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Effect of Terbium Doping on the Microstructure of $Fe_{81}Al_{19}$ Alloys

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Fe-Al alloys are promising, low cost, highly magnetostrictive candidates for energy harvesting applications. In order to investigate the effect of Terbium additions on the microstructure of polycrystalline $Fe_{81}Al_{19}Tb_x$ alloys, samples containing x=0-0.035 at% of Terbium were fabricated and characterized.

The alloys were fabricated by electric arc furnace melting. Each alloy was melted four times to obtain a better homogeneity of the elements. The composition of the alloys was determined by inductively coupled plasma optical emission spectrometry (ICP-OES) using HCl y HF (relation 1:1) for the digestion. The structural characterization of the alloys was carried out by X-ray diffraction, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and optic microscopy.

The atomic percentages measured for Fe and Al obtained by ICP-OES are shown in Table 1. Some Tb was lost during melting because this process involves the application of high temperatures to an alloy whose constituent elements have, on the one hand, a high melting point (Fe) and on the other, a low vapor pressure (Tb), resulting in a part of the Tb evaporating [1].

The crystalline structure of the alloys fabricated, according to the Rietveld refinement of their X-ray diffraction patterns (Figure 1), exhibits bcc A2, $Fe_{81}Al_{19}$ (space group 229) as the main phase (~80%), and two secondary phases: ordered bcc D03, Fe_3Al (space group 225), and bcc D03 Al (space group 225). These results are very similar to those reported for polycrystalline $Fe_{80}Al_{20}$ alloy doped with boron [2], where the boron enters on the alloy in the form of interstitial atoms.

EDS mapping, in backscattered electrons (BSE) mode confirmed the homogeneity of the alloys. In Figure 2 can be seen that Tb was distributed across the surface of the alloy with little preferential places in the microstructure.

The microstructure observed by optical microscopy presents a dendritically solidified matrix. Tb additions creates a non-equilibrium microstructure that may be defined a mixture of a disordered bcc phase (A2 type) and a ordered bcc phase (D03 type) which creates a non-equilibrium microstructure [3]. Besides, the formation of two different types of grains in the microstructure, columnar and equiaxial, can be observed, which contribute, respectively, to a greater and lesser preferential orientation formation in the samples (Figure 3). This granular formation does not depend only to the amount of Tb used on the alloys, but is also related to the cooling mechanism after the electric arc furnace melting method [4].

It is important to mention that this granular formation can either be achieved by heat treatments or by mechanical forging processes, whereas in this study it was directly obtained in the as cast samples. The reason for this is the temperature gradient formed inside the sample during cooling.

References:
[1] TB Massalski in "Binary Alloy Phase Diagrams", (Metals Park, Ohio).
[2] C Bormio-Nunes, CT dos Santos and MB de Souza Dias, Journal of Alloys and Compounds **539** (2012), p. 226.
[3] C Bornio-Nunes, CT dos Santos and IF Leandro, Journal of Applied Physics **109(7)** (2011), p. 07A934.
[4] JH Li, C Yaun and Q Qi, Metals - Open Access Metallurgy **7(2)** (2017), p. 36.

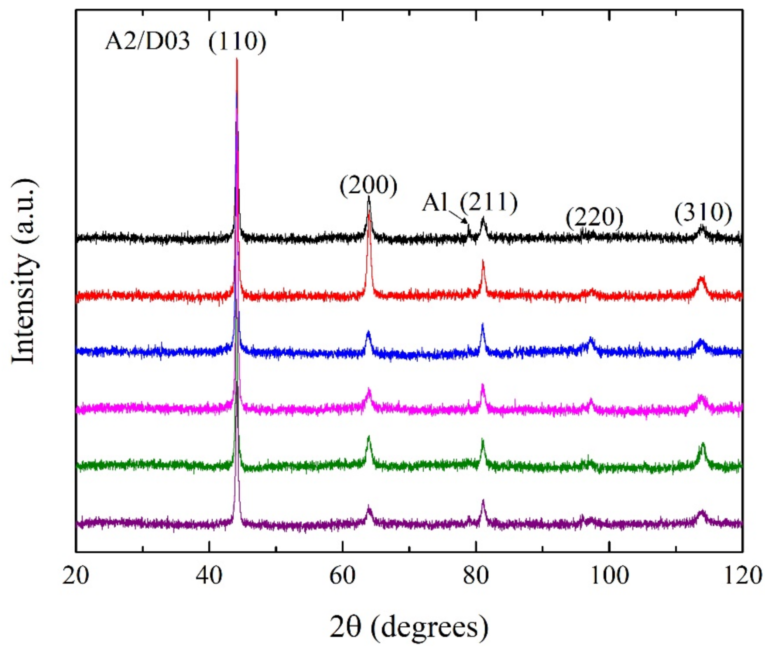

Table 1. Compositions obtained by ICP-OES analysis.

Fe at. %	Al at. %	Tb at. %
← 82.571	17.429	0
← 81.530	18.452	0.018
← 81.289	18.692	0.019
← 81.418	18.557	0.025
← 81.938	18.036	0.026
← 81.671	18.294	0.035

Figure 1. X ray diffraction patterns and composition measured by ICP-OES for all samples.

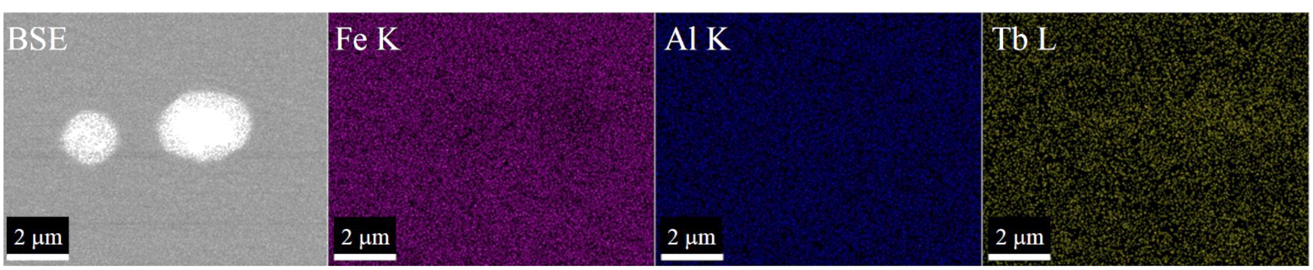

Figure 2. EDS Mapping of $Fe_{81}Al_{19}Tb_{0.035}$ alloy.

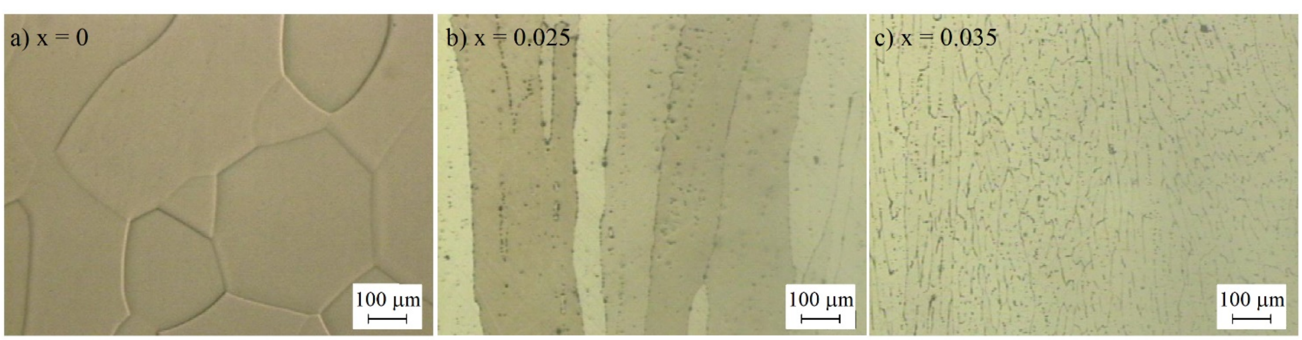

Figure 3. Microstructure of a) 0 at% Tb (equiaxial grains), b) 0.025 at% Tb (columnar grains) and c) 0.035 at% Tb (transition from columnar grains to equiaxial grains).

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