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Revealing mechanism of the ultrafast growth of superconducting epitaxial thin films by in-situ X-ray synchrotron diffraction: from design/installation to measurements

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Investigation on the preparation of efficient and flexible high temperature superconducting materials (HTS) is one of the puzzles to be solved for the Energy Transition goal. One of the important parts of this development is focused on the cost-effective, scalable methods of synthesis of such materials.

Nowadays, HTS based on REBa2Cu3O7 (RE=Y or Rare Earth, REBCO) are manufactured as long, flexible conductors deposited on metallic substrates using thin film technologies, the so-called coated conductors (CC), which are rather expensive. Our approach is to use an innovative method, called Transient Liquid Assisted Growth (TLAG) [1], a non-equilibrium process based on epitaxial crystallization from a transient melt at very high growth rates (100 nm/s, 100 times larger than conventional methods). This process is compatible with low cost, scalable chemical solution deposition methods and allows to grow high temperature epitaxial superconducting films.

However, in order to achieve a deep understanding of such a fast growth process of REBCO films, determine the phases´ evolution and the kinetic phase diagrams that would permit to better control their properties, a new methodology had to be developed. This goal is being achieved through fast acquisition of in-situ X-Ray diffraction data during the TLAG process at the NCD-SWEET synchrotron beamline of ALBA light source in Spain. For that purpose, a unique portable system was developed using a fast heating XRD furnace with controlled atmosphere capable to tune temperature up to 1000 ºC and total pressures from 10-5 bar to 1 bar with controlled oxygen partial pressure and flow rate synchronized with simultaneous acquisition of 2D XRD images at 105 ms/image and 18 keV. Additionally, the system allows for simultaneous analysis of the volatiles with mass spectrometry and in-situ electrical conductivity that permits to follow the phase transformation from the insulating precursor phases to the metallic superconductor phase at the growth conditions.

The ultrafast process of TLAG required very fast time responses of all the systems and accurate time synchronizations. Results on the epitaxial nucleation and growth mechanism of the REBCO phase on STO single crystals and metallic substrates, and TLAG phase evolutions process will be discussed.

[1] L. Soler et al, Nature Communications, 11, 344 (2020)

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