous ferromagnetic ribbons, locally laser annealed to induce geometrical arrays of irradiated zones [1], has been studied. The diameter of these zones was 10 μm . The laser power was high enough to crystallize the irradiated areas [2]. Different arrays were induced, with different symmetries (4-fold: distance between laser impacts 1 mm \times 1 mm, and 2-fold: distance 0.5 mm \times 2 mm).

The measures were performed in two high magnetostriction samples (2605 SC, 2605 S2) and in a low magnetostriction one (2705 M). Disk shape samples of 2 cm of diameter, cut by electrical abrasion, were used in the anisotropy and magnetization measurement. Ring like samples (0.7 cm inner diameter, 2 cm outer diameter) were cut to measure the magnetic losses.

Hysteresis loops and curves of maxima magnetization versus applied field direction at different applied field, were obtained with an original sampling and hold system [3].

Table I shows the magnetization work to magnetize the sample parallel and perpendicular to the rolling direction, in as-cast samples and after different laser annealing. After any local laser annealing the magnetization work in all the samples increase.

Table I. - Work magnetization to magnetize the samples parallel and perpendicular to the rolling direction.

		as-cast	2-fold	4-fold
2705 M ($\lambda_s \approx 0$)	parallel	58	397	313 J/m ³
	perpend.	99	408	313 J/m ³
2605 SC ($\lambda_s = 30 \times 10^{-6}$)	parallel	346	3 245	5 758 J/m ³
	perpend.	490	2 734	5 758 J/m ³
2605 S2 ($\lambda_s = 27 \times 10^{-6}$)	parallel	283	3 295	5 850 J/m ³
	perpend.	283	2 107	5 850 J/m ³

The as-cast 2705 M exhibit a low in-plane anisotropy along the rolling direction, whereas the other as-cast samples display anisotropy perpendicular to the sample surface, but 2605 SC besides shows an in-plane anisotropy in the rolling direction.

Figure 1 shows magnetization curves for samples with high and low magnetostriction. We can see that:

- the anisotropy energy induced by the annealing is greater in the high λ_s samples than in the low λ_s one;
- in the high λ_s samples, the induced easy axis is perpendicular to the rows of laser impacts separated 0.5 mm. In the low λ_s one, the induced easy axis is parallel to the above mentioned rows. However it is very difficult to saturate the sample, and an intersection between both magnetization curves appears, having similar magnetization work (Tab. I);

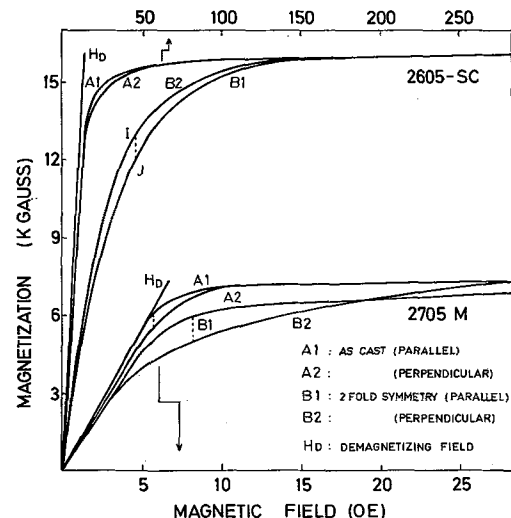


Fig. 1. - Magnetization curves (parallel and perpendicular to the rolling direction) of 2705 M and 2605 SC: as-cast, 2-fold and 4-fold symmetry annealing.

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c) in the low λ_s samples, the initial susceptibility is practically not affected by the annealing, but it is widely reduced in the high λ_s ones.

The different behavior of both kinds of samples can be due to the internal stresses induced in the sample by the volume change, during the cristallization, of the irradiated areas. The internal stresses induce more anisotropy in the high λ_s samples than in the other.

Figure 2a shows, for the as-cast samples, the curves of maxima magnetization *versus* the angle between the rolling direction and the applied field, H , at constant amplitude of H , $(M, \phi)_H$. The amplitude of these curves correspond to the maxima distance between the curves of magnetization parallel and perpendicular to the easy axis (distance i, j Fig. 1). These curves are, in some way, similar to the anisotropy torque curves. 2705 M and 2605 SC show an in-plane easy axis and the 2605 S2 has not any in-plane easy axis.

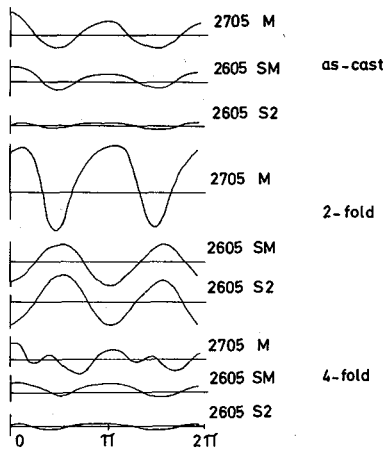


Fig. 2. - $(M, \phi)_H$ curves for the three samples. a) as-cast. b) 2-fold symmetry; c) 4-fold symmetry.

Figure 2b shows the $(M, \phi)_H$ curves for the 2-fold symmetry annealed samples. It can be observed an in-plane easy axis in all of them.

Figure 2c shows the $(M, \phi)_H$ curves for the 4-fold symmetry annealed samples, in the 2705 M, low λ_s , it appears a biaxial anisotropy. In the 2605 SC the in-plane anisotropy is reduced, and the 2605 S2 is still isotropic. Then in the low λ_s sample it is possible to induce a biaxial anisotropy (lightly modified by the initial uniaxial anisotropy of the as-cast sample), whereas conventional annealing are unable to produce this result. Others kinds of irradiation treatment like irradiation by high energy heavy ions neither induce this effect, perhaps due to the at random distribution of damaged regions [4].

The origin of induced anisotropy by local laser annealing can be due to:

a) the internal stress field produced by the change of volume of the irradiated zones;

b) the magnetostatic energy due to the different permeability of the cristallized zones and the rest of the sample.

In 2705 M, because its low λ_s , the anisotropy must be mainly due to the magnetostatic energy capable of inducing biaxial anisotropy. In the other two samples, the anisotropy is mainly due to internal stresses, and the magnetic hardening produced by them masks completely the other effect.

Magnetic losses were evaluated by measuring, in a single above mentioned ring, the first harmonic of the dB/dt and its phase respect to H with a two phases lock-in amplifier. In figure 3, it can be seen as the losses increase in the annealed samples due to the magnetic hardening, but the slope is not dependent on the heat treatments.

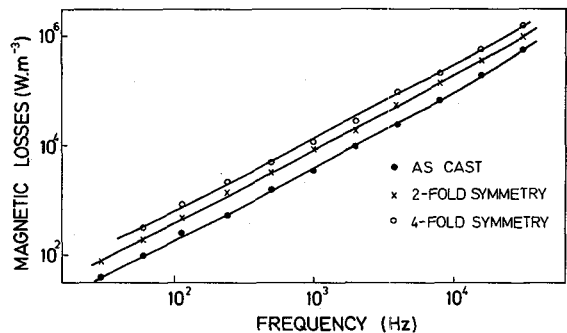


Fig. 3. - Losses *vs.* frequency for an induction of 0.57 T (2705 M).

Acknowledgments

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