EXCESS CONDUCTIVITY IN MAGNETIC SUPERCONDUCTOR $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$

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Temperature dependencies of the excess conductivity σ′(T) and the possible pseudogap (PG), Δ*(T), were first studied in the magnetic superconductor $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$. It was shown that σ′(T) near Tc well described by the 3D Aslamazov–Larkin equation, demonstrating a 3D-2D crossover with increasing temperature. Using the crossover temperature T_0, the coherence length was measured along the c axis, ξc(0) = (2.67 ± 0.02) Å, which correlates with the literature data for strong coupling HTSCs. The pronounced effect of magnetism is found in the unusual dependence of ln σ′ on ln ε with a maximum at TFM~19 K, which is associated with the system transition to the ferromagnetic state with decreasing temperature [1].

The dependence Δ*(T) revealed a number of peculiarities typical of superconductors admit the possibility of the superconductivity - magnetism interplay. This is a high narrow maximum at T=154 K, typical of magnetic superconductors, followed by a minimum at $T_{min} \approx 95$ K. In FeSe compounds, a similar minimum corresponds to the structural phase transition from the tetra - to the ortho - phase at $T_s \sim 90$ K, [2] indicating the possibility of a similar structural transition in $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$. Below T_{min}, Δ*(T) again increases, demonstrating a broad maximum at $T_{pair} \approx 36$ K, followed by a minimum at $T_{01} = 9.4$ K. This form of Δ*(T) is similar to the temperature dependence of the pseudogap in cuprates, which indicates the possibility of implementing the PG state in $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$ at $T < T_{min}$, as is the case in FeSe at $T < T_s$. It was shown that, below T_{01}, Δ*(T) in $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$ is the same as in all HTSCs with a maximum at $T \sim T_0$ and a minimum at $T = T_G$, which indicates a common behavior of both magnetic and nonmagnetic superconductors in the region of superconducting fluctuations near T_c.

Meanwhile, the analysis of Δ*(T) in $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$ reveals a number of peculiarities. The first is an unexpectedly large value of $2\Delta^*(T_c)/k_BT_c = 7.0 \pm 0.1$. It is remarkable, however, that the same value of $2\Delta(T_c)/k_BT_c \sim 7.2$ is obtained from the Andreev spectral analysis of Au – $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$ contacts measured in a zero magnetic field at T = 1.6 K. This result indicates a more complicated mechanism of the SC state implementation in such superconductors as compared to cuprates, especially taking into account the large intrinsic magnetic moment of Dy ions. Secondly, it is the high density of local pairs (n↑n↓) obtained by comparing the experimental values of Δ*/Δ*max with the Peters–Bauer theory. The measured (n↑n↓) (T_G) ~ 0.35 appears 1.17 times greater than (n↑n↓) (TG) obtained for optimally doped YBaCuO single crystals. This result can be explained by the fact that strong intrinsic magnetism of Dy can contribute to the increasing number of FCPs. In this regard, the role of magnetism in the SC pairing mechanism in $Dy_{0.6}Y_{0.4}Rh_{3.85}Ru_{0.15}B_4$is assumed to be very important. Furthermore, as discussed in the Introduction, the possibility of unconventional, e.g. triplet, pairing in superconductors whose strong magnetism coexists with superconductivity can also lead to the increase in (n↑n↓).

[1] A. L. Solovjov, L. V. Omelchenko, V. B. Stepanov, R. V. Vovk, H.-U. Habermeier, H. Lochmajer, P. Przyslupski, and K. Rogacki, Phys. Rev. B 94, 224505 (2016).
[2] A. L. Solovjov, L. V. Omelchenko, A. V. Terekhov, K. Rogacki, R. V. Vovk, E. P. Khlybov, and A. Chroneos, Mater. Res. Express 3, 076001 (2016).