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Novel Phases of High-Tc Cuprates in Superoxygenated and Heterostructured Thin Films*

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Thin films of transition-metal oxides, by virtue of their high surface-to-volume ratio, tend to have very different thermodynamic phase stability than in bulk form. When these films are grown epitaxially on perovskite substrates, the heteroepitaxial mismatch can also induce strong interfacial strains resulting in intergrowths of novel lattice defects [1]. We apply these two concepts of nanoscale materials synthesis to the Y-Ba-Cu-O family of cuprates, in an effort to stabilize novel cuprate phases with very high superconducting critical temperature (Tc). Pulsed laser-ablated deposition is used to grow thin layers of YBa2Cu3O7 (YBCO) epitaxially on and between various cubic perovskites, ranging from insulating titanates to half-metallic maganites. The thin films and heterostructures are also subjected to superoxygenation by annealing under 500 atm of O2 pressure. Atomic-scale transmission electron microscopy and electron energy loss spectroscopy revealed unambiguous evidence for three novel phases of Y-Ba-Cu-O in the nominally YBCO layers. These phases are characterized by either triple-CuO chains, BaO layers within double-CuO chains or extra Y-O layers within the CuO2-Y-CuO2 bilayer; their formation can be attributed to the superoxygenation and heteroepitaxial strain. We discuss the likelihood that these novel cuprate phases have enhanced Tc, in light of a recent pump-probe spectroscopy study [2] of YBCO showing pairing enhancement by dynamic increase of the CuO2 bilayer thickness.

[1] H. Zhang, N. Gauquelin, G. A. Botton, J. Y.T. Wei, Appl. Phys. Lett. 103, 052606 (2013).

[2] W. Hu, S. Kaiser, D. Nicoletti, C. R. Hunt, I. Gierz, M. C. Ho mann, M. Le Tacon, T. Loew, B. Keimer and A. Cavalleri, Nature Materials 13, 705 (2014).

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