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High laser fluence: the new strategy for depositing High Temperature Superconducting films for applications

The established guiding principle for pulsed laser deposition (PLD) of high-quality $YBa_2Cu_3O_{7-x}$ (YBCO) superconducting films suggests that the optimal target-to-substrate distance (TSD) lies near the visible tip of the laser-induced plume, with deviations from this point expected to degrade film properties. We modified our PLD system to allow precise external TSD adjustment over a 110 mm range and systematically studied its influence on the electromagnetic, micro- and nanostructural properties of YBCO thin films. Our analysis, referencing plume propagation models and growth processes, reveals that the optimal TSD range can, in fact, be extended under relatively high laser fluence, depending on the desired film performance and properties. We identify four TSD regimes, each exhibiting unique film characteristics. X-ray diffraction (XRD) θ–2θ scans reveal lattice parameter splitting at the 001 and 002 reflections through the formation of triple peaks, indicative of a tri-layered strain structure. This is the first report of such a structure under nominally monolayer growth conditions without additional fabrication techniques, spanning a 50 mm TSD range. The phenomenon arises from the combined influence of TSD and laser fluence, driving transitions between monolayer and multilayer-like growth. Remarkably, high-quality superconducting properties and crystallinity are preserved across a broad 50 mm TSD window, yielding films with variable total thickness, layer thickness, surface structure, and growth modes. This insight and tunability deepen understanding of growth mechanisms and deposition dynamics, offering new pathways to tailor surface morphology and performance in electronics and high-power applications through controlled structural evolution and efficient deposition rates.

Field of Condensed Matter

Superconductivity

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