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Nano-Ni Addition to MgB_2 : Effects on the Superconducting Properties

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Abstract – Samples of MgB_2 pure phase, with Ni nanoparticles addition, were prepared using a solid diffusion reaction method. Clearly the Ni nanoparticles act as effective pinning centers and enhance the critical current values, especially for a sample with 0.5% Ni. A negligible amount of Ni diffuses inside the MgB_2 pure grains, thus having a small effect on the transition temperature.

Since the discovery of superconductivity in MgB_2, several studies [1-3] have discussed possible ways to improve the critical current density (J_c) and other relevant properties of small samples as well as long wires. Here we analyze the pinning of vortex lines, which directly affects J_c, in samples that contain a mixture of MgB_2 with small amounts of Ni nanoparticles (nano-Ni) [4] with sizes in the range of 5 - 20 nm. A stoichiometric mixture of Mg and B powders was annealed in a furnace under argon atmosphere, for 5 h at 800 °C. Next, five samples were prepared by mixing the reacted material with nano-Ni, using mass fractions of 0.5%, 1%, 2%, 3% and 5%. Finally, each sample was pressed and sintered in the shape of a small bar. X-ray data indicated a dominant presence of MgB_2, with small impurity amounts of MgO and some other non-identified phase(s). Magnetic domains, associated with nano-Ni dispersed in the matrix, were imaged through a combined use of Atomic Force Microscopy (AFM) and Magnetic Force Microscopy (MFM) techniques (Fig.1). Scanning Electron Microscopy images revealed that all samples were porous; with MgB_2 grain sizes around 5 µm. The superconducting critical temperature (T_c) for all samples was relatively high, around 37.5 K, although it shows a slight decrease by increasing the nano-Ni content, consistent with a small diffusion of Ni inside the MgB_2 grains. Magnetization curves (MxT and MxH) were measured in all samples, using a Quantum Design PPMS machine. Using Bean´s Model [5] J_c was calculated (Fig. 2), showing the highest values (e.g. $J_c \sim 1.4\times10^6$ A/cm^2 at 2.4T; 5K) for the sample with 0.5% nano-Ni. Possibly this represents the best compromise between a favorable effect on magnetic pinning and an unfavorable effect on decreasing T_c. The jumps in J_c that occur mainly at low fields and low temperatures (T<20K) are caused by thermomagnetic instabilities, common in MgB_2. Usually these instabilities can be reduced or suppressed by adding large fractions of good thermal conductors, like copper or silver, as typically made in superconducting wires. A more complete discussion of the data will be presented at the conference.

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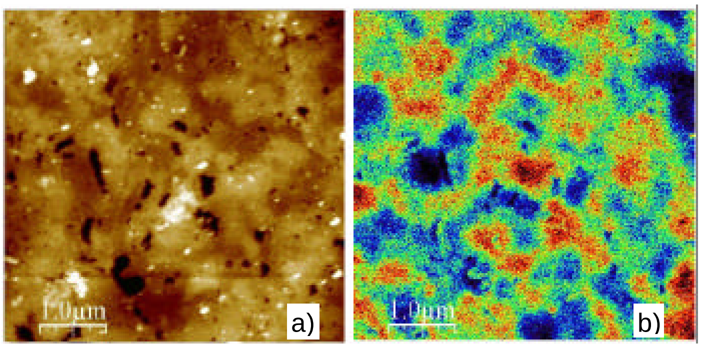

Figure 1: (a) AFM and (b) MFM images, for the same polished area of sample MgB_2:0.5% Ni (T=300K). Clustered regions in (b) correspond to ferromagnetic domains.

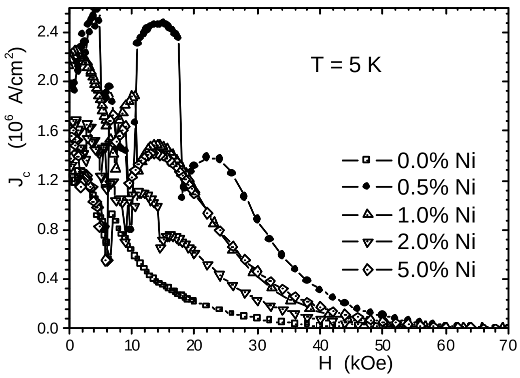

Figure 2: Jc × H curves for sample MgB_2:0.5%Ni at T = 5 K.

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