Magnetic anisotropy control in Co-based amorphous wires for enhanced soft magnetic properties

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Amorphous $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ wires (120 µm diameter) with a saturation magnetization of 0.68 T, coercive field below 8 A/m, and magnetic permeability up to 200,000 were studied under controlled thermal and stress conditions. Stress-annealing induced a reversible perpendicular anisotropy and shifted the magnetostriction coefficient from -0.7×10^{-6} to $+0.35 \times 10^{-6}$. These findings highlight the potential of tailored anisotropy for enhancing the stability and functionality of soft magnetic wires in sensing applications.

Keywords: Creep induced anisotropy; stress annealing; soft magnetic properties; anelastic strains

1. Introduction

The circular symmetry, intrinsic magnetoelastic properties, and anisotropies of Fe-based and Co-based soft magnetic amorphous and nanocrystalline wires play a crucial role in determining their macroscopic magnetic behaviour and overall performance.

This work aims to investigate how controlled thermal treatments and mechanical stresses can modify the magnetic properties of Co-based amorphous wires. These induced modifications are essential, as they directly influence the suitability of these materials for specific sensing and technological applications.

2. Results and discussion

We have investigated amorphous wires with a nominal composition of $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ and a diameter of 120 µm, fabricated using in-rotating water spinning technology. These wires exhibit a saturation magnetization of 0.68 T, a coercive field below 8 A/m, and magnetic permeabilities of up to 200,000 at low magnetic fields (a few A/m). However, certain applications require controlled and stable values of magnetic permeability over a broader range of magnetic fields. Such behaviour can be achieved through thermal treatments under applied longitudinal stress, as the resulting changes in magnetic behaviour are crucial for specific applications.

The shape and inclination of the longitudinal B-H curves (Figure 1) indicate that stress-annealing induces a perpendicular anisotropy in the wires, with its magnitude dependent on the annealing temperature, the current passing through the wires, and the applied longitudinal stress. This induced anisotropy was found to be reversible after a subsequent heat treatment.

The observed creep-induced anisotropy originates from the orientational ordering of small atomic clusters within the amorphous matrix, resulting in anelastic strains perpendicular to the tensile stress applied during annealing. Our research has revealed a prolonged relaxation phenomenon associated with this effect, lasting several days. To mitigate it, we focused on reducing microscopic non-uniformities in the wires, which contribute to the development of creep-induced anisotropy.

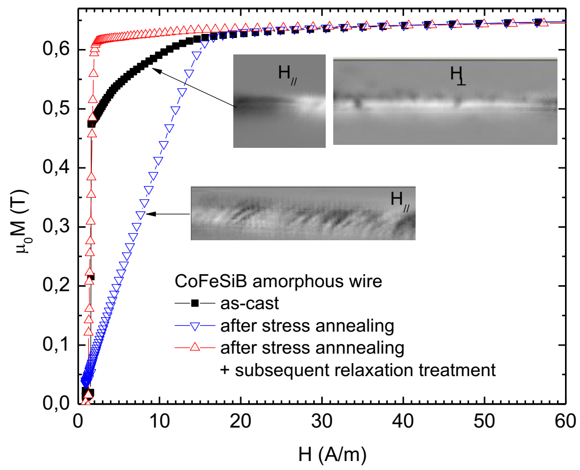

Figure 1: The magnetization curves and magnetic domain structures of Co-based nearly zero magnetostrictive amorphous wires demonstrate the presence of induced perpendicular anisotropy in stress-annealed wires and the reversibility of magnetization processes with annealing.

These changes are also reflected in the magnetostrictive behaviour of the wires. Specifically, the saturation magnetostriction coefficient (λ_s) varies from slightly negative values (-0.7×10^{-6}) in the as-cast state to slightly positive values ($+0.35 \times 10^{-6}$) after inducing perpendicular anisotropy. A thorough understanding of these aspects is essential for advancing cutting-edge sensing applications.

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