Electron-phonon scattering and thermoelectric power of high-temperature superconductors

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We analyze the recent experimental data on the normal-state thermoelectric power of high-temperature superconducting cuprates (HTS). We demonstrate that both temperature dependence and sign of the Seebeck coefficient (S) of different HTS families may find a consistent interpretation in the framework of model based on phonon renormalization of S in the presence of subsitutional disorder.

As HTS become superconducting under doping and substitutional disorder is very important, the usual phonon drag does not contribute significally to transport properties. At the same time, the electron-phonon interaction in these superconductors seems to be rather strong, and, as it was originally proposed in Ref. [1], in this situation the Seebeck coeffient is governed by the processes of electron-phonon-impurity interference in the metallic state.

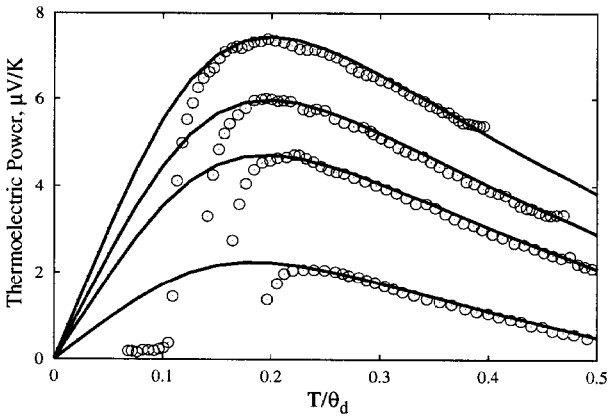
The main equation for Seebeck coefficient in this model reads:

$$S(T) = S_d F(T, \Delta Z, \lambda), \qquad (1)$$

where S_d is the diffusion thermopower, ΔZ is the effective charge of the impurity atom with respect to the host atom in th lattice and λ is the electron-phonon interaction constant. The model predicts that for positive ΔZ, the thermopower is negative and decreases monotonically. For negative ΔZ diffusion and interference contributions to thermopower are of different signs, what leads to a more complex temperature dependence: the thermopower increases at low temperatures, has a maximum and then decreases, changing a sign. The magnitude of the maximum and the temperature at which the thermopower changes the sign are determined by the values of λ and ΔZ.

The comparison of theoretical results with recent experimental data on $Bi(Tl)_2Sr(Ba)_2CaCu_2O_{8+\delta}$, $YBa_2Cu_3O_{7-x}$, $La_{2-x}Sr_xCuO_y$, $HgBa_2CuO_{4+\delta}$ [2, 3, 4, 5, 6] with different substitutions demonstrates the good quantitative agreement with the effective charge of imputiry atom, ΔZ, being the only adjustable parameter which changes with variation of alloying element content. Example of such analysis is presented in the Figure. The Figure shows the experimentally measured thermopower from Ref. [2] and calculated from Eq. (1) as a function of T/Θ_d, where Θ_d is the Debye temperature.

The obtained results shed ligth on the mechanisms of transport phenomena in high-temperature superconducting cuprates.



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