Soft magnetic properties and microstructure of the conventionally and ultra-rapidly annealed FeCoB(SiCu) high-B_s alloys

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This research focuses on the impact of different annealing methods on the soft magnetic properties and nanocrystalline structure of FeCoB(SiCu) high-B_s alloys. Amorphous precursor ribbons of three different alloy compositions were processed using conventional isothermal annealing as well as an ultra-rapid annealing technique, which involves a pair of preheated massive Cu blocks. We analyse and compare the development of the nanocrystalline structure and the resulting soft magnetic properties after applying different annealing techniques.

Keywords: nanocrystalline alloys; ultra-rapid annealing; soft magnetic properties; microstructure

1. Introduction

Results published during the recent years show that ultra-rapid annealing is an effective method for achieving excellent magnetic properties in nanocrystalline soft magnetic materials, even with a reduced amount of non-ferromagnetic elements in the alloy [1, 2]. This research focuses on the role and importance of Si and Cu during the nanocrystallization process occurring during ultra-rapid annealing of selected FeCoB(SiCu) high-B_s alloys, and compares the results with the ones obtained after conventional isothermal annealing.

2. Results and discussion

Amorphous precursor ribbons, with a nominal composition of $Fe_{64}Co_{21}B_{15}$, $Fe_{64}Co_{21}B_{10}Si_5$ and $(Fe_{64}Co_{21}B_{10}Si_5)_{99}Cu_1$ were produced by planar flow casting. Figure 1 shows thermomagnetic curves of the respective as-quenched specimens. Using these data, conventional isothermal annealing (CA) was performed in a custom-built vacuum furnace at temperatures in the range of the onset of primary crystallization.

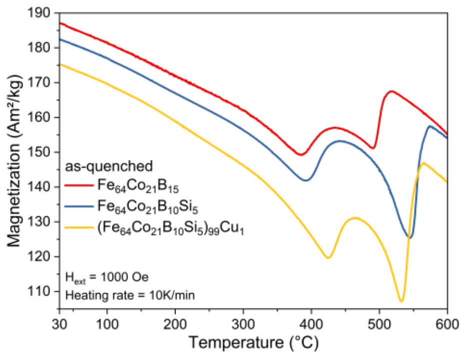

Figure 1: Thermomagnetic curves of the studied as-quenched ribbons.

At the same time, another set of samples was ultra-rapidly annealed (URA) under vacuum by compression for 0.5 seconds between massive Cu blocks. For each alloy, optimal processing parameters were determined using the T_{x1} + 100°C estimation [3] and subsequent fine-tuning, with the main goal to achieve formation of nanocrystalline grains, lowest coercivity and highest saturation magnetization at the same time.

Hysteresis loops of the annealed samples (both URA and CA, see Figure 2) were acquired using the Förster-type B-H loop tracer. Significant differences between the results obtained for individual annealing techniques are caused by different crystallization processes resulting from distinct annealing temperatures and heating rates. Nevertheless, only the alloy containing Cu, which is a known nucleation agent causing the refinement of nanostructure, shows substantial decrease in H_c, similar to FeCoBCu (see [4]).

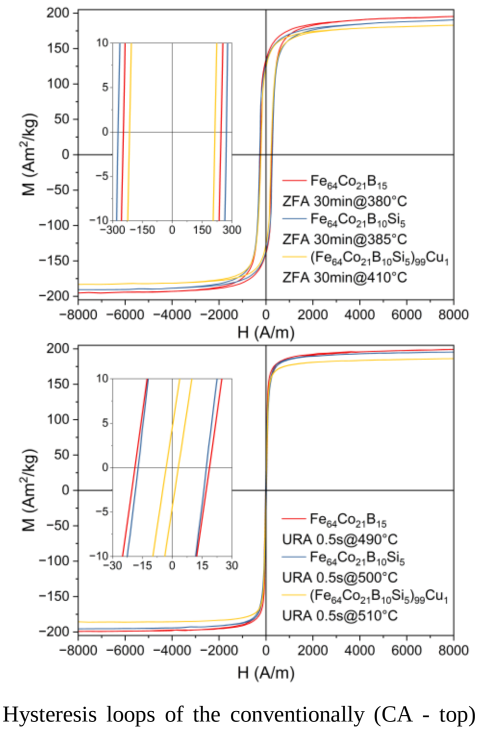

Figure 2: Hysteresis loops of the conventionally (CA - top) and ultra-rapidly (URA - bottom) annealed ribbons.

Our work further explores the development of nanocrystalline structures of the studied alloys after exposing to CA and URA annealing. We discuss and compare the grain size and crystal phases using the results obtained by the XRD and TEM and relate them to the resulting magnetic properties.

References

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Acknowledgements: This research was supported by the projects APVV 23-0281, VEGA 2/0148/23, JRP NOMAGRAD and PostdokGrant APD0066