Effect of Oxygen Incorporation on Soft Magnetic Properties of Iron-rich CoFe Alloys

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A previous study[1] has shown that the magnetic properties of electrodeposited CoFe alloys, such as the easy and hard axis coercivities, decrease with increasing Fe alloy composition from ~46wt% up to ~66wt% as shown in Figure 1. The bath described in the previous study[1] was operated at a pH of 3.0.
The purpose of this work is to study the region of alloy composition between 90wt% Fe in CoFe and pure Fe using the bath described in [1]. This is a relatively high pH bath compared to the state of the art that shows that pure Fe plating requires very low pH in order to limit the oxygen content through hydroxide incorporation.
A series of iron-rich CoFe films were galvanostatically electrodeposited using a bath described in a previous study[1]. The different alloy compositions were prepared by gradually adding cobalt to an iron-only bath. The range of alloy compositions varied from 90-100wt/% Fe with a constant thickness of ~1μm. Films were thermally annealed. Alloy composition was measured using X-Ray Fluorescence, and magnetic properties were measured with a Vibrating Sample Magnetometer. Electron microprobe and ESCA were performed to determine the quantity and chemical nature of the impurities (O, C and S) present in the CoFe films.
As shown in Figure 2, a rapid increase of both easy and hard axis coercivities was observed for CoFe films with alloy composition greater than ~95wt% Fe. As an example, Figure 3 represents a comparison of BH loops for CoFe films with alloy composition below the threshold (Fig. 3 (a) for 93 wt% Fe) and over the threshold (Fig. 3 (b) for 100wt% Fe). In addition, the physical and magnetic properties of pure iron electrodeposited in this study differ greatly from the properties found in literature[2] for bulk Fe.
Electron microprobe study of CoFe films exhibiting very low coercivities (<95wt%), and respectively high coercivities (>95wt%) showed a clear difference of oxygen content in the alloys, 0.65 wt% respectively 1.47wt%.
CoFe alloys with alloy composition near but below the 95wt% Fe threshold showed similar soft magnetic property degradation after annealing. This is in contrast with previous results that showed that coercivity of plated CoFe films decreased after annealing.
XPS analysis was performed to understand the role of the oxygen in the films and the link with the annealing conditions. Results showed that the oxygen was present in the form of Fe_2O_3 and that the level of Fe_2O_3 increased significantly after annealing. This indicates that the precipitation of oxygen into Fe_2O_3 increases the coercivity of the film.

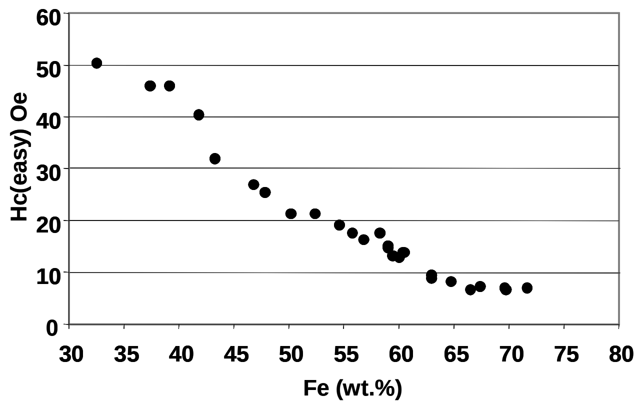

Figure 1.
Easy-axis coercivity of electroplated CoFe as a function of iron content from ref [1].

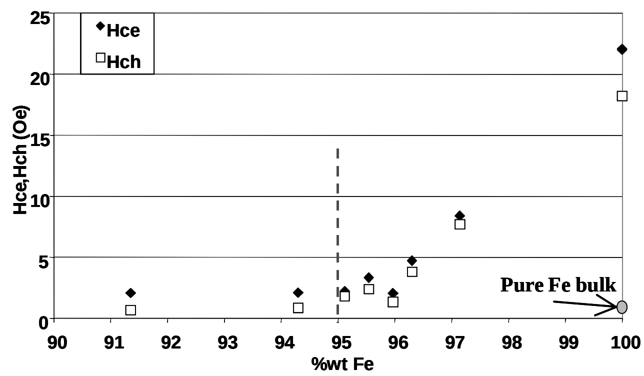

Figure 2.
Easy-axis and hard-axis coercivities of electroplated CoFe as a function of iron content (BH-looper data)

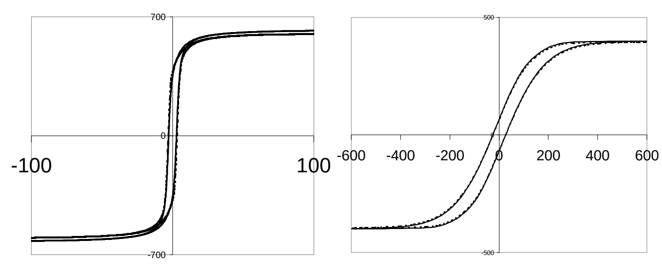

Figure 3.
(a) B-H loop of Co_7Fe_{93}, (b) B-H loop of pure Fe

References

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[2] R.M. Bozorth, Ferromagnetism, Van Nostrand Publish. Princeton, NJ (1951).