Minnealloy, a high saturation, critical element free, soft ferromagnetic material

Will Echtenkamp[a], Andrew S. Padgett[b], Steven House[b], Sean R. Bishop[b], Daniel R. Lowry[b], Jian-Ping Wang[a]

[a] *University of Minnesota, Minneapolis, Minnesota 55455, USA*
[b] *Sandia National Laboratory, Albuquerque, New Mexico 87185, USA*

Soft ferromagnetic materials play a crucial role in the world's electrical system, in particular serving as essential components of all transformers, electrical motors, and generators. We develop and evaluate Minnealloy, α″-Fe_{16}(NC), a novel soft magnetic material composed only of Fe-N-C. Minnealloy has the benefit of being free of the critical elements cobalt, nickel or silicon, while providing performance superior to today's soft magnetic materials. It has been shown that the saturation flux density is 27% higher than pure iron, and the coercivity can be maintained around 10 Oe[1-4]. Minnealloy ribbons have been fabricated by melt-spinning, a manufacturing compatible and scalable process. The effects of the post melt-spinning processes on the stoichiometry, phase purity, microstructure, and magnetization are studied and the feasibility of using Minnealloy ribbon in high frequency transformer cores is explored.

Keywords: Minnealloy; Soft magnetic materials; Critical element free; High saturation magnetization, Pulse transformers;

1. Results and discussion

Fe-C precursor ribbon was prepared using a melt spinning machine. The thickness of the ribbon fabricated was 20-30 μm. The carbon content of the ribbon was later measured by XPS to be approximately 10 atomic% C. The melt-spun ribbons were then oxidized in a tube furnace at 975 ºC for 30 minutes in atmosphere and reduced in a pure H_2 atmosphere at 350 ºC for 2 h.

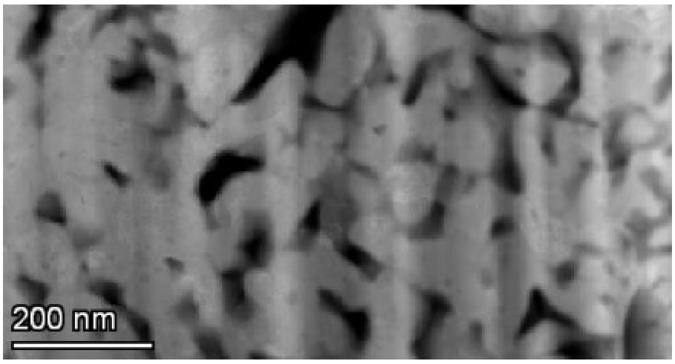

Figure 1 : HAADF image showing the nanometer sized pores in the ribbon

As a result of the oxidation/reduction steps the ribbon becomes extremely porous with pores ranging in size from 10s of nanometers to a micrometer. The finished ribbon was analyzed using scanning transmission microscopy. The high angle annular dark-field images show the porous structure of the ribbon, as seen in Figure 1, as well as confirms the presence of carbon and nitrogen.

Immediately after reduction and without exposing the samples to atmosphere, the ribbons were nitrided in an atmosphere of pure NH_3 at 182 ºC for 12 h. The samples were allowed to cool to room temperature before being exposed to atmosphere.

The increased surface area of the ribbon due to the oxidation reduction treatment enhanced the incorporation of nitrogen in the lattice. X-ray diffraction measurements were taken on the ribbon after nitriding. As shown in Figure 2, while the ribbon partially remains iron, a significant fraction has been converted into Minnealloy.

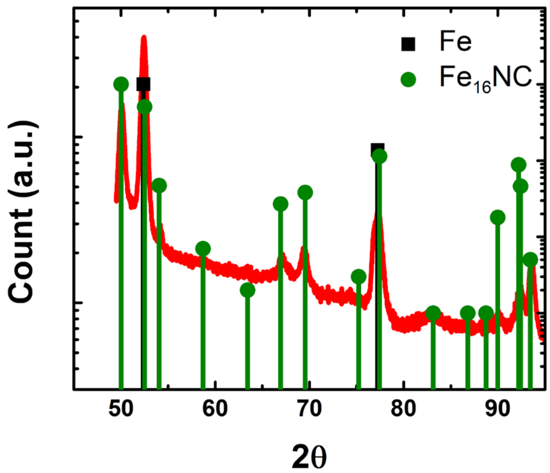

Figure 2: X-ray diffraction measurement showing the presence of Minnealloy in the sample

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Acknowledgements: This work was supported by Laboratory Directed Research and Development (LDRD) funding from Sandia National Laboratories as Project No. 229418. Parts of this work were carried out in the Characterization Facility, University of Minnesota, which receives partial support from the NSF through the MRSEC (Award No. DMR-2011401) and the NNCI (Award No. ECCS-2025124) programs. Portions of this work were conducted in the Minnesota Nano Center, which is supported by the National Science Foundation through the NNCI under Award No. ECCS-2025124.