Novel Superoxygenated Phases in Superconducting Cuprate Thin Films

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The superconducting critical temperature ($T_c$) of hole-doped cuprates tends to increase with their lattice complexity, which is generally correlated with higher states of oxidation. For YBa$_2$Cu$_3$O$_{7-\delta}$ (YBCO-123), it is known that solid-state reaction in high-pressure oxygen can induce the formation of more complex and oxidized phases such as Y$_2$Ba$_4$Cu$_7$O$_{15-\delta}$ (YBCO-247) and Y$_2$Ba$_4$Cu$_8$O$_{16}$ (YBCO-248). In this work, we apply this superoxygenation concept of material synthesis to nanoscale thin films which, owing to their large surface-to-volume ratio, are more thermodynamically reactive than bulk samples. Epitaxial thin films of YBCO-123 were grown by pulsed laser deposition on (La, Sr)(Al, Ta)O$_3$ substrates, and post-annealed in up to 500 atm of oxygen at 800°C. Our post-annealed films show robust superconducting transitions with $T_c$ ranging from 80 to 93K. Transmission electron microscopy and X-ray absorption spectroscopy were used to probe the lattice structure and oxygen stoichiometry. Our measurements show clear evidence of conversion to YBCO-247 and YBCO-248 in the superoxygenated films, as well as YBCO-125, a novel YBCO phase that has three CuO chains per unit cell and potentially higher $T_c$.

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