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# Correlation between vortex pinning and defect landscape in TLAG -$YBa_2Cu_3O_{7-\delta}$ nanocomposite films

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High temperature superconductors (HTS) are one of the most ambitious achievements since the discovery of superconductivity and they have the potential to revolutionize large-scale applications in the form of coated conductors (CC). $REBa_2Cu_3O_{7-\delta}$ (REBCO, RE = Rare Earth) coated conductors which belong to the class of HTS called cuprates are one of the highly studied materials due to their exceptional superconducting properties. However, there are still some scientific and engineering challenges set forth in the fabrication of high-performance CC. The novel growth method developed at ICMAB for the fabrication of REBCO films is an ultrafast (100 - 1000 nm/s) and cost-effective technique which combines Chemical Solution Deposition (CSD) with a non-equilibrium Transient Liquid Assisted Growth (TLAG) method [1,2]. Therefore, TLAG aims to overcome the high cost-performance ratio of the fabrication of REBCO CC.

REBCO successfully covers a wider range of magnetic field - Temperature (H - T) region than any other existing superconducting materials. However, to satisfy the different applications of REBCO coated conductors, one must do a broad characterization on the dependence of critical current density ($J_c$) on magnetic field (H), temperature (T) and the orientation of magnetic field (θ). The final Jc is determined by the vortex pinning mechanism at each H-T region and this is highly correlated to the microstructure of the REBCO films. There have been many efforts in the community to optimize the pinning landscape by nano-engineering the coated conductors and the best way has been the addition of nanoparticles or nanorods to the REBCO films which can enhance Jc in magnetic fields in the so-called nanocomposite CC [3]. Also, to reduce the cost-performance ratio, recently the focus is not only on increasing Jc but also on increasing the growth rates [4]. Therefore, nowadays it is very interesting to study the microstructure and vortex pinning mechanism in TLAG-CSD nanocomposites being a non-equilibrium growth method with ultrafast growth rates [4].

In this work we study different nanocomposites based on the concentration, size and type of nanoparticles by electrical transport measurements to understand the pinning mechanism and with the help of Transmission Electron Microscopy (TEM) and advanced x-ray diffraction we are able to correlate these properties to the microstructure and strain. The nanocomposites used in this study include 6,12,18, and 24% mol $BaZrO_3$ or$BaHfO_3$ preformed nanoparticles with sizes of 5, 7 and 10 nm, and various thickness. All the TLAG nanocomposites shows higher $_0H^*$ and nanostrain (ε) and the effective anisotropy factor is reduced down to $_{eff}$ = 2-3.5 which in the case of pristine films is 5-7. From the angular dependent transport study, the anisotropic peak around ab-planes is broadened in nanocomposites compared to pristine, signaling an increase of short stacking faults density relevant for vortex pinning at low temperatures and high magnetic fields. These additionally formed stacking faults are also responsible for breaking the twin boundary coherence which prevents vortex channeling at low temperatures. The overall $J_c$ (θ) dependence has been improved in most of the H-T region for TLAG nanocomposites compared to TLAG pristine films. Finally, the effect of nanoparticle concentration and layer thickness will also be discussed.

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[2] Rasi, Silvia, et al. "Kinetic Control of Ultrafast Transient Liquid Assisted Growth of Solution-Derived YBA 2 Cu 3 O 7 -x Superconducting Films."Advanced Science, vol. 9, no. 32, 2022, p. 2203834.
[3] Vallès, Ferran, et al. "Optimizing vortex pinning in yba2cu3o7-X superconducting films up to high magnetic fields."Communications Materials, vol. 3, no. 1, 8 July 2022.
[4] Puig, Teresa, et al. "Impact of high growth rates on the microstructure and vortex pinning of high-temperature superconducting coated conductors."Nature Reviews Physics, vol. 6, no. 2, 4 Dec. 2023, pp. 132–148.

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