MAR11-2010-001348

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

London penetration depth as a sensitive tool for determining the superconducting gap structure in iron-pnictide superconductors

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In the high$-T_c$ cuprates, experiments and theories have relied on a single-band picture that is essentially two- dimensional with a single superconducting gap, which provided a simple way to understand the angular dependence of the superconducting order parameter. In iron-based superconductors, the experimental mapping of the superconducting gap structure is complicated by the doping- dependent, multi-band electronic structure with three- dimensional character and the existence of at least two distinct superconducting gaps. Focusing on precision measurements of the London penetration depth, $\lambda(T)$, in "122" $Ba(Fe_{1-x}T_x)_2As_2$ (T=Co,Ni,Ru,Pt,Pd,Co+Cu) single crystals, I will discuss the systematics of the ubiquitous power law temperature variation of the in-plane penetration depth, $\lambda_{ab}(T) = \lambda_{ab}(0) + \beta T^n$, and of the absolute value, $\lambda_{ab}(0)$, with the doping level, x. To understand the role of disorder and pairbreaking scattering, the effect of heavy ion irradiation has been systematically studied and the results are compared with other systems, most notably stoichiometric LiFeAs. Together with the doping dependence of the out-of- plane London penetration depth, $\lambda_c(T)$, and comparisons to thermal conductivity and specific heat data, these results strongly suggest the development of a significant in-plane anisotropy of the superconducting gap(s) and are also consistent with the appearance of accidental c-axis nodes (not imposed by symmetry) for concentrations moving away from optimal doping. By taking pairbreaking scattering into account, the data for the optimally doped compounds are well described by weak-coupling superconductivity with two nodeless superconducting gaps having amplitudes that differ by about a factor of two. I conclude by emphasizing the significant role of three-dimensionality and scattering in determining the electrodynamics of iron-based superconductors.