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Advanced characterization to underpin the mechanisms of ultrafast transient liquid assisted growth of superconducting epitaxial layers

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The unique electrical and magnetic properties of high temperature superconducting (HTS) materials have made them excellent candidates for the energy transition demands facing our society. However, their fabrication costs are high due to the need for km-long thick epitaxial films using thin film growth technologies. At ICMAB, we have developed a low-cost, high-throughput growth method that combines chemical solution deposition (CSD) with an ultra-fast non-equilibrium transient liquid-assisted growth method, Transient Liquid Assisted growth (TLAG) [1]. The fast growth rates found, beyond 1000 nm/s, and the use of CSD allow the demands on cost reduction to be met. However, the control of the growth process by kinetics made advanced characterizations a requirement. On the one hand, we used probe-corrected transmission electron microscopy and spectroscopy (HR-TEM, STEM, EELS), providing an ideal tool to study the growth evolution of films and nanocomposites, identify microstructural defects and embedded non-superconducting nanoparticles with atomic resolution, which strongly determined the superconducting properties of the material.

On the other hand, we developed a fast in-situ synchrotron XRD growth platform to achieve the time scale needed to follow the growth process and determine the phase transformations from precursors to intermediates and the final epitaxial layer. Synchrotron experiments were performed on DiffAbs (Soleil) and NCD-SWEET (ALBA), with a 2D detector that acquires images in the range of 100ms/image down to 9ms/image. We have built the test bench on a mobile rack, coupling the XRD furnace with gas and pressure systems, and incorporating an in-situ mass spectrometer and an in-situ conductivity measurement.

Together, the combined use of these advanced instrumentations allows us to underpin the growth mechanisms and defect microstructure generated by this novel TLAG method [2,3]. In particular, kinetic phase diagrams of the TLAG process can be determined, a homogeneous to heterogeneous epitaxial growth reorientation phenomenon of YBCO has been observed and growth rates could be determined. In addition, composition gradient samples can be studied [4]. The talk will present ongoing research and new opportunities.

[1] L. Soler et al, Nat. Commun., 11, 344 (2020)
[2] S. Rasi et al, Adv Sci, 9, 2203834 (2022)
[3] L. Saltarelli et al, ACS Appl. Mater. Interfaces 14 48582 (2022)
[4] A. Queralto et al, ACS Appl. Mater. Interfaces 13, 9101 (2021)

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