Nanostructured magnetic powders produced by gas atomization

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New compositions of Fe-Si-B-P-Nb-Cu powders were produced by gas atomization with helium [1]. The powder fraction with a particle size below 20 μm exhibited an amorphous structure (Figure 1). The $(Fe_{0.76}Si_{0.09}B_{0.10}P_{0.05})_{97.5}Nb_{2.0}Cu_{0.5}$ (at. %) alloy was annealed in the supercooled liquid region (480 °C) and at the first crystallization peak (530 °C). Annealing this alloy in the supercooled liquid region (at 480 °C) mainly produced structural relaxation, yielding a significant reduction of the coercive field (from 2.24 to 0.94 Oe) and an increment of the saturation magnetization (from 139 to 146 emu/g). Annealing at the first peak temperature (at 530 °C), produced a microstructure formed by a-Fe(Si) nanocrystals of approximately 16-17 nm in diameter, embedded homogeneously in an amorphous matrix (Figure 2). This material exhibited better soft magnetic properties than the amorphous precursor (saturation magnetization of 144 emu/g and a coercive field of 0.69 Oe in the sample annealed for 30 min). The saturation magnetization at room temperature is rather similar for the amorphous relaxed sample (annealed at 480 °C) and for the nanocrystalline alloys (annealed at 530 °C), indicating that both the crystalline and the relaxed amorphous phases have similar saturation magnetization [2]. The very low coercivity of the nanocrystalline alloy is explained by the random averaging of the magnetocrystalline anisotropy of the a-Fe(Si) nanocrystals within a larger ferromagnetic correlation exchange volume [3].

References

[1] K. L. Alvarez et al., Journal of Alloys and Compounds, 810 (2019) 151754
[2] J. González, Applied Physics Letters, 85 (2004) 5944–5946
[3] G. Herzer, Acta Materialia, 61 (2013) 718–734

Figures

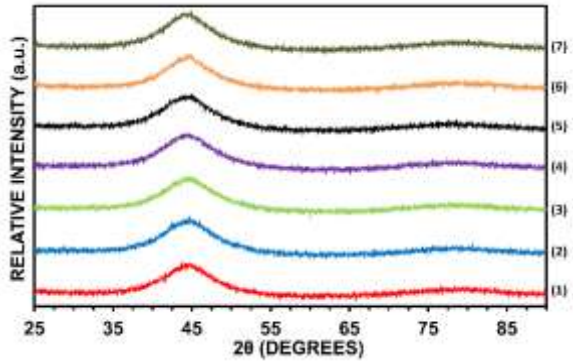

Figure 1: X-ray diffraction patterns of gas atomized powders with particle size < 20 μm of 7 different compositions in the system Fe-Si-B-P-Nb-Cu

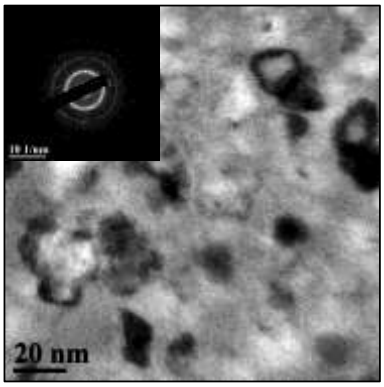

Figure 2: Bright field TEM image and SAD pattern (inset) of $(Fe_{0.76}Si_{0.09}B_{0.10}P_{0.05})_{97.5}Nb_{2.0}Cu_{0.5}$ alloy annealed at 530 °C for 30 min