Highlights

Activity A - Novel superconducting and functional materials for energy and environment - 2021

Nanoscale analysis of superconducting Fe (Se,Te) epitaxial thin films and relationship with pinning properties

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The process of developing superconducting materials for large scale applications is mainly oriented to optimize flux pinning and the current carrying capability. A powerful approach to investigate pinning properties is to combine high resolution imaging with transport measurements as a function of the magnetic field orientation, supported by a pinning modelling. We carry out Transmission Electron Microscopy, Electron Energy Loss Spectroscopy and critical current measurements in fields up to 16 T varying the angle between the field and c-axis of Fe(Se,Te) epitaxial thin films deposited on CaF_2 substrates. We find evidence of nanoscale domains with different Te:Se stoichiometry and/or rotated and tilted axes, as well as of lattice distortions and two-dimensional defects at the grain boundaries. These elongated domains are tens of nm in size along the in-plane axes (Fig. 1). We establish a correlation between these observed microstructural features and the pinning properties, specifically strongly enhanced pinning for the magnetic field oriented in-plane and pinning emerging at higher fields for out-of-plane direction (Fig. 2). These features can be accounted for within a model where pinning centers are local variations of the critical temperature and local variations of the mean free path, respectively. The identification of all these growth induced defects acting as effective pinning centers may provide useful information for the optimization of Fe(Se,Te) coated conductors.

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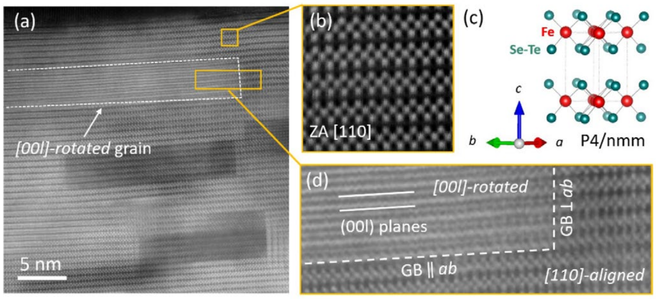

Fig. 1: Structure of the Fe(Se,Te) film at high-resolution. (a) High-resolution Z-contrast STEM image of the [110]-oriented $FeSe_{1-x}Te_x$ film. (b) Enlarged view of the atomic lattice and corresponding 3D atomic model of the unit cell in (c). (d) Detail of GBs between a rotated grain and a not-rotated one.

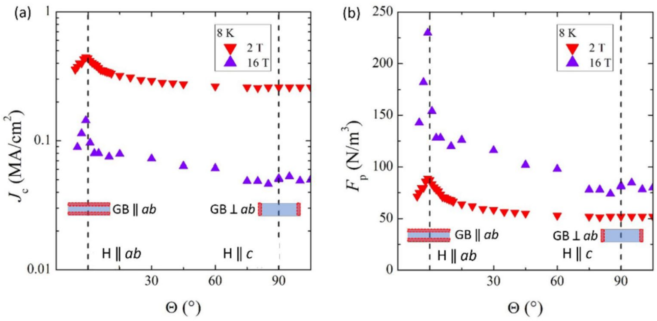

Fig. 2: Angular dependence Jc(θ) in semi-log scale (a) and pinning force (b), at 8 K and in fields of 2 and 16 T. The huge peak at H//ab is the signature of the pinning mechanism related to the 2D GB // ab defects. The small peak detectable at 16 T correlates with the 2D GB ⊥ ab observed defects, and indicates that c-axis correlated defects might become active as pinning centers at high fields.