The effect of magnetic annealing on the crystallographic texture of Fe-2.6 % Si

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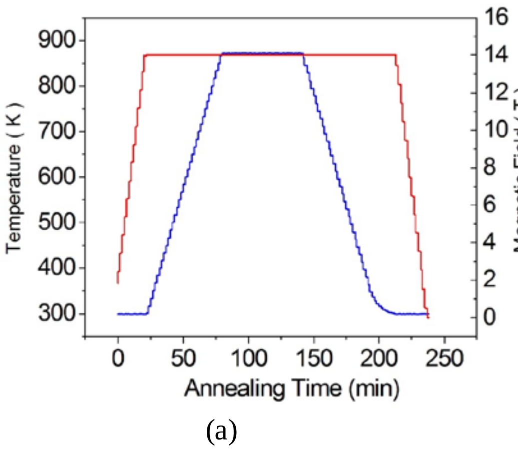
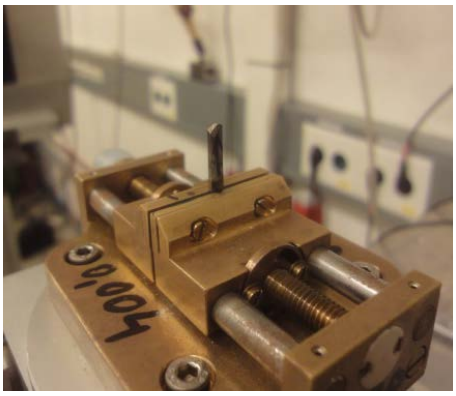
The term of magnetic annealing is used regularly to indicate the application of a magnetic field while a material is being heat treatment. In 1913, Pender and Jones observed a marked improvement in permeability of a 4% Si-Fe as a result of the application of an alternating magnetic field during cooling of the alloy from 800°C to room temperature [1]. The primary benefit of magnetic annealing, however, had not been fully recognized until Kelsall, in 1934, reported in detail the remarkable changes in magnetization behavior of Permalloys (55-80% Ni-Fe) caused by magnetic annealing. Therefore, many researchers succeeded in applying magnetic field during annealing of various alloys such as Co-Ni, Fe-Co, Fe-Al, Fe-Si and Fe-Ni [1].

Sample processing was undergoing for steps: First was cold rolling to 75% reduction; second was an intermediate annealing of 60 min at 600°C; third was another cold rolling to 60% reduction; final step was annealing inside a magnetic furnace (magnetic annealing). The temperature was increased up to 600°C with a heating rate of 10°C /min, hold for 1h at 600°C and finally cooling down to 25°C. Process parameters are shown in fig 1a.

Pole figure measurements for quantitative texture analysis were performed at the high energy materials science beamline HEMS@ Petra III using an energy of 87.7keV (wavelength of 0.1425 Å). A beam size of 600µm x 600µm was used to get sufficient grain statistics. The sample to detector distance was 1123 mm. An area detector type Perkin Elmar (PE) with a resolution of 200µm x 200µm was used with an exposure time of 1 sec. The data analysis was carried out by a software package written by S.B.Yi to extract pole figure data from area detector images including corrections for anisotropic absorption and constant volume during sample rotation [3]. The orientation distribution function (ODF) was calculated by ISEM (Iterative Series Expansion Method) [2]. The Fe2.6%Si sheet plates were oriented with the rolling plane perpendicular to the beam direction and with the rolling direction (RD) to the top, see fig 1b.

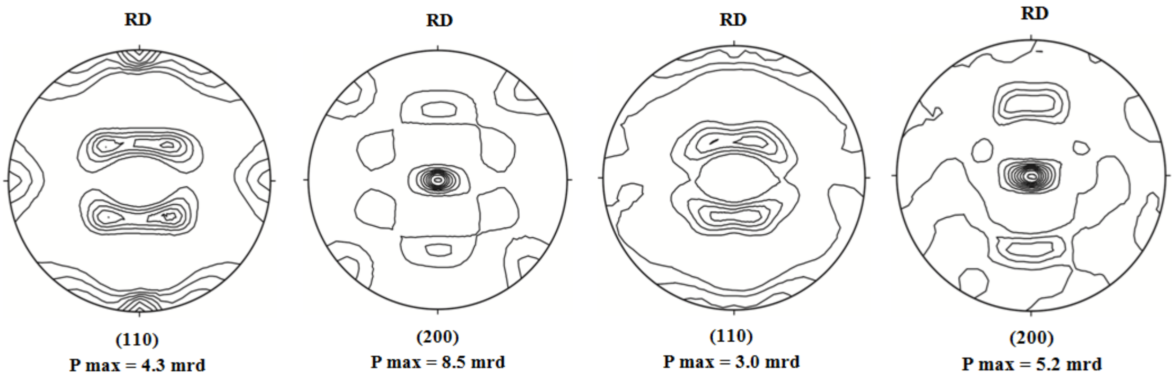


(a)



(b)

Figure 1a: Schematically presentation of the magnetic annealing at during 14 Tesla
Figure 1b: Fe-2.6%Si sample mounted on sample stage at HEMS@ Petra III PO7B



(a) (b)

Figure 2: The (110) and (200) pole figures after 60 % cold rolling plus annealing at 600°C with external field at (a) 7 Tesla (b) 14 Tesla

The results observed after 7 Tesla annealing, see fig. 2a and fig 3, show an increase of the intensity spread along θ fiber <100>||ND compared the texture without external magnetic field (0 Tesla). Particular the rotated cube component (001)[110]develops much stronger.

After 14 Tesla annealing the texture is much weaker, see fig 2b and fig. 3.The key difference is the development of the cube component (001)[100] with reduction of the rotated cube. The α-fibre distribution is similar to the sample without magnetic annealing. In the θ fiber one can see two components rotated 30° from rotated cube.

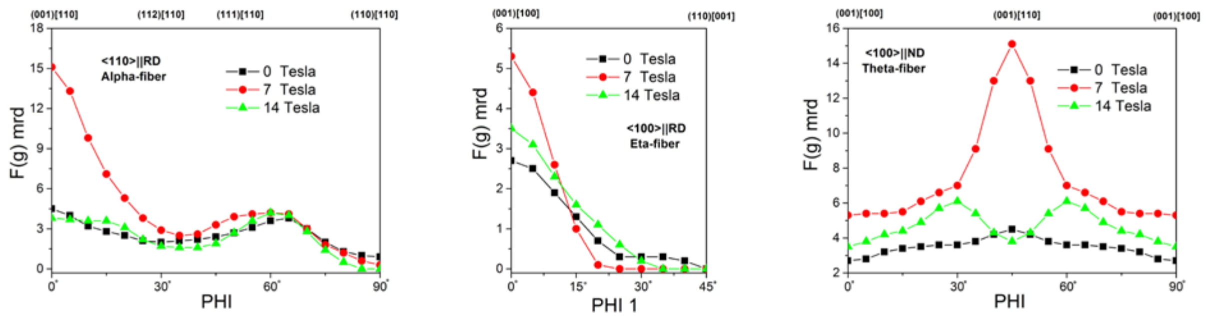


Figure 3: The α, η and θ texture fibers after magnetic annealing

Reference

[1] C.W. Chen: Magnetism and Metallurgy of Soft Magnetic Materials, Dover Publications – INC, New York, 1986.

[2] H. J. Bunge, M. Dahms, The iterative series- expansion method for quantitative texture analysis, J. Appl. Cryst., Vol. 22, (1989), pp. 439-447.

[3] S.B.Yi, private communication