Assessing the influence of crystallographic orientation, stress and local deformation on magnetic domains using electron backscatter diffraction and forescatter electron imaging

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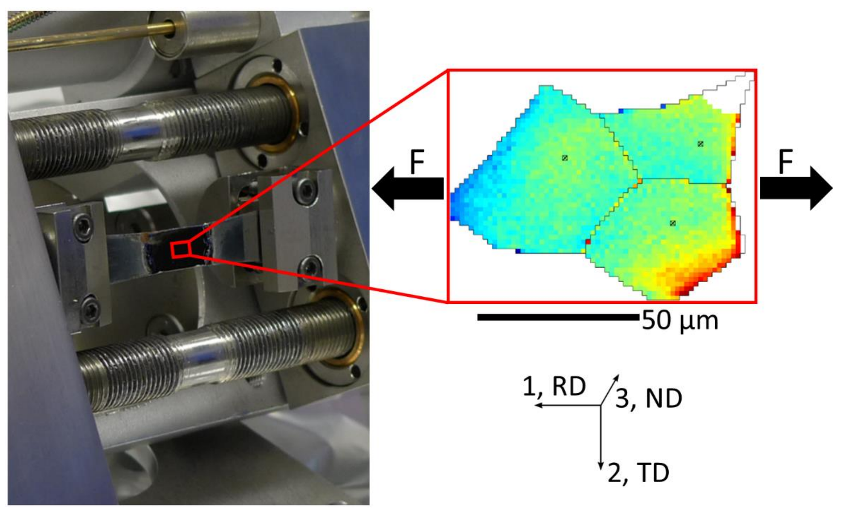
Introduction

Non-oriented electrical steel (NOES) is used in the rotor of an electric engine and is a key component in the transformation process from electric to mechanic energy. The randomness of the texture is important to globally provide a uniform magnetic flux in rotating magnetic fields. However, there is a dependence of the magnetic properties on the grain orientation. A method is presented which enables a combined examination of the influence of tensile stress, of crystal orientation and of stress induced changes in the texture on the magnetic domains.

Material and experiment



A fully processed non-oriented Fe 3.3 at.% Si electrical steel cut in rolling direction (RD) was examined. A quasi-static in-situ deformation experiment was carried out using a micro-tensile device in the SEM. The surface magnetic domains were determined for eight ascending stress levels with forescatter diodes by revealing type 2 magnetic contrast. In addition, the crystallographic texture was mapped through EBSD, and strains and rotations were determined by the use of HR-EBSD relatively.

Results

Grain #1 (see Fig. 1) possessed a certain amount of rotations about the transverse axis prior to loading which influenced the deformation behavior significantly. At 421 MPa strains appeared in grain 1 in the vicinity of the grain boundaries, which were accompanied by enhanced grain rotations. After unloading, residual strains developed with the rotation field almost unchanged.

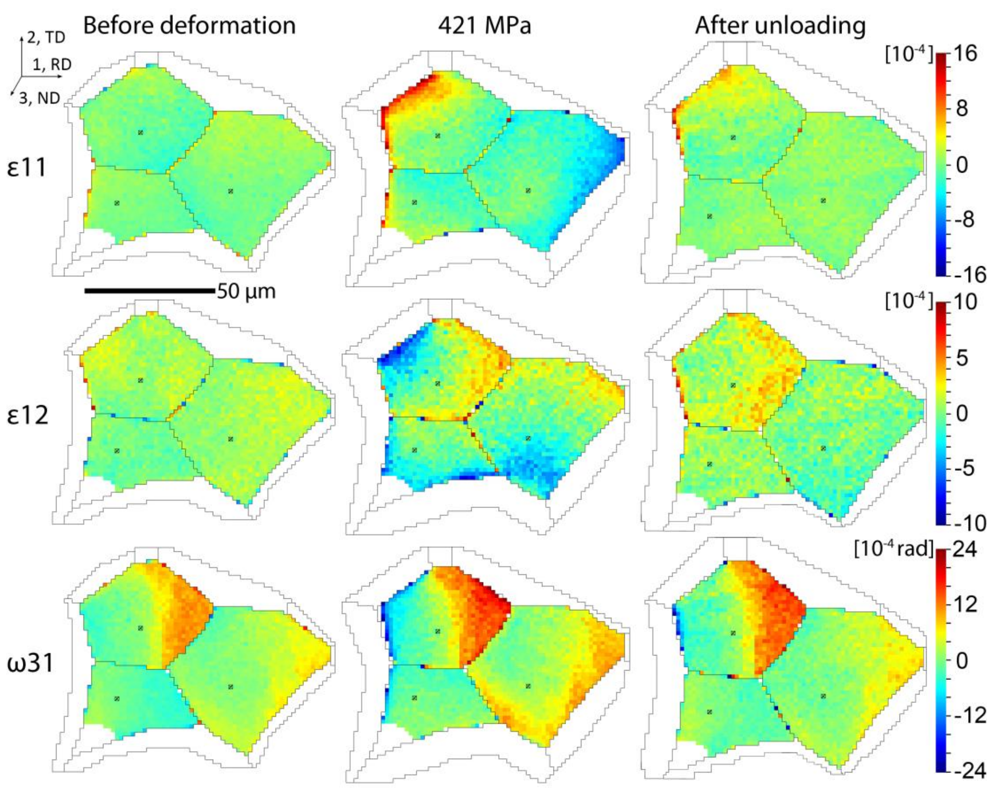


Fig. 1 Relative strains ε11 and ε12 and rotation ω31 before deformation, at 421 MPa and after unloading determined with CrossCourt.

Fig. 2 shows that, prior to deformation, the magnetic domains in grains 1, 2, 3 were branched, while in grains 4, 8 and 9 they were roughly aligned along an easy axis ([100] directions). Generally, if the angular difference is small between an easy axis and the surface, an alignment along this axis is energetically favored. Otherwise branching occurs to reduce the demagnetizing fields. If angular differences between the easy axes of neighboring grains are small, domains cross grain boundaries (e.g. grains 8 and 9). At 421 MPa the domains in most grains aligned along the easy axis closest to the stress direction. Moreover, an alignment over grain boundaries was present if the angular difference between easy axes was suitable. Otherwise compensating domains formed. After unloading branched domains appeared in most grains. Grain #4 is a special case, as slip lines hindered the domain alignment.

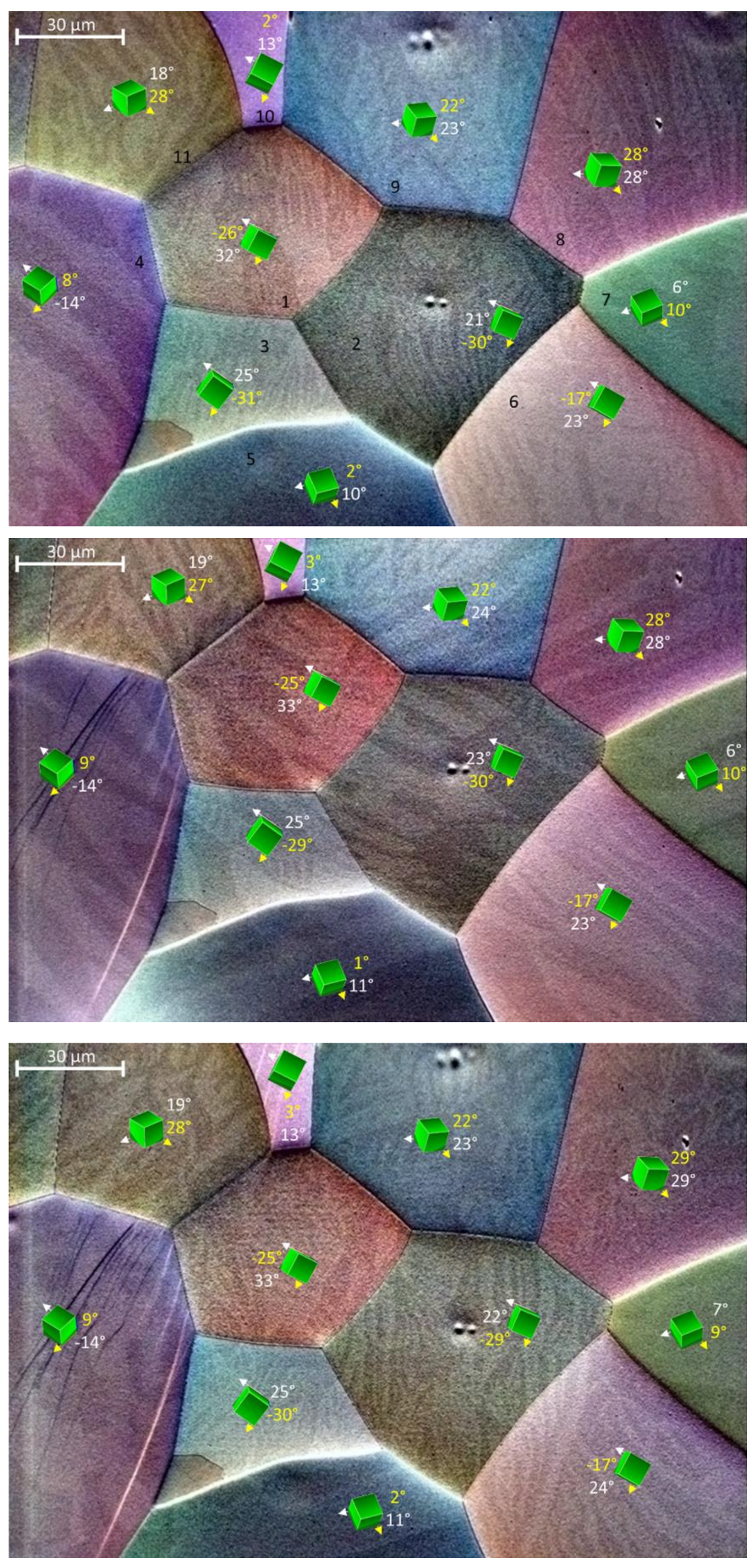


Fig. 2 Magnetic domains before deformation, at 421 MPa and after unloading.

Conclusions

CrossCourt proved to be a powerful tool in determining relative strains and rotations at the microstructural level. A complete characterization of magnetic domains has to rely both on the orientation of a specific grain and on the orientation of all surrounding grains. This applies to the unloaded case as well as to the loaded case. If local loading exceeds the elastic limit, slip lines hinder the domain alignment after unloading.

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