Magnetic Domain Behavior around Grain Boundary in Fe-3%Si Grain Oriented Electrical Steel

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1. Introduction

The control of magnetic domain structure and its behavior is imperative for the further improvement of iron loss in Grain oriented (GO) electrical steel which is mainly used for transformers. In view of a magnetization process as rearrangements of domain structure, the iron loss is mainly originated from supplementary domain structure and domain wall pinning during magnetization process. Essentially, these magnetic domain defect structures are strongly related to crystal orientations and crystallographic defects in GO steel. Grain boundary (GB), the most typical defect of crystals, is known to work as a site for domain nucleation as well as domain wall pinning [1]. In the current study the magnetic domain behavior around GBs was investigated during magnetization of GO electrical steel and the domain behavior was discussed in connection with the grain boundary characteristics.

2. Experimental Procedure

0.3 mm thick Fe-3%Si GO electrical steel was used for this study. The sheet was cut into 15 mm diameter disc-shaped sample containing the boundaries of interest. The crystallographic information of the GBs were evaluated with electron backscatter diffraction (EBSD). From the diffraction pattern data obtained with EBSD, GBs were characterised by GB plane orientation. The GB plane orientation was defined by the angle γ between the GB normal and the rolling direction (RD) of the sample. Magnetic domain structure and its behavior at the characterised GBs in an external field have been observed using Magneto-Optic Kerr microscopy.

3. Results and Discussion

The GB with 3° misorientation angle was selected for the current study and it was classified into small rotation angle GB segments (SRGB) and large rotation angle GB segments (LRGB) by using GB plane orientation γ as qualitative criterion. SRGB and LRGB were defined as GBs with $\gamma \leq 10°$ and $\gamma \geq 70°$, respectively.

Fig. 1 presents the domain motion on a SRGB and a LRGB during a quarter cycle of 0.1Hz excitation at a field strength of 17.0 mT along the specimen RD, which is close to the surface-parallel magnetic easy axis. The lancet domains are only able to penetrate the GB in case of the SRGBs as indicated in Fig.1(S1-S3). In addition, the regions near the SRGBs achieve magnetic saturation at a lower applied filed, as can be inferred from the comparion of the images (L5) and (S5) of Fig. 1.

The different magnetic domain behavior around these two distinct types of GBs can be explained by differences in the magnetic interface charge density at the GBs [2]. The different interface charge density will generate different magneto-static energy [3], and accordingly affect the domain configurations at the GBs [4].

4. Conclusions

The magnetic domain behavior at a 3° misoriented GB in Fe-3%Si steel was investigated. The results show that the GB geometry characteristics affect the domain behavior around the GBs. SRGBs allowed the lancet domain walls to penetrate through the boundary, whereas LRGBs prevented that. It resulted in the magnetic saturation at a lower external magnetic field in the region near the SRGBs. The fact that there are favorable GB geometry characteristics for the supplementary domain motion and the flux flow implies that GB engineering of GO electrical steels may result in a further reduction of iron losses in GO electrical steel.

5. References

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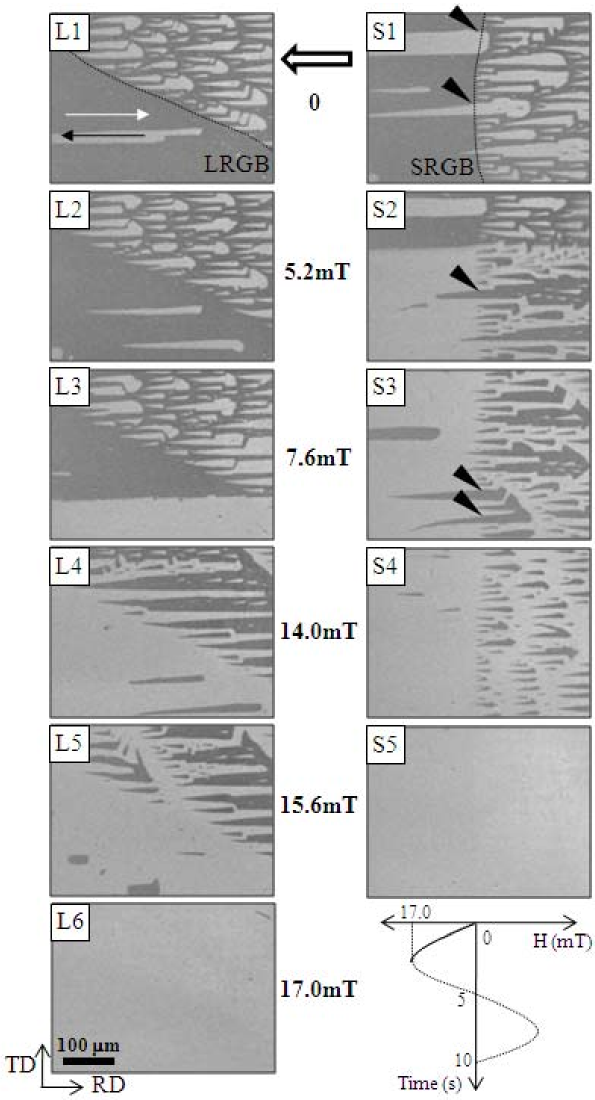

Fig. 1. Magnetic domain patterns at increasing field during a quarter cycle of an ac field along the RD. The large arrow shows the external field direction.
Pictures (a1-a6): patterns obtained on the LRGB.
Pictures (b1-b5): patterns obtained on the SRGB.