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Study of the Fe_xNi_y-Ag System Prepared by Mechanical Alloying

Gema González[1], Daniel Ibarra[1], Javier Ochoa[1], Rafael Villalba[1], Esteban Barrios[2], Freddy Arenas[2]

[1]Lab. Ciencias e Ingeniería de Materiales, Instituto Venezolano de Investigaciones Científicas, Caracas, Venezuela, gemagonz@ivic.ve
[2]Instituto Universitario de Tecnología, Región Capital, Lab. Microscopía Electrónica, Caracas.

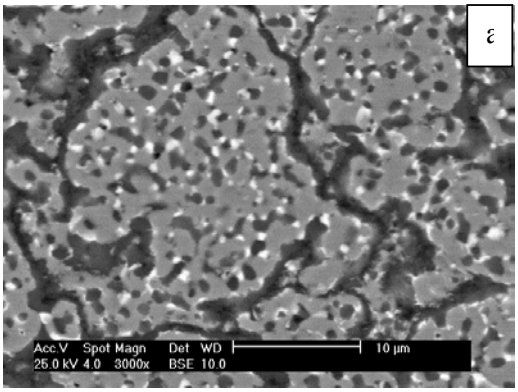
The Fe-Ni-Ag system is of particular interest for its potential applications as soft magnetic granular alloys formed by small magnetic grains embedded in a non-magnetic metal matrix. It is formed by two binary immiscible systems under equilibrium conditions : Fe-Ag and Ni-Ag and one binary system Fe-Ni. These materials are particular important for magnetoresistive properties [1]. The properties of these alloys are closely related to their microstructure, therefore a detailed study of the transformations occurring during milling was undertaken considering materials pre-alloyed with several concentrations of Fe and Ni and then further alloyed with different Ag content. Heat treatments of the mechanically alloyed powders were performed and structural characterization of the sintered powders was carried out.

Elemental high purity (99.99%) Fe, Ni and Ag powders with an average particle size of 4.5, 1.2 and 1.3 μm respectively, were blended in a WAV turbula for 2h. The compositions were Fe 30, 50 and 70 at.%, Ni 70, 50 and 30 at% and Ag in balancing concentration to give alloys compositions of $(Fe_x\text{-}Ni_{100-x})_y\text{-}Ag_{100-2y}$(x= 30, 50, 70 and y=5,20,60). The powders of Fe and Ni were mechanically alloyed under nitrogen atmosphere in a high energy mill SPEX 8000, using hardened steel vials and balls with a ball-to-powder weight ratio of 8:1 and milling periods of 1, 5, 10, 25 to followed the formation of the Fe_xNi_y compound. And then further milled with Ag was carried out for 10 h. The powders from the different milling periods and compositions were pressed at 350 MPa and sintered in a graphite crucible at 900ºC for 40 min in argon atmosphere. The products were characterized by optical microscopy, x-ray diffraction (XRD) using a Siemens 5005 diffractometer with Cu- K_α radiation (Ni filter) operating at 40 keV and 20 mA. Scanning electron microscopy (SEM) analysis was performed in a Phillips XL30 attached with an EDX DX4 and a EBSD system. Transmission electron microscopy (TEM) was carried out in a Phillips CM10. Samples for TEM were cut by ultramicrotomy techniques and collected in a holey carbon grid.

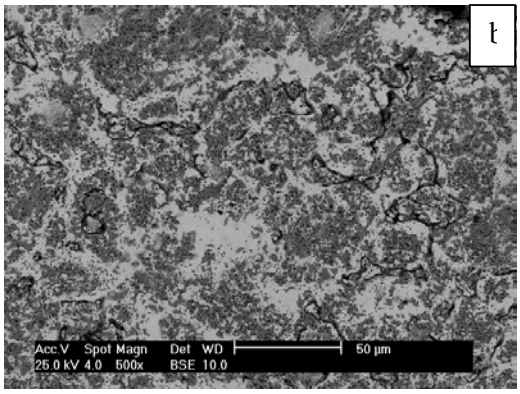
The $Fe_{30}Ni_{70,}$ $Fe_{50}Ni_{50,}$ are very similar showing the formation of the ordered FeNi compound. In the $Fe_{70}Ni_{30}$ composition the formation of a mixture of phases was observed, the ordered FeNi and the disordered Fe(Ni) compounds. The mixture of these systems with Ag showed the metal compounds surrounded by Ag forming islands of Fe_xNi_y-Ag, There was also evidence of Ag diffusing into the FeNi resulting in the formation of a FeNiAg phase. Backscattered images together with EDX analysis confirmed this result as seen in Fig. 1. For low Ag content (5%), silver seems to joint the grains and help sintering. For high Ag content 60%, islands of FeNi surrounded by Ag are observed. Sintering is always improved with the Ag content. Backscattered electron diffraction patterns were taken on the different Fe_xNi_y phases showing a cubic symmetry for all the cases studied.

References

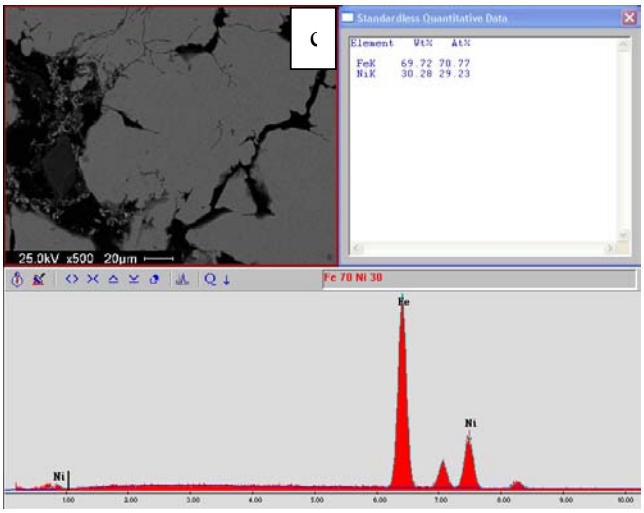
[1] N. S. Cohen, Q.A. Pankhurst and L.Fernandez Barqu'n, *J. Phys. Cond. Matter* 11 (1999), 8839



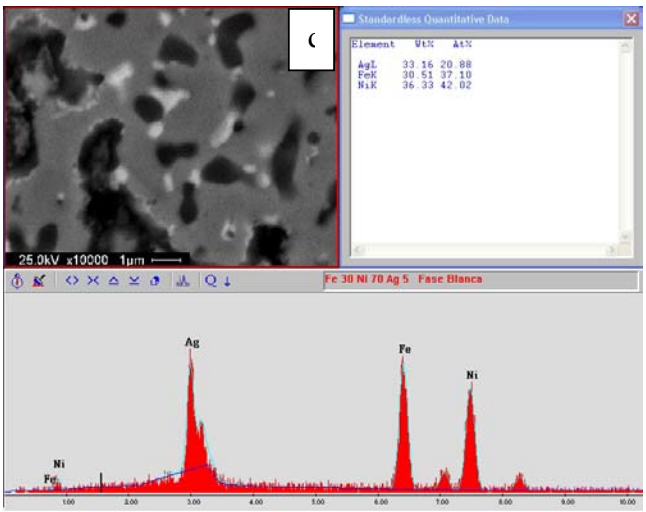
$Fe_{70}Ni_{30}$-Ag_5



$Fe_{30}Ni_{70}$-Ag_{60}



$Fe_{70}Ni_{30}$



$Fe_{30}Ni_{70}$-Ag_5

Fig. 1 Electron backscattered images of a. $Fe_{70}Ni_{30}$-Ag_5, b. $Fe_{30}Ni_{70}$-Ag_{60}, c. $Fe_{70}Ni_{30}$, d. $Fe_{30}Ni_{70}$-Ag_5

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