Influence of disorder on the fundamental properties of Iron Based Superconductors

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Influence of disorder on the fundamental properties of Iron Based Superconductors

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Summary

In my PhD thesis work I report on the effects of disorder on the superconducting properties of Iron Based Superconductors (IBSs) and on their order parameter symmetry.
The research work involved measurement of critical temperature, London penetration depth, quasiparticle conductivity and surface impedance of IBS single crystals performed with a microwave resonator technique, that has been optimized for this task during this PhD project. Measurements were performed on samples of the Ni doped CaK-1144 family ($CaKFe_4As_4$ grown at Ames Laboratories) and of the Ba-122 family ($BaFe_2As_2$) with different kinds of doping (Co, K, and P grown at the the University of Tokyo and Rh at Ames Laboratories) covering all the possible typologies: electron doping, hole doping and isovalent substitution.
The same samples were characterized both in the pristine state and after successive doses of ion irradiation, in order to study the modification of their properties with increasing disorder. Ion irradiation was performed at the Laboratori Nazionali di Legnaro of the Istituto Nazionale di Fisica Nucleare (INFN): 3.5 MeV proton irradiation at the CN accelerator, 250-MeV Au ion irradiation at the Tandem accelerator and-1.2 GeV Pb ion irradiation at the Piave-Alpi accelerator. The details of the irradiation experiments are determined on the basis of Monte Carlo simulations performed with precompiled codes.
The measured critical temperature, London penetration depth and quasiparticle conductivity are then compared to theoretical predictions obtained solving the multiband Eliashberg equations in order to validate the pairing models and extract additional information. This comparison allows to investigate the behaviour of the superconducting gaps as a function of temperature and for increasing disorder.

With this approach it has been possible first to discuss the behavior of pristine single crystals of $BaFe_2As_2$ with different substitutional species (K, Co and P) covering hole and electron doping and isovalent substitution. Then the effectcs of disorder introduced by 250 MeV Au ions in K doped $BaFe_2As_2$ samples were analyzed showing that T_c degradation and London penetration depth behavior due to the presence of disorder can be fully explained by the $s_\pm$ order parameter symmetry promoted by antiferromagnetic spin fluctuations. Finally it has been possible to experimentally identify, in Rh-doped $BaFe_2As_2$ irradiated with high doses of 3.5 MeV protons, the transition from $s_\pm$ to s_{++} order parameter symmetry (previously theoretically predicted) and propose additional signatures of the transition itself. Moreover, the experimental investigation of the London penetration depth anisotropy in $CaKFe_4As_4$ and it's dependence on Ni doping and pointlike disorder was carried out, as well as a comparison of how the morphology of irradiation induced defects impacts the critical temperature degradation with increasing disorder.