Artificial and Self-assembled Pinning Centers in $Ba(Fe_{1-x}Co_x)_2As_2$ Thin Films as a Route to Very High Current Density

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Introduction

In order to consider a superconductor suitable for application it must have high critical temperature T_c, large upper critical field H_{c2}, irreversibility field close to H_{c2} and low anisotropy. Improving the pinning properties by introducing defects acting as pinning centers is also of great importance to enhance the in-field performances. In high-T_c $YBa_2Cu_3O_{7-x}$ the addition of pins without T_c suppression is limited to 2-4 vol%. Here we studied the pinning properties of $Ba(Fe_{1-x}Co_x)_2As_2$ (Co-Ba122) thin films with a self-assembled or artificially introduced pins.

Experimental

We studied thin films grown by PLD starting from both high (HOC) and low oxygen content (LOC) Co-Ba122 targets. [1] The presence of oxygen generates $BaFeO_2$ (BFO) secondary phases that can act as pinning centers. We also used an undoped Ba122 target to artificially introduced non-superconducting defects via a multilayer deposition. The microstructures were determined by transmission electron microscopy (TEM) and the transport properties were investigated in high field up to 45T at the NHMFL.

Results and Discussion

We found that HOC single layers can accept an extremely high density of self-assembled defects, up to 20%vol., without T_c degradation. The cross-sectional TEM image of **Figure 1**(a) shows *c*-axis BFO nanorods (NR) and additional nanoparticle (NP) arrays arranged along the *ab*-planes with *c*-axis spacing of about 18 nm. The higher magnification (Figure 1(b)) shows that both nanoparticles and nanorods have a 4-5 nm diameter, the right size to match the vortex diameter. From the planar view (Figure 1(c)) we estimated that the nanorod average spacing is ~12.5 nm, corresponding to a matching field B_ϕ of ~13.2 T. Figure 1(d) reveals that this high density of defect is able to increase J_c in a wide angular and field range respect to a cleaner film. In particular we noticed that the critical current density J_c at 20T still exceeds 10^5 A/cm^2 with an almost isotropic behavior and we measured a global pinning force density F_p close to 50 GN/m^3.[1] We also studied LOC multilayer thin films with artificially introduced undoped Ba122 defects. In this case an even larger but more anisotropic J_c is achievable. This occurs thanks to the presence of plate-like precipitates parallel to the *ab*-planes, short vertically aligned nanorods and round nanoparticles that uniformly enhance J_c .[1]

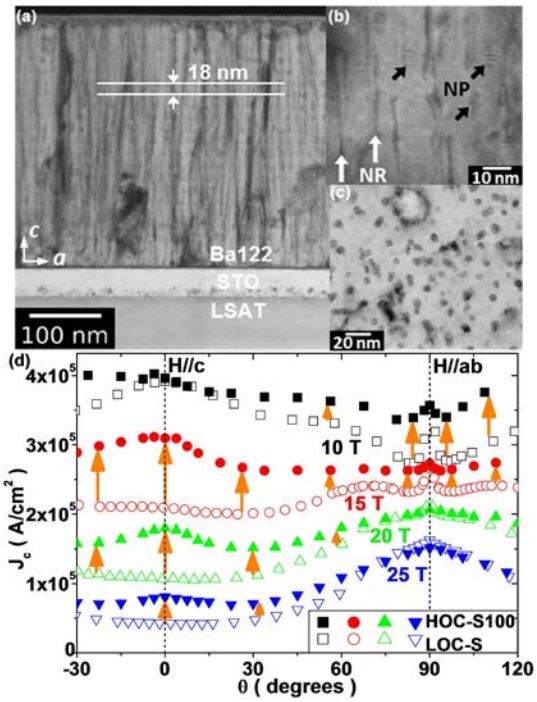

Figure 1. (a)-(b) TEM cross-section images of a high oxygen content $Ba(Fe_{0.92}Co_{0.08})_2As_2$ thin film showing *c*-axis nanorods (NR) and *ab*-arranged nanoparticles (NP). (c) Planar view showing a high density of nanorods. (d) J_c (θ) for a low oxygen content (LOC-S) and a high oxygen content (HOC-S100) film.

Conclusions

We demonstrated that Co-Ba122 accepts an extremely high density of pinning center, 4 or 5 times more than in $YBa_2Cu_3O_{7-x}$. This peculiarity allowed us to significantly improve the in-field performances up to very high field.

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References

[1] Tarantini, C., *et al*., Phys. Rev. B, **86**, 214504 (2012).