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Planckian Dissipation in $Bi_2Sr_2Ca_2Cu_3O_{10-\delta}$

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Abstract : Since the discovery of high temperature superconductivity (HTSC) in cuprates, several aspects of this phenomena have fascinated physics community. The most debated one is the linear temperature dependence of normal state resistivity over wide range of temperature in violation of with Fermi liquid theory. The linear-in-T resistivity (LITR) is the indication of strongly correlated metallic, known as “strange metal”, attributed to non Fermi liquid theory (NFL). The proximity of superconductivity to LITR suggests that there may be underlying common origin. The LITR has been shown to be due to unknown dissipative phenomena, restricted by quantum mechanics and commonly known as ‘‘Planckian dissipation” , the term first coined by Zaanen and the associated inelastic scattering time τ and given by $1/\tau=\alpha k_BT/\hbar$, where ħ, kB and α are reduced Planck’s constant, Boltzmann constant and a dimensionless constant of order of unity, respectively. Since the first report, experimental support for α ∼ 1 is appearing in literature. There are several striking issues which remain to be resolved if we desire to find out or at least get a clue towards microscopic origin of maximal dissipation in cuprates. (i) Universality of α ∼ 1, recently some doubts have been raised in some cases. (ii) So far, Planckian dissipation has been demonstrated in overdoped Cuprates, but if the proximity to quantum criticality is important, then Planckian dissipation should be observed in optimally doped and marginally underdoped cuprates. The link between Planckian dissipation and quantum criticality still remains an open problem. (iii) Validity of Planckian dissipation in all cuprates is an important issue. Here, we report reversible change in the superconducting behavior of high temperature superconductor Bi2Sr2Ca2Cu3O10+δ (Bi-2223) under dynamic doping induced by photo-excitation. Two doped Bi-223 samples, which are x = 0.16 (optimal-doped), x = 0.145 (marginal-doped) have been used for this investigation. It is realized that steady state photo-excitation converts magnetic Cu2+ ions to nonmagnetic Cu1+ ions which reduces superconducting transition temperature (Tc) by killing superfluid density. In Bi-2223, one would expect the maximum of suppression of Tc should be at charge transfer gap. We have observed suppression of Tc starts at 2eV, which is the charge transfer gap in Bi-2223. We attribute this transition due to Cu-3d9(Cu2+) to Cu-3d10(Cu+), known as d9 − d10 L transition, photoexcitation makes some Cu ions in CuO2 planes as spinless non-magnetic potential perturbation as Zn2+ does in CuO2 plane in case Zn-doped cuprates. The resistivity varies linearly with temperature with or without photo-excitation. Tc can be varied by almost by 40K be photoexcitation. Superconductivity can be destroyed completely by introducing ≈ 2% of Cu1+ ions for this range of doping. With this controlled variation of Tc and resistivity, detailed investigation has been carried out to reveal Planckian dissipation underdoped to optimally doped Bi-2223. The most important aspect of this investigation is that we could vary Tc dynamically and reversibly, so that LITR and associated Planckian dissipation can be studied over wide ranges of Tc without changing the doping chemically.

Keywords : linear resistivity, HTSC, Planckian dissipation, strange metal
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