3D grain growth in electrical steel sheet studied by laboratory X-ray diffraction contrast tomography

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Abstract

Electrical steel sheets are widely used for transformers and motors. To increase the efficiency, it is critical to reduce iron loss, especially the hysteresis loss. The microstructure, texture and grain diameter of the sheets should be controlled during grain growth to reduce the hysteresis loss. Conventional 2D techniques, such as EBSD and XRD, have provided much information about the microstructure evolution during annealing. However, uncertainties related to the bulk kinetics remain. Recently, 3D characterization methods have been developed to overcome the limitations in 2D characterization, and laboratory X-ray diffraction (LabDCT) has become useful method due to its easy accessibility and non-destructive nature. In this study, grain growth within electrical steel sheets was investigated by statistical and local analysis using LabDCT. The aim is to understand how the local grain structure as well as the texture affect the growth behavior.
The material is Fe-3wt% Si, which was cold-rolled to 0.3 mm thickness and annealed to a fully-recrystallized state. This sample was annealed at 830 ∘C in 3 time steps. LabDCT measurements were performed using a Zeiss Xradia 520 Versa X-ray microscope. The sample was scanned in a magnified geometry. A total of 181 diffraction projections were obtained during a sample rotation of 360∘. The grain reconstruction was performed with GrainMapper3D (Xnovo Technology ApS).
The results show that on average the grain growth follows Hillert's law: namely larger grains grow and smaller grains shrink. However, there are many grains that do not follow the law. To understand the reasons, the local grain structure around a small grain was , as an example, analyzed in detail. It is shown that this grain is not consumed by the neighboring large grains because of low angle grain boundaries between them. This result underscores the importance of the local grain neighborhood in determining the microstructural evolution process.

Keywords: Grain growth, 3D, DCT, texture, electrical steel

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