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Unconventional isotope effects in high-temperature cuprate superconductors

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A brief review on unconventional oxygen-isotope ($^{16}O/^{18}O$) effects (OIE) in cuprate high-temperature superconductors (HTS) is presented. First the doping dependence of the OIE on the superconducting transition temperature T_C in various HTS is discussed. For all cuprate HTS families the OIE exponent of T_C (α_O) shows a generic trend: In the underdoped regime α_O is large ($\alpha_O > 0.5$) and becomes small in the optimally doped and overdoped regime. Magnetization, magnetic torque, and muon-spin rotation OIE studies of the in-plane penetration depth $\lambda_{ab}(0)$ in doped $La_{2-x}Sr_xCuO_4$ and $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ indicate a substantial oxygen-mass dependence of the quantity $\lambda_{ab}^{-2}(0) \propto \rho_s(0)$ (superfluid density) which increases with reduced doping. Even at optimal doping, where the OIE on T_C is small, a pronounced OIE on $\lambda_{ab}(0)$ is present [1]. Note that an OIE on the penetration depth is not expected for a conventional phonon-mediated superconductor. The oxygen-isotope shifts of T_C and $\lambda_{ab}(0)$ exhibit a correlation that appears to be generic for various families of HTSC. Site-selective OIE investigations of $Y_{1-x}Pr_xBa_2Cu_3O_{7-\delta}$ clearly reveal that the planar oxygen atoms mainly contribute to the total OIE on T_C as well as on $\lambda_{ab}(0)$ at all doping levels. These unusual OIE's, which are beyond the scheme of BCS theory, may be explained with a polaron theory [2]. It is found that the coupling of the electronic degrees of freedom to the Jahn-Teller Q_2-type mode is the origin of these isotope effects.

References:

[1] R. Khasanov et al., Phys. Rev. Lett. 92, 057602-1 (2004)
[2] A. Bussmann-Holder and H. Keller, cond-mat/0409738

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