In-plane and out-of-plane superconductivity of Marcury-based multilayer high-T_c superconductors

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Marcury-based high-T_c cuprate ($HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$) is an n-layer superconductor: n layers of CuO_2 planes are separated by the insulating HgO and BaO structures. As the number of layers n increases, the superconducting transition temperature T_c increases, peaks at $n = 3$ and decrease above $n \geq 4$. The tri-layer material ($n = 3$: $HgBa_2Ca_2Cu_3O_{8+\delta}$) currently has the world record of the highest $T_c = 135$K among all the cuprate superconductors under ambient pressure. We investigated two complimentary features for this novel series of multilayer superconductors: *in-plane* superconducting condensate weight by transverse-field muon spin relazation (TF-μSR) and *out-of-plane* superconductivity response by optical reflectivity measurement.

For 3- and 4-layer marcury cuprates, the plot of T_c vs. in-plane condensate weight (Uemura-plot) generally follows the universal relation, although due to the optimal doping, the data points deviates to the larger condensate weight side, as has been observed in optimally doped cuprates. For the 4-layer material ($HgBa_2Ca_3Cu_4O_{10+\delta}$), static magnetism was searched for in zero-field μSR. Slight enhancement of relaxation was observed at $T = 2$K compared to that for 150K. This suggests that (quasi) static moment start to develop for $n = 4$ material, but not as large nor static as has been proposed for $n = 5$ material by NMR [1] and μSR [2].

The c-axis optical conductivity exhibits a borad peak developing below T_c in the energy range of several 10 meV. The c-axis condensation energy calculated from the energies of this mode follows the T_c variation for the $n = 2, 3, 4$ and 5 layer materials. This supports the interpretation that the optical active mode is caused by the Josephson coupling between the CuO_2 planes, and suggests that c-axis correlation within the n-layer CuO_2 blocks may play some role to detemine the superconductivity T_c [3].

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[2] K. Tokiwa *et al*, Physica C 388-389 (2003) 243-244.
[3] Y. Hirata, *et al*, submitted (2007).