EFFECT OF ELECTRIC CURRENT ANNEALING IN PHASE TRANSITION OF MN-AL ALLOY

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The electronic structure of any material can be modified when it is exposed to high density electric currents or high strength electric fields, caused by the increased electronic/ionic mobility. Electromigration effects can have desirable uses (1), but also be a problem, for example in IC circuit design (2). However, the increased electronic/ionic mobility can be used to tailor the material properties by modifying e.g. phase formation, phase stability, density of defects etc. Our goal is to understand, by theoretical (DFT calculation) and experimental approaches, and utilize these effects in the processing of hard magnetic materials and to quantify the influence of the electric current on microstructure and magnetic properties.

In our work, we investigated the influence of the electric current density on the phase formation in Mn-Al alloys during the heat treatment process. For this, $Mn_{54}Al_{46}$ melt spun ribbons, with typical cross-section of 0.03x5 mm were heat treated under applied electric current in a home build device. The device allows the sample temperature and resistance to be measured simultaneously. This approach allows to decouple the macroscopic Joule heating and the effect of electric current during annealing by detecting changes in the phase transition temperature through resistance variations.

The results have shown that increasing the current density from 2.5 (solid line) to 30A/mm^2 (dashed line) the phase transition temperature was shifted to 55°C towards lower temperature, as shown in Figure 1a. This can be seen by the resistance drop over the annealing temperature. This drop is related to the transition of hcp structure to the tetragonal $L1_0$ phase, which presents lower resistance due to the ordered structure. It worth mentioning that the phase transition happened in a temperature window of 75°C for both cases. The phase transition was also confirmed by magnetic measurements (Figure 1b), were the initial state (as-spun) is non-magnetic and the $L1_0$ is ferromagnetic.
The systematic shift in the phase transformation temperature was observed with increasing current density. Based on these results, new possibilities of changing the phase stability conditions and, consequently, microstructure can be used to enhance magnetic properties of Mn-Al alloys.

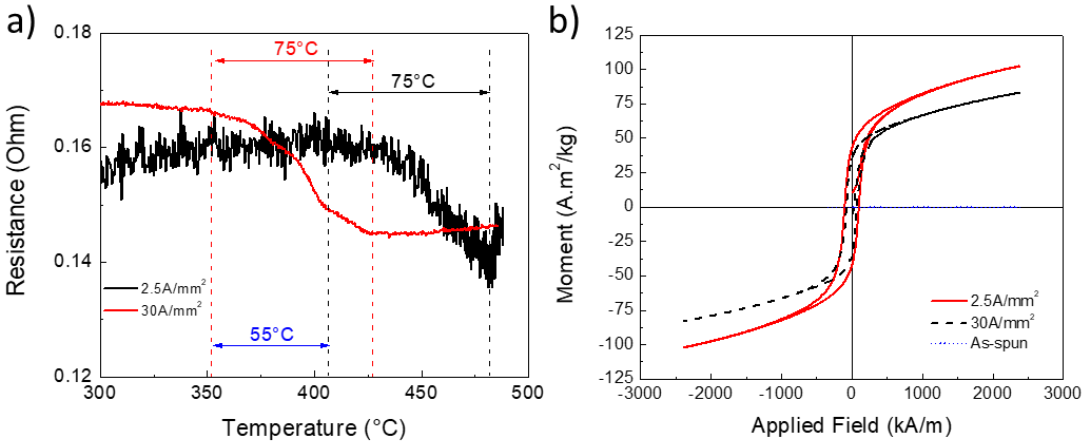

Figure 1 – Resistance change vs. temperature (a) and magnetic properties of the electrically annealed samples (b), as a comparison, the initial state (as-spun) is also shown.

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