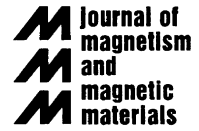




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Giant magnetoresistive properties of $\text{Fe}_x\text{Au}_{100-x}$ alloys produced by mechanical alloying

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Abstract

The $\text{Fe}_x\text{Au}_{100-x}$ alloys were produced for the first time by mechanical alloying. Resistance of samples with iron concentrations of $x = 15, 20, 25,$ and 30 at% were measured at 77 K under an applied field of 14 kOe . A maximum in magnetoresistive ratio ($\Delta\rho/\rho$) of 3.5% was obtained for $\text{Fe}_{25}\text{Au}_{75}$. Samples were annealed in order to enhance magnetoresistive properties. These samples exhibit larger ratios, primarily due to the elimination of defects. X-ray diffraction Mössbauer spectroscopy and magnetoresistance measurements were performed, in order to correlate bulk and hyperfine magnetic properties with crystalline structure. X-ray diffractograms show an FCC structure, with no evidence for a BCC one. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Magnetoresistance—giant; Alloys; Mechanical alloying

A giant magnetoresistivity in granular materials was first realized in 1992 [1], following the idea that magnetic particles immersed in a non-magnetic matrix can orientate with an external field, changing in this way the scattering of the conduction electrons. From that time, much work was done on such systems, using different production techniques. Some of it was produced by mechanical alloying. Mechanical alloying (MA) stands for a set of techniques, involving the kneading of the starting materials by means of milling or repeated pressing [2]. This kneading provides energy that allows the system to reach metastable states. In our case, non-mixing systems such as Fe–Cu or Fe–Ag can be driven to form non-random solid solutions [3]. As giant magnetoresistivity requires, in granular systems, the existence of non-connected ferromagnetic entities in the body of a non-magnetic matrix, MA is a suitable method to produce samples with such effect. In this work, we report the preparation of solid solutions of Fe–Au which show GMR effect.

High purity powders of Fe and Au were loaded, under an Ar atmosphere, into a sealed container with 43 stainless steel balls, giving a powder to ball mass ratio of 1 : 25. Then, milling was done in a water-refrigerated vibratory mill Nissin Gikken NEV-MA8. Samples with different milling times and concentrations were produced. Resultant powders were compacted into small ingots and then magnetoresistivity was measured with the usual method, with magnetic field applied perpendicular to the direction of the electric current. Annealing of the samples was done in order to enhance magnetoresistive properties. The optimum regime was 24 h at 773 K . Samples were measured at room temperature and 77 K . Magnetic field was varied from 0 to 14 T. Room-temperature X-ray diffraction (XRD) and Mössbauer spectroscopy (ME) experiments were carried out.

X-ray diffractograms taken on all samples show the same features: broadened FCC peaks, suggesting that Fe is dissolved into the Au matrix. Peaks are slightly shifted toward higher angles, consistently with this interpretation. Sample magnetoresistance ratio vs. iron concentration is showed in Fig. 1. Magnetoresistance increases with concentration, reaching a maximum of 3.5% of GMR ratio at $x = 25$ at% for a sample with 20 h of milling. Then, GMR ratio diminishes. Annealed samples

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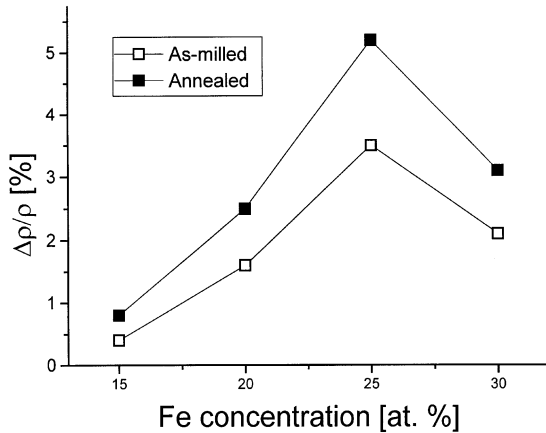


Fig. 1. The GMR ratio evolution with x . Measurements were taken at 77 K, under a field of 14 kOe.

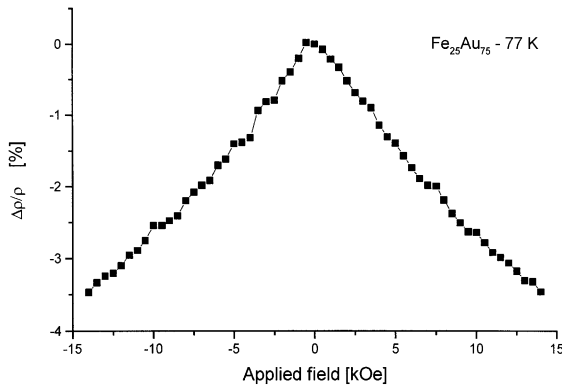


Fig. 2. The GMR ratio vs. applied field of $\text{Fe}_{25}\text{Au}_{75}$ milled for 20 h, measured at 77 K.

have, for similar concentrations, better ratios than as-milled ones (5.2% at 77 K for $x = 25$ at%). Saturation is not reached in any case (Fig. 2), suggesting small particle size of ferromagnetic entities. Mössbauer spectra exhibit a doublet, broad and slightly asymmetric for all the samples (Fig. 3). Fitted hyperfine parameters of samples milled for 20 h do not change appreciably with x . Quadrupole splitting is about 0.58 mm/s, isomer shift $\delta = 0.41$ mm/s, almost the same values for all the samples considered. The values obtained for δ are different from those reported in the literature for AuFe ($\delta = 0.628$ mm/s) [4]. Linewidth increases from about 0.45 mm/s (lower concentrations) to 0.5 mm/s for $x = 30$ at%.

Milling causes atomic-level mixing of Fe and Au. Because the majority element is gold, the crystalline

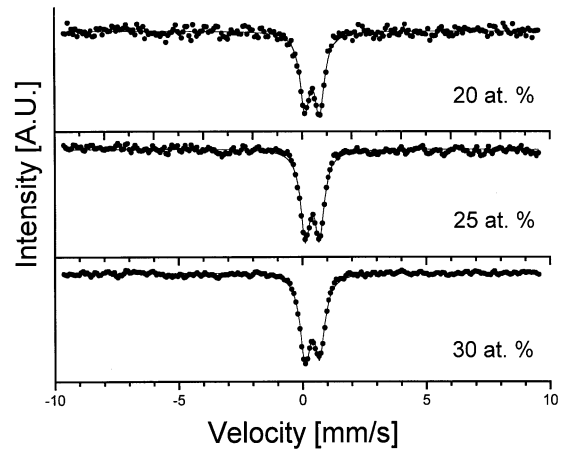


Fig. 3. Room-temperature ME spectra of samples with 20 h of milling: broadened doublets, slightly asymmetric. Numbers indicate Fe concentration.

structure is FCC. The GMR graphs suggest small-sized magnetic particles. Iron atoms would arrange in small size clusters, presumably superparamagnetic (SP), or even lower order arrangements (isolated, dimers, trimers). Such variety could be possible because MA produces strongly disordered alloys. Room-temperature Mössbauer spectroscopy shows no evidence of α -Fe in SP state. Anyway, some kind of ferromagnetic entities follow the external field, producing GMR effect. The increase of GMR ratio with iron concentration could be due to this cause: when x grows, density of magnetic entities grows, giving rise to more field-dependent scattering. Trespassing percolation threshold, large finite clusters smear down the system turning the system into a normal ferromagnetic state, explaining in such way the diminishing of GMR ratio for $x = 30$ at%. These results agree with the magnetic behavior reported earlier in the literature [5]. Additional data are needed in order to complete the picture of the system.

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