Soft magnetic behavior and magnetization reversal in rapidly solidified submicronic amorphous wires

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Here we report on the soft magnetic properties and magnetization reversal mechanisms in rapidly solidified cylindrical amorphous wires with diameters between 100 and 950 nm. Employing hysteresis loop measurements, domain wall velocity measurements, and Lorentz transmission electron microscopy, we have found distinct domain wall behaviors linked to magnetostriction. Nearly zero magnetostrictive wires maintain stable vortex domain walls under magnetic fields, whereas highly magnetostrictive wires exhibit domain wall elongation due to magnetoelastic interactions. These insights highlight their promising potential for applications in magnetic microsensors and domain-wall-based logic devices.

Keywords: soft magnetic wires; domain walls observation; amorphous submicronic wires

1. Introduction

Rapidly solidified cylindrical amorphous wires exhibit outstanding soft magnetic properties resulting primarily from their lack of magnetocrystalline anisotropy and enhanced cylindrical symmetry. Recent advancements have enabled the synthesis of these wires at submicrometric scales, specifically between 100 and 950 nm in diameter, significantly enhancing their potential in soft magnetic applications [1]. This work focuses on the magnetization reversal mechanisms in submicronic amorphous wires characterized by axial magnetic bistability, which occurs when the applied magnetic field surpasses the critical switching field [2].

2. Results and discussion

Unlike their micrometer-sized counterparts, submicronic wires exhibit bistable magnetization reversal irrespective of the magnitude and sign of their magnetostriction coefficient. Utilizing inductive axial hysteresis loops, domain wall velocity (Sixtus-Tonks-type) measurements, and Lorentz transmission electron microscopy (LTEM), we have systematically investigated the soft magnetic response and domain wall dynamics during magnetization reversal.

LTEM imaging reveals that domain walls in submicronic wires consistently exhibit vortex structures, regardless of their dimensions or composition. However, their behavior under applied magnetic fields varies significantly with magnetostriction. In nearly zero magnetostrictive $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ wires, the symmetry and structure of vortex domain walls remain stable under varying magnetic field amplitudes and orientations. In contrast, highly magnetostrictive $Fe_{77.5}Si_{7.5}B_{15}$ amorphous wires display a distinct elongation and widening of domain walls upon field application, as shown in Figure 1, attributed to substantial magnetoelastic coupling and significant internal stresses induced by rapid solidification. The observed differences in domain wall behavior explain the variations in the values of the switching field, as illustrated in Table I, and in propagation dynamics.

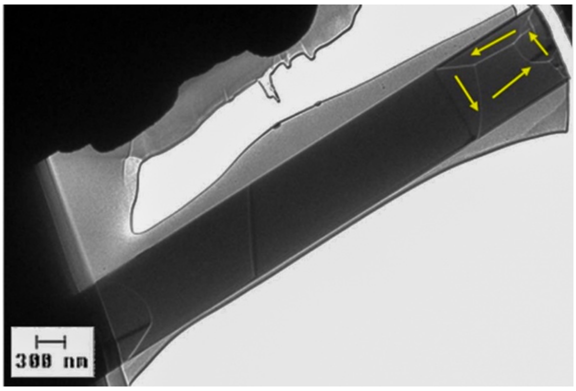

Figure 1: Elongated domain wall in a highly magnetostrictive $Fe_{77.5}Si_{7.5}B_{15}$ sample.

Table I. Amorphous sample diameters and switching field values.

Composition	Diameter (nm)	Switching Field (A/m)
$(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$	300	990
$(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$	450	650
$Fe_{77.5}Si_{7.5}B_{15}$	100	13300
$Fe_{77.5}Si_{7.5}B_{15}$	300	4970

These findings not only elucidate fundamental magnetization processes in soft magnetic amorphous wires but also underscore their suitability for advanced technological applications, including highly sensitive magnetic microsensors, magnetic domain wall logic devices, and other domain-wall-based technologies.

References

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