Highlights

RESEARCH AREA 1 - Superconductors and Innovative materials for Energy and Environment - 2024

Unveiling intrinsic material and extrinsic pinning dimensionality in superconductors: Why Fe(Se,Te) is able to mimic YBCO

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Discovery of iron-based superconductors paved the way to a competitor of high-temperature superconductors, easier to produce, better performing in high fields, and promising to be less expensive. This work presents a deep analysis of H-θ phase diagram of PLD-processed Fe(Se,Te) superconducting films revealing material and pinning anisotropy at once. Critical parameters are investigated by resistivity measurements as a function of temperature, field, and angle R(T,H,θ). By selecting different thresholds along the R(T,H,θ) curves, all possible regimes are investigated. Surprisingly, anisotropy arises moving from the upper critical field toward the irreversibility line: gradually a non-monotonous transition from 3D to 2D, and backward to 3D occurs. Although Fe(Se,Te) appears as a 3D superconductor, its anisotropic pinning landscape shows similarities with an intrinsic layered superconductor: Fe(Se,Te) definitively mimics YBCO. In particular, H-θ phase diagram and TEM analysis reveal 2D Lego-block features in Fe(Se,Te) superconducting films.

In this work, we explore the different regimes along the resistive transition by choosing several thresholds to determine the critical fields and looking to the resulting angular dependence $H_{c2}(\theta)$ and $H_{irr}(\theta)$ in Fe(Se,Te) and YBCO materials. Our findings highlight how $H_{c2}(\theta)$ changes by changing the threshold from the 90% to the 50% of R_N; this can be interpreted as a different structural and pinning influence on determining the H-θ phase diagram. We have developed a general method to disentangle material dimensionality and pinning anisotropy, which are key constraints for applications, and that can be used as a guide for any other superconducting material.

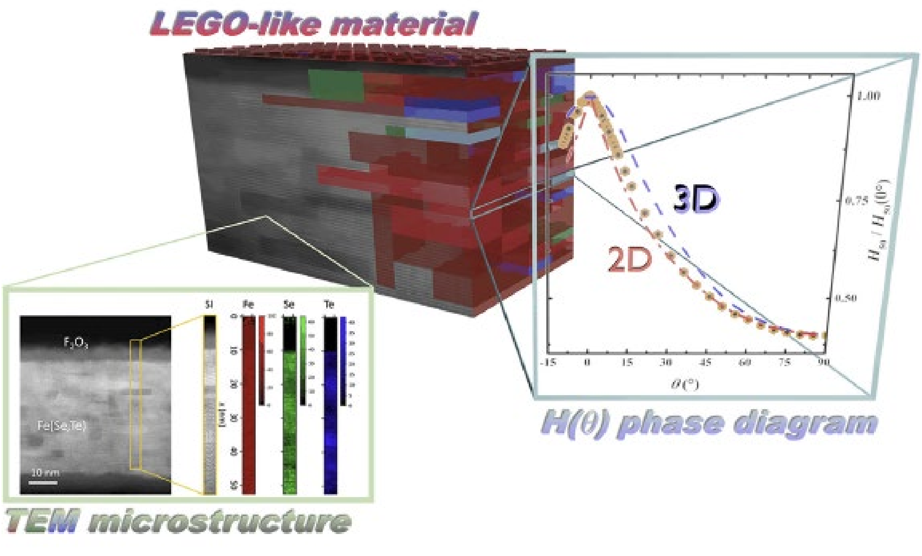

Fig. 1: A sketch of the overall 2D grains-blocks growth in Fe(Se,Te) films that mimics a continuous layered structure of YBCO, resulting in a similar 2D anisotropic pinning behaviour as proved by the $H_{50}(\theta)$ curve. High-magnification STEM micrograph showing the region where spectrum imaging was performed. EELS elemental maps of Fe, Se, and Te in the spectrum imaging region.