Magnetic properties and domain observations of annealed Fe-Si-B-C amorphous ribbons

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Abstract

The magnetic properties of a ferromagnetic material deeply depend on its domain structure. In this work, domain structures were observed by Lorentz microscopy in transmission electron microscopy. A systematic study of the evolution of the domain structure in Fe-Si-B-C amorphous ribbons after thermal annealing treatments is presented, correlating the results with the crystalline structure, hysteresis curves and coercivity measurements. The size of magnetic domain significantly decreases after crystallization and the domain wall is restricted by these α-Fe dendrites. This phenomenon is taken as the cause of raising coercivity in crystalline structure. The changes in the 3d state occupancy of amorphous regions were investigated by EELS, which is closely related to the magnetic properties of Fe-based alloys.

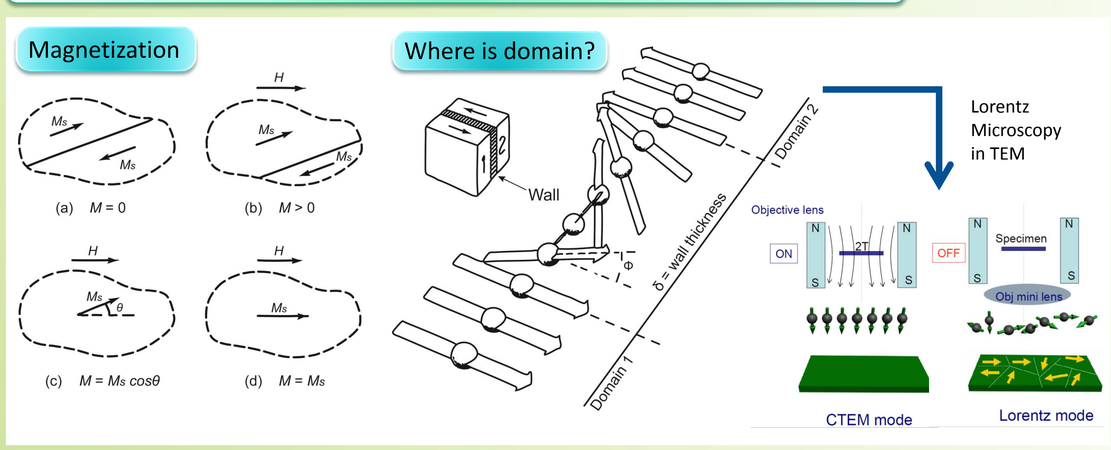
Background

Fe-based amorphous ribbon

- Due to the featured amorphous structure, Fe-based amorphous ribbon has excellent soft magnetic properties!
- Before application, these cores need to be annealed to enhance their performance.

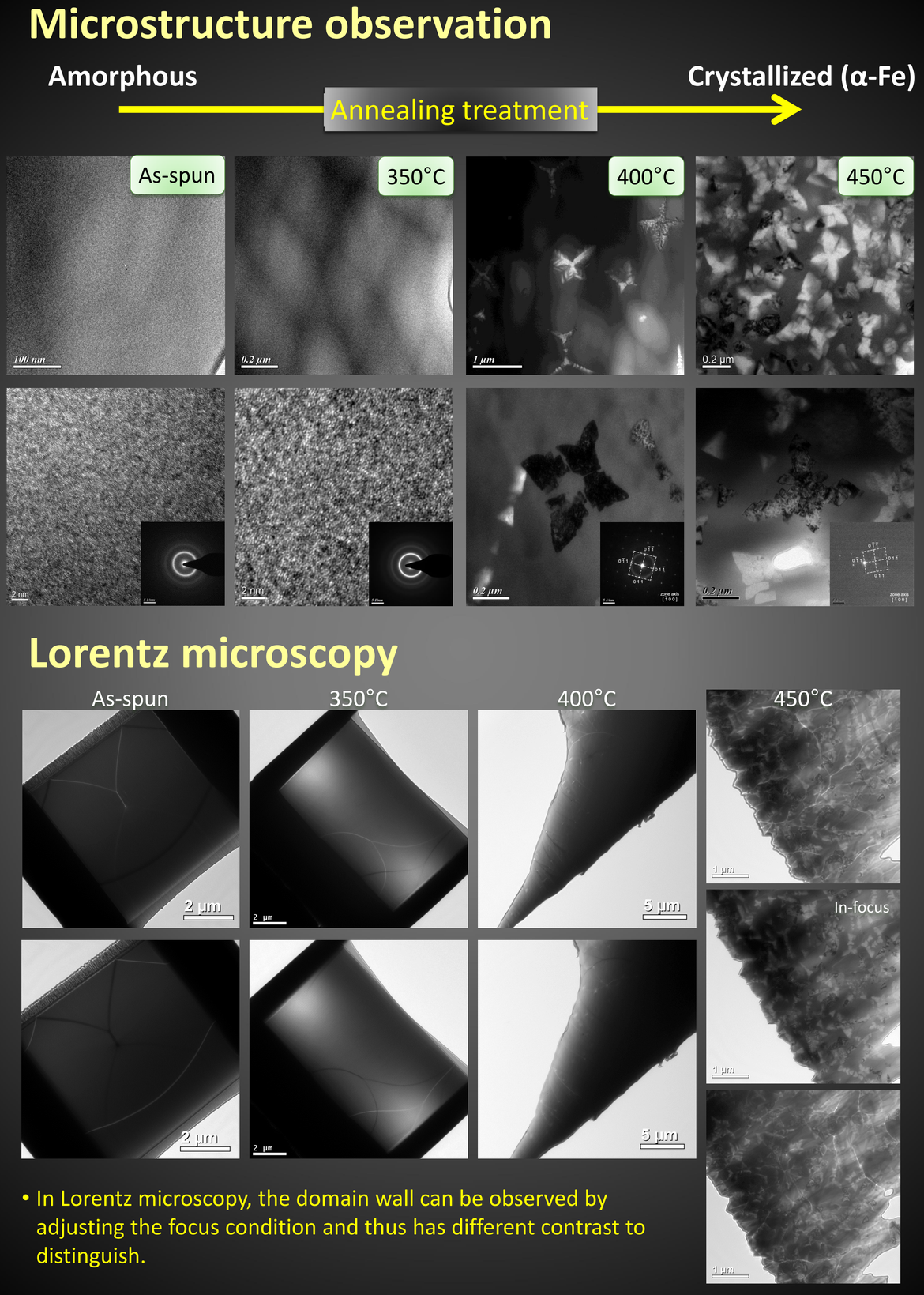
Material	Saturation flux density Bs (T)	Coercivity force (A/m)	Electrical resistivity (μΩ·m)	Core losses (W/kg)
Traditional Si-steel	2.03	45	0.5	0.440
Fe-based amorphous ribbon	1.56	2.0	1.3	0.070

Annealing magnetization and domain observation



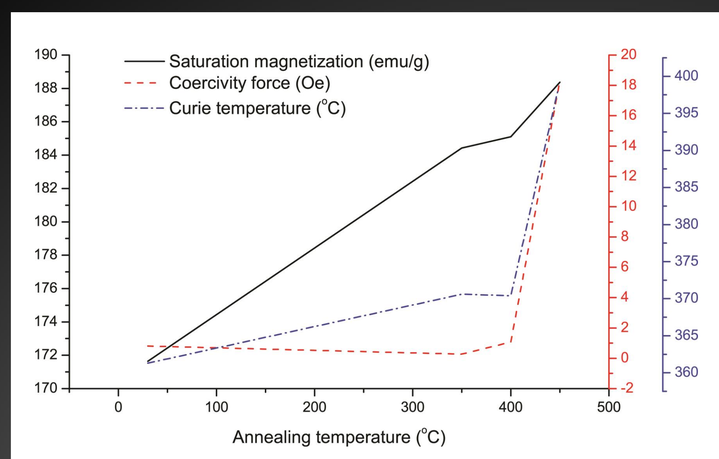
Experiments and Results

Microstructure observation



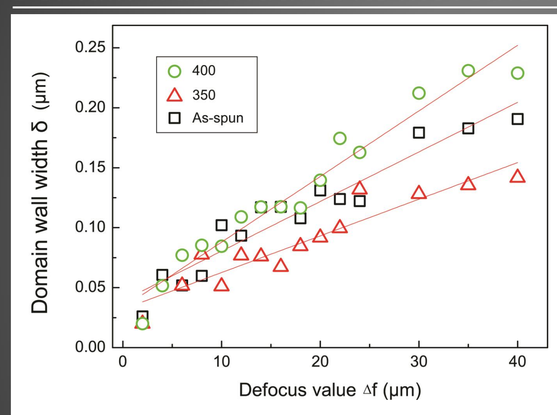
- In Lorentz microscopy, the domain wall can be observed by adjusting the focus condition and thus has different contrast to distinguish.

Magnetic properties analysis



- As the annealing temperature raises, the enhancement of saturation magnetization is significant.
- Once the crystallization starts, the coercivity increases.
- The optical annealing condition is about 350~400°C, which has enhanced saturation magnetization and low coercivity due to its amorphous matrix.

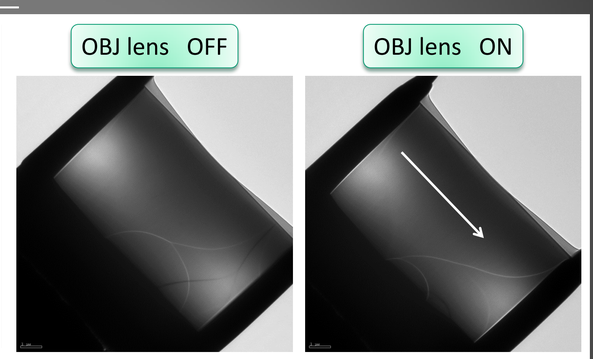
Domain wall width & its movement



The domain width is closely related to the anisotropy, which influences the magnetization process.

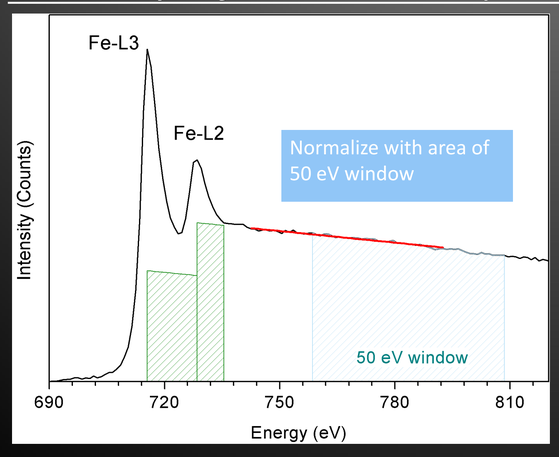
$$\delta = \sqrt{A/K_u}$$

δ: domain wall width
A: exchange stiffness const
K_u: magnetic anisotropy const



The arrow indicates the direction of the magnetic field of object lens.
The magnetic filed of objective lens is about 2T.

EELS analysis for 3d state occupancy



$$I^{C}_{3d} = 10.8(1-0.1n)$$

Specimen	3d occupancy	Δe⁻
As-spun	6.65	-
350 °C	7.94	1.29
400 °C	7.13	-0.81
450 °C	6.79	-0.16

- 3d state occupancy in annealed ribbon shows a similar changes with magnetic properties.

Acknowledgement

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