Strip Thickness, Directionality of {110} grains, and Magnetic Induction in Inhibitor-Free 3% Si-Fe Strips

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1. Introduction

Grain-oriented 3% silicon steels are widely used in transformer cores. The important properties in this application are high magnetic induction and low core loss at an operating frequency. Magnetic induction is mainly determined by the crystallographic orientations of grains consisting of the alloy sheets. Commercial grain-oriented 3% silicon steels usually reveal a magnetic induction over 1.8 Tesla (90% of the theoretical value) due to a sharp {110}<001> preferred orientation. The core losses, on the other hand, are affected by numerous factors such as magnetic induction, grain size, sheet thickness, surface morphology, etc.

2. Experimental procedures

The alloy strips containing 11 ppm of sulfur were prepared through induction melting, hot- and cold-rolling processes. The 2.8 mm thick hot-rolled sheets were successively cold-rolled to a final thickness of 0.1, 0.15, or 0.2 mm. Between the cold-rolling processes, an intermediate annealing was performed at 800℃ for 20 minutes under a high vacuum of 7×10^{-6} Torr. Final reduction in thickness was fixed at 60%. The strip samples (10 mm in width and 100 mm in length) were heated to 1200℃ with a heating rate of 25℃/h under a hydrogen atmosphere, prior to vacuum annealing at the temperature for 12 h. The crystal orientation of each grain in finally annealed strips was identified with an etch-pit method [1].

3. Results and discussion

Fig. 1 shows changes in surface area of grains and magnetic induction as a function of strip thickness. The 0.2 mm thick strips were composed of {100} and {111} without any trace of {110} grains, resulting in a poor magnetic induction. This is no surprise because {100} grains usually have a randomly distributed <001> direction, i.e. easy magnetization direction, and a {111} grain has no <001> crystal direction parallel to a strip surface. The 0.15 mm thick strips, by contrast, consisted entirely of {110} grains and a high magnetic induction of 1.98 Tesla was obtained. The 0.1 mm thick strips, however, showed a poor magnetic induction despite of the complete {110} texture. The reason for this anomalous magnetic induction is due to the deviated <001> crystal direction from the rolling direction, as shown in Fig. 2. All the sheets contain three major texture components: near {211}<011>, near {111}<112>, and {100}<011>. It is noted that the core of the near {111}<112> component in the 0.1 mm thick strips deviates as much as 15 degrees from the exact position of φ_1=90°. This deviation is probably resulted from rotation of the <111> slip direction on a normal to the strip surface rather than rotation toward thickness direction during cold rolling process. According to the nucleation and selective growth mechanism [2,3], it is expected that the <001> directions of the recrystallized {110} grains also deviate approximately 15 degrees from the rolling direction, which results in the poor magnetic induction of the 0.1 mm thick strips. In addition, the absence of {110} grains in the 0.2 mm thick strips is due to a retarded start of later {110} selective growth arising from a weakened surface effect in the thicker strip.

References

[1] N. H. Heo, *Metall. Mater. Trans.*, vol. 36A, 2555-2559, 2005.

[2] N. H. Heo and J. W. Yim, *J. Kor. Phys. Soc.*, vol. 44, 1547-1551, 2004.

[3] N. H. Heo, J. Y. Soh, J. M. Oh, and S. B. Kim, *J. Magn. Magn. Mater.*, vol. 320, e635-e637, 2008.

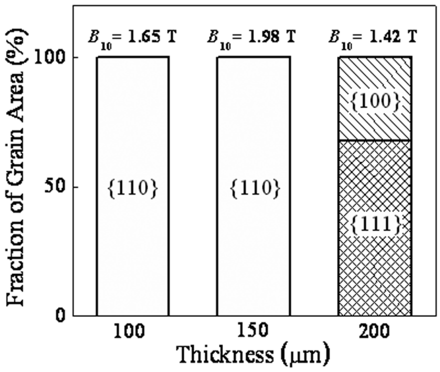

Fig. 1. Fraction of surface area of grains as a function of strip thickness.

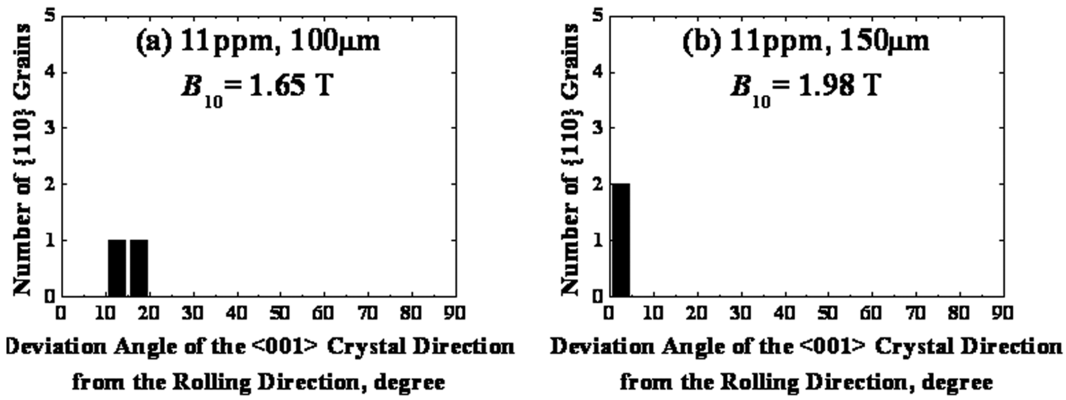

Fig. 2. Deviation angle distribution between the <001> direction of {110} grains and the rolling direction.