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Effects of magnetic impurity Co on stripe phase of $(Bi/Tl)_2(Sr/Ba)_2CaCu_2O_{8+\delta}$ superconductors

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Abstract. The effects of Co impurity substitution at the Cu site of bilayer bismuth and thallium cuprates have been studied over a wide range of carrier concentration. For both the systems it is found that the suppression of the superconducting transition temperature, T_c is more rapid in the underdoped region. No anomalous suppression of T_c at $p \sim 1/8$ (p is the hole concentration per Cu ion) is found for different Co concentrations. This indicates that magnetic impurity Co behaves differently with respect to pinning of dynamical stripes as was observed in the case of non-magnetic impurity Zn by Akoshima *et al.* [Phys. Rev. B **57**, 7491 (1998)] in bilayer bismuth cuprate. Pseudogap magnitude (E_g) for each Co doping are observed to have a correspondence with a related characteristic temperature T^* obtained from thermopower measurements where T^* increases with increasing Co-concentration at a fixed carrier concentration. Both T^* and E_g are found to follow an inverse power law ($\sim \frac{1}{p^n}$) with different n values.

PACS. 74.25.Fy Transport properties (electric and thermal conductivity, thermoelectric effects, etc.) – 74.72.Hs Bi-based cuprates – 74.72.Jt Other cuprates, including Tl and Hg-based cuprates

1 Introduction

In high temperature superconductors (HTSC) the evolution of charge dynamics over the temperature doping ($T_c - p$) phase diagram is established to be unconventional in reference to the Fermi liquid description of which the conventional metals and superconductors belong. Because of the presence of antiferromagnetic (AF) fluctuations even in the doped phases and strong electron-electron correlation effects, the response of the holes is markedly different from the free electron behavior giving rise to unconventional behavior in almost all the transport properties of HTSC. Consequently, it is commonly accepted that an understanding of the charge dynamics is an important step to elucidate the mechanism responsible for the occurrence of superconductivity at high temperature. Various experimental studies such as neutron scattering experiments [1], muon spin relaxations [2] and nuclear quadrupole resonances [3] have revealed that the distribution of electronic charge and spin is not homogeneous but can be thought of as being confined to separate linear regions within the CuO_2 planes and thus resembling stripes that cannot be described in terms of the so-called Fermi liquid theory. Experimental investigation suggests that the superconductivity and stripes in HTSC have a deep and profound relationship and it is also proposed that the dynamical stripe fluctuation is a possible driving force for HTSC [4].

Recently, a new phenomenon has been established experimentally in materials with reduced carrier density, commonly called "underdoped". Different classes of experiment on underdoped HTSC reveal indirect [5–7] as well as direct [8] evidences for the presence of a gap-like feature termed as "Pseudogap" in the electronic excitation spectrum of low energy excitations below a certain temperature $T^* \gg T_c$. Emery *et al.* [9] have developed a preformed pair model for the pseudogap based on microstripes. The direct evidence of the stripe order of holes and spins has come from the neutron scattering measurements performed by Tranquada *et al.* [1] in the low temperature tetragonal (LTT; space group $P4_2$/ncm) phase of $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$ (LNSCO) at the specific hole concentration $x = p \sim 1/8$ exhibiting anomalous suppression of T_c. The observed elastic superlattice peaks in the neutron scattering experiments corresponds to charge stripe order at $T_{charge} = 65$ K followed by a spin stripe order at a lower temperature $T_{spin} = 50$ K indicating that the charge order is a precursor of the spin order. The static stripe order in this material is comprised of a spatial separation of the spin and charge into AF stripes of three Cu atoms wide separated by antiphase domain boundaries where the doped holes reside on every

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second Cu atom. In LNSCO, the formation of static stripes is associated with structural transition at low temperature from the low temperature orthorhombic (LTO; space group Bmab) to LTT phase due to the tilt of the CuO_6 octahedra producing stripe pinning potential leading to the occurrence of 1/8 anomaly mentioned above. Similar explanation also explains successfully the anomalous reduction of T_c at $x = p \sim 1/8$ initially observed in $La_{2-x}Ba_xCuO_4$ (LBCO) [10] undergoing structural phase transition from LTO to LTT phase. It was pointed out by Maeno *et al.* [11] that the equation $2/n^2$ ($n=$ integer) was a key to solve the so-called 1/8 problem ($n = 4$). The authors have explained this problem with the help of localized hole pairs forming a 4×4 square superlattice in the CuO_2 plane of LBCO with $p \sim 1/8$. On the other hand, in the LTO phase of $La_{2-x}Sr_xCuO_4$ (LSCO) [12] at $x = p \sim 1/8$, superconductivity is weakly suppressed in comparison with the LBCO system. For the partially Zn-substituted $La_{2-x}Sr_xCu_{1-y}Zn_yO_4$ ($x = p \sim 1/8$ and $y = 0.005-0.025$) where LTT phase does not appear at low temperature, Koike *et al.* [13] observed an enhancement of the 1/8 anomaly and also noticed anomalies in the transport properties *e.g.*, thermoelectric power (TEP) and Hall coefficient, which are likely to be attributed to the formation of the stripe patterned static order of holes and spins on account of Zn impurity. If the dynamical stripe correlations of holes and spins are characteristic of the CuO_2 plane with $p \sim 1/8$, it will exists not only in the La-214 system but also should be present in all HTSC cuprates with $p \sim 1/8$. Recently, it has been found [14] from muon spin relaxation measurements in the partially Zn-substituted $YBa_2Cu_{3-2y}Zn_{2y}O_{7-\delta}$ (Y-123) that the magnetic correlation between Cu-spins is enhanced singularly at $p \sim 1/8$ (corresponding to $7 - \delta = 6.65$) where superconductivity is suppressed anomalously. This result suggests the existence of dynamical stripe correlation in Y-123 phase and that they tend to be pinned by a small amount of Zn impurity. In another work [15] the authors have also reported anomalous suppression of superconductivity in Zn-doped $Bi_2Sr_2Ca_{1-x}Y_x(Cu_{1-y}Zn_y)_2O_8$ (Bi-2212) with $p \sim 1/8$ ($x \sim 0.3$) and $y = 0.02-0.03$. They also found that for the same samples transport properties such as electrical resistivity and thermoelectric power are less metallic than usual. The authors interpreted the results considering the stripe model namely, substitution of Zn for Cu in Bi-2212 froze the normally moving spins and charges into a static structure. Thus both the LTT distortion and non-magnetic Zn impurities are believed to stabilize stripes. Since the static striped phase propagate along a single direction, the fluctuations associated with a striped phase are expected to be one dimensional (1D). The direct evidence of the 1D charge transport in the striped phase has come from the dramatic decrease of the Hall coefficient starting around T_{charge} in the static spin charge stripe order phase of $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$ reported by Noda *et al.* [16].

Though a number of experiments confirmed the existence of stripe phases in HTSC but its role in the carrier dynamics is yet to be understood. Moreover, interplay between the physics of stripe and the formation of the pseudogap also remains unclear. In order to address this issue we have systematically studied the charge transport properties such as electrical resistivity (ρ), Hall coefficient (R_H) and thermopower (TEP, S) as a function of controlled Co doping in $(Bi/Tl)_2(Sr/Ba)_2Ca_{1-x}Y_x(Cu_{1-y}Co_y)_2O_{8+\delta}$ with $x = 0.0-0.5$ and $y = 0.0-0.08$ covering the range from highly underdoped to optimum doped including the $p \sim 1/8$ ($x \sim 0.3$) region. The carrier concentration of both the systems has been changed by changing the yttrium concentration x.

2 Experimental techniques

$(Bi/Tl)_2(Sr/Ba)_2Ca_{1-x}Y_x(Cu_{1-y}Co_y)_2O_{8+\delta}$ samples with different x and y ($x = 0.0-0.5$ and $y = 0.0-0.08$ for Bi-2212 and $x = 0.0-0.3$ and $y = 0.0-0.06$ for Tl-2212) have been prepared following the conventional solid state reaction route [17]. For Bi-system, stoichiometric amounts of appropriate oxides and carbonates were mixed throughly and then reacted in air at temperatures ranging between 860 to 900 °C for several days with intermediate grindings. Y- and Co-doped Tl-2212 samples were prepared using matrix method. The $Ba_2Ca_{1-x}Y_x(Cu_{1-y}Co_y)O_{4+0.5x}$ compositions were prepared by calcining stoichiometric mixtures of respective oxides and carbonates at 930 °C for 24 h in air with several intermediate grindings. Finally, Tl_2O_3, CuO, CoO and $Ba_2Ca_{1-x}Y_x(Cu_{1-y}Co_y)O_{4+0.5x}$ were mixed with molar ratio 1:1 (such that Tl:Ba:$Ca_{1-x}Y_x$:$Cu_{1-y}Co_y$=2:2:1:2) pressed into pellets, wrapped in Pt-foil, sealed in an evacuated quartz tube which was then annealed at 830 °C for 6 h and then cooled to room temperature at the rate of 40 °C/h. The X-ray diffraction patterns of all the samples thus prepared are found to be single phase having orthorhombic and tetragonal structures for the Bi- and Tl-systems, respectively. Substitution of yttrium (Y) at Ca sites leads to a change in the carrier concentration of the samples. A scanning electron microscope equipped with EDS (Oxford, Link ISIS) attachment operated at an accelerated voltage of 25 KV was used for the composition analysis of all the samples using ZAF quantitative analysis programme. Energy dispersive X-ray fluorescence analysis was used to estimate the Co concentration of all the samples. For each yttrium doping, incorporation of Co causes systematic changes in the lattice parameters suggesting that Co goes into the lattice sites. In addition, both X-ray rietveld analysis and EDS studies confirm the presence of Co impurities at the Cu sites. Both Y and Co concentrations are found to be within 10% of the nominal composition. Thermopower (TEP, S) of all the samples were measured using a differential technique over the temperature range 77–320 K. Using two heaters a temperature gradient δT was created across the samples and the voltage δE developed between the hot and cold ends of the thermocouple formed by the sample and Cu wires was measured. Pressed pellets of each samples were mounted by pressed contact between the copper plates and the whole system was placed in a glass dewar attached with a temperature controller (Lake Shore Cryotronic, DRC-93C) and interfaced with a computer which records the TEP values as a function of temperature. The dc electrical resistivity measurements were performed following four probe technique. The Hall voltage measurements have been carried out at room temperature under magnetic field of 20 kOe. The magnetic field was reversed to eliminate any magnetoresistance. The average of four to five sets of data were taken to calculate the Hall voltage [17].

3 Results and discussions

We have measured systematically the temperature variation of the electrical resistivity (ρ) of $(Bi/Tl)_2(Sr/Ba)_2Ca_{1-x}Y_x(Cu_{1-y}Co_y)_2O_{8+\delta}$ as a function of Co concentration (y(%)=0, 2, 4, 6, 8) corresponding to each of the yttirum concentrations in the range ($x = 0-0.5$) including the anomaly region $p \sim 1/8$ ($x \sim 0.3$). We observed that when the Y concentration is low ($x \leq 0.10$) all the Co-doped samples belonging to Bi- and Tl-2212 yield metallicity and superconductivity. Moreover, in both Bi- and Tl-2212, it is found that for high yttirum content samples, Co substitution introduces a semiconducting like behavior of resistivity in Co-riched samples. In Figure 1 we present representative plots of $\rho(T)$ as a function of Co concentration (y) corresponding to $x = 0.30$ *i.e.*, $p \sim 1/8$ for Bi-2212 (Fig. 1a) and Tl-2212 (Fig. 1b), respectively. The variation of T_c as a function of x for different Co concentration (y) is shown in Figure 2a for Bi-2212 and Figure 2b for Tl-2212. Figure 2 clearly depicts that for both Bi- and Tl-2212 systems, at a fixed Co concentration (y), T_c decreases smoothly as the doping level (x) increases. In addition, as y increases T_c decreases at a faster rate with x. When y has reached to its highest value (*e.g.*, $y = 0.08$ for Bi-2212 and $y = 0.06$ for Tl-2212), the decrease of T_c is more rapid even for low values of x. Thus with increasing Co content, the T_c *vs.* x curve shifts smoothly to the lower x region without showing any plateau or local minimum of T_c around $p \sim 1/8$ ($x \sim 0.3$). In contrast at $x = p \sim 1/8$ both LBCO [10] and LNSCO [1] exhibit an anomalous suppression of superconductivity, which is believed to be due to the pinning of dynamical stripes induced by the LTT distortion. In $La_{2-x}Sr_xCuO_4$, similar suppression of superconductivity is enhanced markedly through the partial substitution of Zn for Cu though the system does not exhibit the LTT phase [13]. Akoshima *et al.* [15] also observed a local minimum of the superconducting transition temperature T_c as a function of x at $p \sim 1/8$ (which corresponds to $x \sim 0.30$) in the partially Zn-substituted $Bi_2Sr_2Ca_{1-x}Y_x(Cu_{1-y}Zn_y)_2O_8$ with $y =$ 0.02–0.03 (see Fig. 2 of Ref. [15]). On analogy with the results for LBCO and LNSCO systems mentioned above, Akoshima *et al.* [15] have concluded that the suppression of T_c in Bi-2212 is due to the pinning of dynamical stripes through partial substitution of non-magnetic Zn for Cu. It

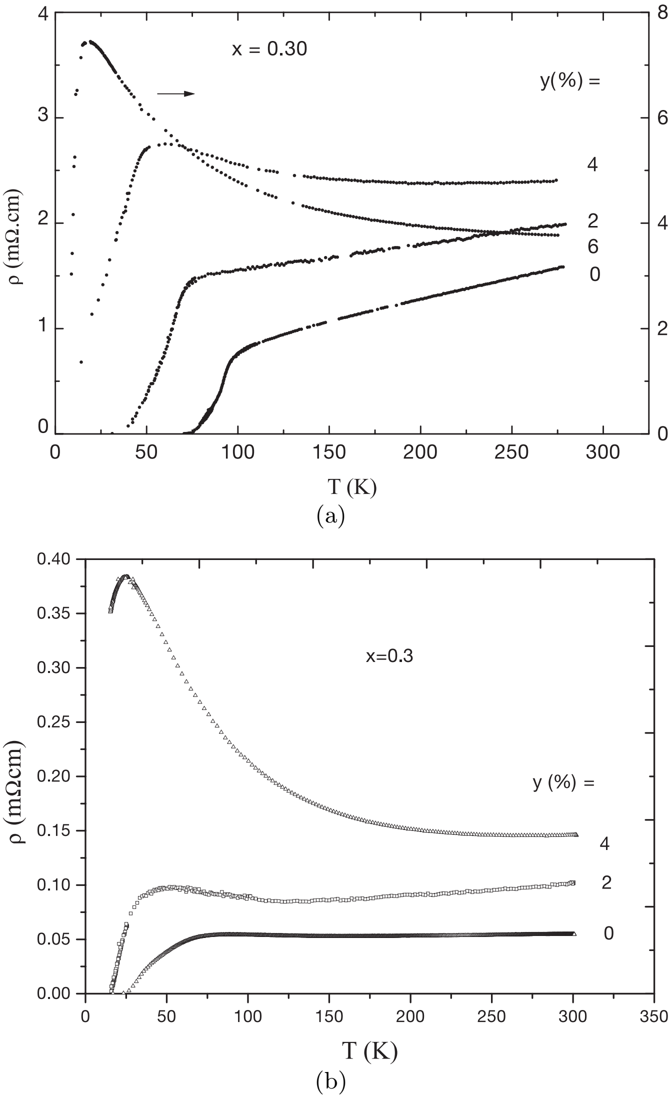
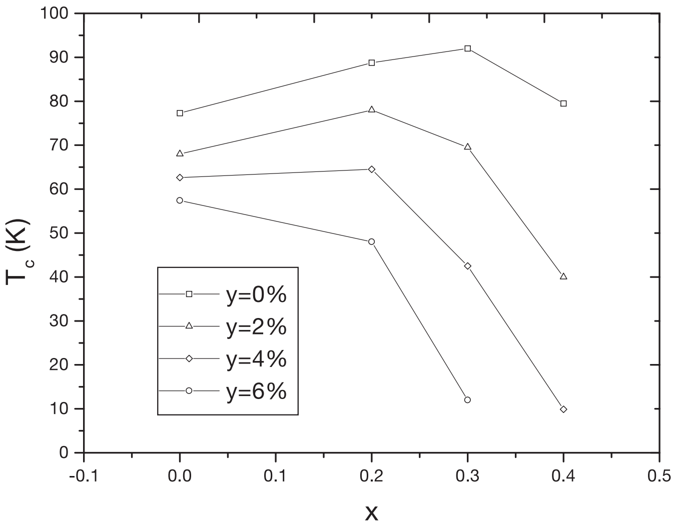


Fig. 1. (a) Temperature dependence of the electrical resistivity (ρ) of $Bi_2Sr_2Ca_{0.7}Y_{0.3}(Cu_{1-y}Co_y)_2O_{8+\delta}$ for various Co concentrations (y(%)=0, 2, 4, 6). (b) $\rho(T)$ dependence of $Tl_2Ba_2Ca_{0.7}Y_{0.3}(Cu_{1-y}Co_y)_2O_{8+\delta}$ for various Co concentrations (y(%)=0, 2, 4).

is to be mentioned here that Akoshima *et al.* [14] change the x value in their samples by 0.0125 but the range of x over which the anomaly in T_c occurs is 0.15 and this is appreciably larger than the x interval in our samples. Thus if there exists any anomaly in T_c suppression in Bi-/Tl-2212 system it should reflect some signatures in our samples with x=0.05 intervals. Absence of any depression in the superconducting T_c in our Co-doped Bi- and Tl-2212 around $p \sim 1/8$ could have the implication that the magnetic impurity substitution, namely, Co for Cu, may not be suitable for pinning of dynamical stripe phases.

We have measured the temperature variation of the thermopower S for $(Bi/Tl)_2(Sr/Ba)_2Ca_{1-x}Y_x$ $\times(Cu_{1-y}Co_y)_2O_{8+\delta}$ as a function of Co-concentration (y(%)=0, 2, 4, 6, 8) for each of fixed yttrium concentration



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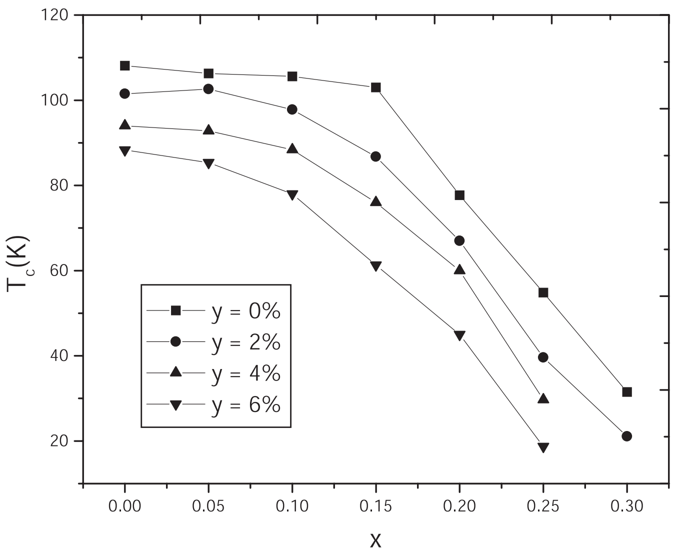

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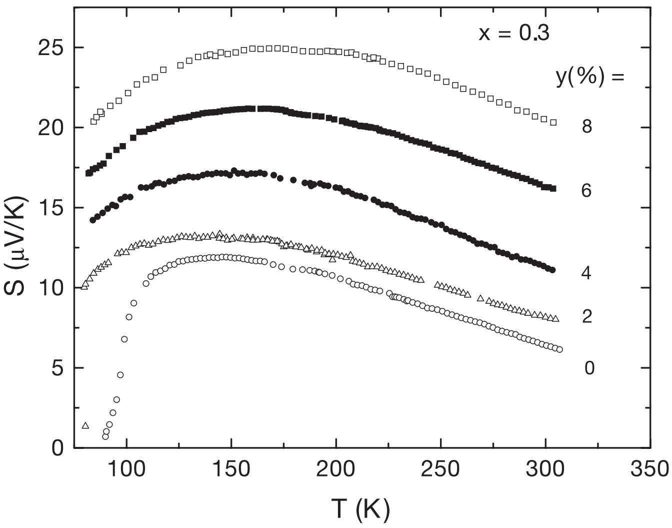
Fig. 2. Suppression of T_c as a function of Y-concentration (x) corresponding to various Co contents (y) (a) for Bi-2212 and (b) for Tl-2212.



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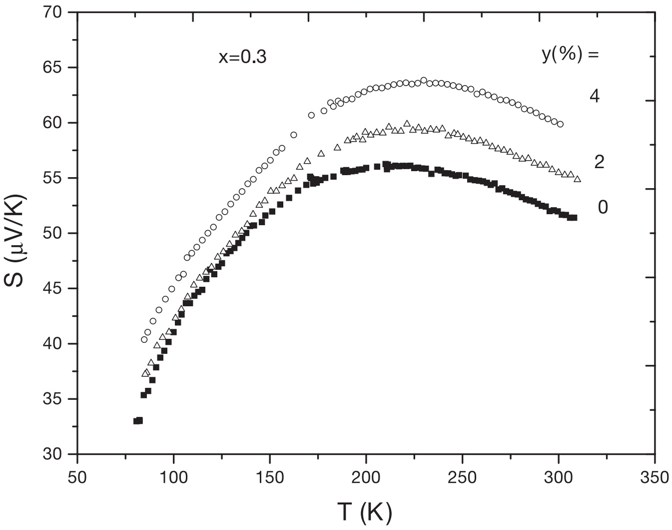


(b)

Fig. 3. (a) $S(T)$ variation of $Bi_2Sr_2Ca_{0.7}Y_{0.3}(Cu_{1-y}Co_y)_2O_{8+\delta}$ samples for various Co concentration (y(%)=0, 2, 4, 6, 8). (b) The behavior of $S(T)$ of $Tl_2Ba_2Ca_{0.7}Y_{0.3}(Cu_{1-y}Co_y)_2O_{8+\delta}$ for various Co concentration (y(%)=0, 2, 4).

(x)=0, 0.1, 0.20, 0.30 and 0.5. For the undoped Bi-2212 (x=0 and y=0) S is found to be negative while it is positive in the case of Tl-2212 (x=0, y=0). Similar type of $S(T)$ behavior is maintained up to the highest doping level of Co. On increasing Y concentration, the broad peak that appears in the $S(T)$ curve shifts towards higher temperatures. Representative plots of $S(T)$ as a function of Co-content (y(%)=0, 2, 4, 6, 8) corresponding to $x = 0.30$ is shown in Figure 3a for Bi-2212 and Figure 3b for Tl-2212, respectively. For both the systems S has been found to increase linearly with decreasing temperature, shows a peak slightly above T_c and then falls sharply to zero at T_c. Moreover, we have found that for a given Y concentration, T_c decreases linearly with increasing S_{300} both for Bi and Tl-2212 systems, respectively. Generally, in oxygen deficient high-T_c systems [18], it is found that T_c varies parabolically with S_{300} and corresponding T_c suppression is attributed to decrease of carrier density. We have measured the Hall coefficient (R_H) of $Bi_2Sr_2Ca_{0.6}Y_{0.4}(Cu_{1-y}Co_y)_2O_{8+\delta}$ and $Tl_2Ba_2Ca_{0.7}Y_{0.3}(Cu_{1-y}Co_y)_2O_{8+\delta}$ samples as function of Co concentration (y(%)=0,2, 4, 6) and observed [17] that for both the samples R_H does not depend on the impurity concentration (y). This observation suggests that in both the systems Co is in the Co^{2+} state in the CuO_2 plane. For Bi-2212 Maeda *et al.* [19] also observed that the hole concentration remains unaltered with impurity doping at the Cu site. Thus the increase of S_{300} with Co doping is not clear at present.

Tallon *et al.* [20] measured TEP of $YBa_2Cu_{3(1-y)}Zn_{3y}O_{7-\delta}$ (Y-123) and $YBa_2Cu_{4(1-y)}Zn_{4y}O_8$ (Y-124) systems, for different carrier concentration with varying Zn content. The broad peak of the $S(T)$ behavior is suggested to be due to the opening of the pseudogap in the normal state excitation spectra. Moreover a strong enhancement of $S(T)$ is observed which is suppressed with Zn-doping. But in our Bi- and Tl-2212 systems, no such enhancement in $S(T)$ occurs whereas for a particular yttrium concentration the temperature (T^*) at which the broad peak appears, shifts towards high temperature side with increasing Co content. The above picture looks different in the case of Zn doping. Generally, in high-T_c cuprates, S decreases with increasing Zn content [21,22,20]. But in $Bi_2Sr_2Ca_{1-x}Y_x(Cu_{1-y}Zn_y)_2O_8$ system Akoshima *et al.* [15] observed that around $p \sim 1/8$ ($x \sim 0.3$) region, S increases with increasing Zn content (y in the range 0.02 to 0.03). The authors explained the increase in S is due to the increase of the anomalous part of $S(T)$ introduced by Sera *et al.* [21]. This anomalous term is due to spin fluctuation or spin correlation. Following Tranquada *et al.* [1] they also concluded that the enhancement in the spin correlation may be due to the pinning of the dynamical stripe phase in some regions with substitution of Zn for Cu around $p \sim 1/8$. Thus the above result implies that the role played by magnetic and non-magnetic impurities in the thermopower of high-T_c cuprates is different.

For both Bi- and Tl-2212 systems, the suppression of T_c due to the in-plane impurity (Co) substitution can be understood [23,17] considering the the Abrikosov-Gorkov (AG) relation [24]

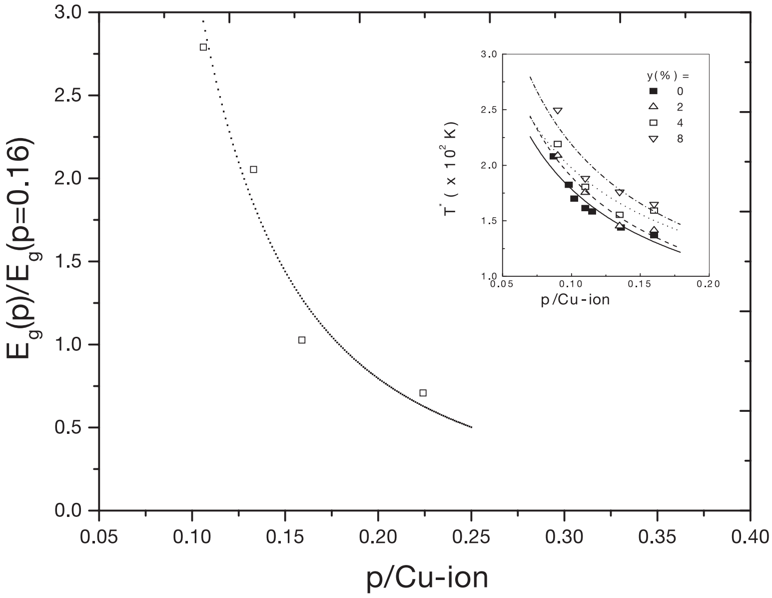
$$-\ln\left(\frac{T_c}{T_{co}}\right) = \psi\left[\frac{1}{2} + \frac{\Gamma}{2\pi k_B T_c}\right] - \psi\left[\frac{1}{2}\right], \qquad (1)$$

for unitary pair breaking valid for d-wave superconductors. In equation (1) $T_{co} = T_c\ (y = 0)$, $\psi[z]$ is the digamma function for argument z and $\Gamma = n_i/\pi N(E_F)$ is the pair-breaking scattering rate with $n_i = \alpha y/abc$ representing the density of impurity scatterers per unit volume, α being the number of CuO_2 planes per unit cell and a, b, c being the lattice parameters. A justification for using the AG relation (1) for the short coherence length cuprate superconductors can be found in [25]. We have fitted the experimentally measured T_c suppression data to the AG relation (1) using $N(E_F)$ as a free parameter and its values were thereby found corresponding to each doping. $N(E_F)$ values thus obtained shows a progressive depletion towards underdoping. This could imply the opening of a gap of growing magnitude in the normal state electronic excitation spectra. Assuming that the depletion in $N(E_F)$ is caused by pseudogap E_g, we calculated a DOS (density of state) within the "DOS-suppression picture" using a phenomenological form of the quasiparticle energy proposed previously [26]

$$E_k = \left[\epsilon_k^2 + E_g\left(\mathbf{k}\right)^2\right]^{1/2} \qquad (2)$$

where ϵ_k represents the tight binding band energy. In the absence of any experimental band structure data for Tl-2212, we considered ϵ_k obtained by a six parameter tight-binding fit to the ARPES data on bilayer bismuth cuprate [27]. Here $E_g(\mathbf{k}) = (E_g/2)|\eta_k|$ with E_g being the pseudogap magnitude and $\eta_k = \cos k_x a - \cos k_y a$ (a is the in-plane lattice constant of a square lattice) is the $d_{x^2-y^2}$ symmetry factor associated with the pseudogap [8]. For both Bi- and Tl-2212, we estimated E_g at a fixed doping level by fitting its values in such a way that the DOS at Fermi energy, calculated within the "DOS-suppression picture" (2) matches $N(E_F)$, found out previously from the data analysis.

For both the systems, values of E_g thus obtained shows a sharp rise towards underdoping and vary as a power of inverse doping. In Figure 4 we have presented the variation of $E_g(p)/E_g(p{=}0.16)$ as a function of p for Bi- and Tl-2212 systems, respectively. Figure 4 depicts that E_g also varies inversely with p *i.e.*, $E_g \sim 1/p^n$ where $n = 2.06$ and 0.41 for Bi- and Tl-2212 systems, respectively. We have estimated p using the reported [18] universal behavior of $S_{300\mathrm{K}}$ with p observed for various high-T_c cuprates. Values of T^* (where T^* is defined as the temperature at which the broad peaks in S appears *i.e.*, where S becomes maximum) have been plotted as a function of p in inset of Figure 4a for Bi- and Figure 4b for Tl-2212 systems. Figure shows that for both the systems T^* grows towards underdoping. An empirical relation $T^* = \frac{c}{p^n}$ yields values of c and n in the range 37–46 and 0.55–0.69 for the Co-doped Tl-2212. Similarly for the Co-doped Bi-2212 we obtained $c = 37-51$ and $n = 0.58-0.70$. Comparing these values with that of $HgBa_2CuO_{4+\delta}$ ($c = 60$ and $n = 0.54$) [17], one can state that in general T^* varies as $\frac{1}{p^n}$, when n lies in the range 0.54–0.70. So both T^* and E_g grow with decreasing carrier concentration as $\frac{1}{p^n}$ with different values of n. Such a similarity between T^* and E_g confirms the idea that T^* is an energy scale related to E_g. Moreover, for each Y concentration, substitution of Co at the Cu-site increases T^*. This increase in T^* is not due to any carrier reduction since the Co-substitution does not change the carrier concentration of the system. So one could interpret this result within a preformed pair model introduced by Emery *et al.* [9]. The authors concluded that at T^*, antiferromagnetic correlations starts to build up in the spin domain of the stripes and pseudogap of finite magnitude appears. Whereas for particular doping $p \sim 1/8$, at T_c Josephson coupling between metallic stripes which yields global phase coherence, is being disturbed either by structural distortion [1] or by the introduction of impurities [15] resulting a suppression of T_c. Thus at $p \sim 1/8$ the anomalous suppression of superconductivity is due to the pinning of dynamical fluctuating charge stripes. Whereas at doping levels other than $p \sim 1/8$, the suppression of superconductivity due to non-magnetic Zn impurity follows the usual unitary pair breaking effect within the AG formalism. Now in case of Co impurity doped Bi- and Tl-2212 systems, we have found [17] that for all doping levels the suppression of T_c follows the unitary pair breaking formalism showing no anomaly at $p \sim 1/8$. However the pseudogap increases with the decrease of carrier concentrations. This suggests that probably magnetic impurity Co does not have any role in pinning the dynamical



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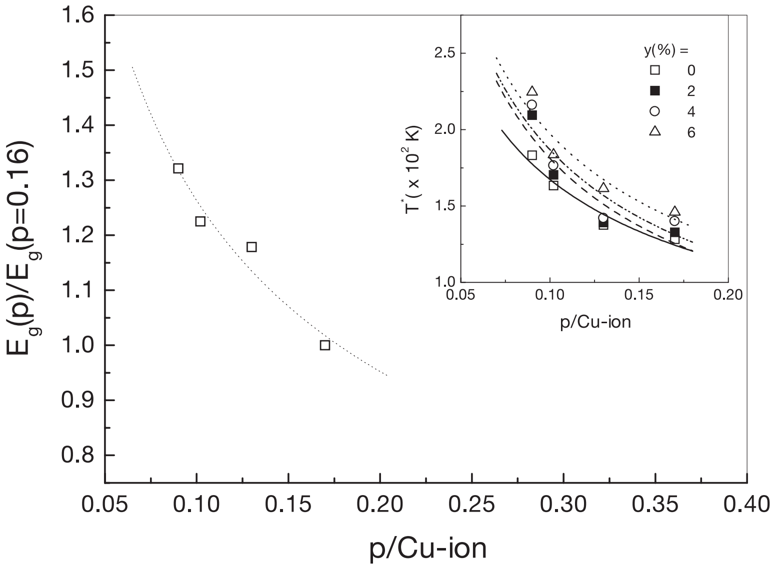

(b)

Fig. 4. Variation of $E_g(p)/E_g(p{=}0.16)$ as a function of hole concentration p (a) for Bi-2212 and (b) for Tl-2212. Insets. Symbols represent values of T^*, as estimated by thermoelectric power measurement, as a function of p for various Co content (y). p values of cobalt free samples are used here, as the carrier concentration remains unaffected by Co substitution. Solid and dashed lines are power law fit to the data.

fluctuating charge stripes at $p \sim 1/8$. It is to be mentioned here that for each doping, the pseudogap opening temperature T^* increases with increasing Co concentration in our samples, and this suggests that the magnetic ion Co might have an effect to enhance the temperature T^* at which the antiferromagnetic correlations build up. In contrast, in case of Zn-doped Bi-2212 system [15] it is observed that at $p \sim 1/8$ where pinning of dynamical charge stripe occurs there is no appreciable change in T^* with Zn concentration. Similar results have also been observed in the transport data reported by Kakinuma *et al.* [28] in the overdoped region ($p \sim 0.22$) of Zn-doped La-214 system. Thus it seems that when pinning of stripe correlation is present T^* remains unchanged whereas absence of pinning leads to a change in T^*. To obtain a clear view regarding this issue, further experimental data on various high-T_c cuprate families are needed.

4 Conclusions

Our experimental results clearly demonstrate the absence of any anomalous suppression of superconductivity for Co-doped Bi- and Tl-2212 systems at $p \sim 1/8$ suggesting magnetic impurity Co is ineffective in pinning dynamical stripes. For all doping levels, the suppression of superconductivity due to in-plane Co impurity follows the usual unitary pair breaking effect within the AG formalism. We observed that magnetic and non-magnetic impurities affect thermopower (S) differently where once again for non-magnetic Zn substituted Bi-2212 an anomalous enhancement of S around $p \sim 1/8$ was reported [15] but for magnetic Co substituted Bi- and Tl-2212 samples no such anomalous enhancement of TEP have been detected by us. Analysis of the T_c suppression data reveals analogous p-dependence of both T^* and E_g, suggesting that T^* is an energy scale related to E_g. Moreover, for a particular Y concentration, substitution of Co at the Cu-site of Bi- and Tl-2212 systems increases T^*. Comparing our present results with existing data in literature, it seems that when pinning of stripe correlation is present, T^* remains unchanged whereas absence of pinning leads to a change in T^* and E_g.

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