μSR study of slightly pressurized organic superconductor κ-(ET)$_4$Hg$_{2.89}$Br$_8$

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Organic superconductors are single-band system, similar to high-critical-temperature (high-T_c) cuprates superconductors. A distinct difference can be observed in their lattice, *i.e.*, squared cuprates and triangular organics. In the case of squared cuprates, the Mott insulating state has an antiferromagnetic (AF) ground state in the 1/2-filled band case, while the anisotropic triangular ($t = t'$) organics also exhibit AF state. Here, t and t' are the nearest and next nearest transfer integral between sites, respectively. For a triangular lattice Mott insulator, owing to geometrical frustration ($t \sim t'$), the system cannot be magnetically ordered down to the mili-Kelvin order, *i.e.*, a spin liquid state. Owing to hole doping, it should also become metallic and superconducting (SC). However, the realistic candidate material was limited until the discovery of hole-doped organic superconductor κ-(ET)$_4$Hg$_{2.89}$Br$_8$ (κ-HgBr). In metallic state, resistivity exhibits the linear-temperature dependence, $\rho \propto T$, which is not a Fermi-liquid behavior. The susceptibility from 300 to 2 K is nearly perfectly scaled to that of a non-doped spin liquid organic insulator κ-(ET)$_2$Cu(CN)$_3$.[1)] By pressure, this non-Fermi-liquid behavior turns into conventional Fermi-liquid behavior at the $P_c = 0.5$ GPa, where T_c is also the highest (~7 K) in the pressure-temperature phase diagram.[2)] The non-Fermi-liquid behavior at low-pressure region is similar to the metallic state of high-T_c cuprates or low-pressure range of multi-band heavy fermion CeCoIn$_5$, and it is referred to as a strange metallic region.[1,2)] Because κ-HgBr exhibits similarities with other strongly correlated electron systems, it is interesting to determine the type of Cooper pairing that occurs in κ-HgBr.

We aim to determine the pairing symmetry in κ-HgBr by μSR. We performed μSR measurement down to 0.3 K on the ARGUS spectrometer at the RIKEN-RAL muon facility with HELIOX cryostat and fly-path setup. We developed a technique for applying a decent pressure on κ-HgBr crystals because at ambient pressure, the SC state of κ-HgBr is not bulky due to the inhomogeneous state.[3)] Approximately 130 mg crystals were carefully aligned and stuck together using diluted polymer glue. This strategy was effective for applying enough pressure on the sample as we conducted magnetization measurement using SQUID with a similar sample setup. Figures 1(a) and (b) show the result of SQUID measurement. The demagnetization effect due to sample shape was treated for all analyses. The temperature dependence of susceptibility determined $T_c = 4.6(2)$ K whereas the field dependence of magnetization (MH-curve) was measured at several temperatures; the SC volume fractions were estimated at each temperature. Consequently, the estimated SC volume fraction at 2 K was found to be approximately 90%, as shown in Fig. 1(a). Comparing this with the referred result obtained from ac-susceptibility measurement,[3)] a pressure of at least 0.3 GPa was applied to the sample. This expectation was confirmed by the estimation of the lower-critical field, H_{c1}, by SQUID, resulting in the absolute value of H_{c1} at 0 K, *i.e.*, 27 Oe. The result is consistent with the measurement performed using zero-filed (ZF) μSR at 0.3 K. H_{c1} was estimated as follows. The sample was ZF-cooled to 0.3 K. Transverse-field (TF) was applied for approximately 10 min to destroy the shielding field. After cutting off the TF, the ZF-relaxation rate was measured. At TF = 25 Oe, the relaxation rate started to increase. Therefore, we concluded that the sample was in bulk condition and a slight pressure, $P \gtrsim 0.3$ GPa, was applied. Using these results, we measured the ZF-μSR relaxation rate in κ-HgBr down to 0.3 K. The temperature independence of ZF-relaxation rate was observed, indicating that spontaneous internal fields do not appear in the superconducting state. This result is consistent with that in Ref. 4), in which the measurement was performed down to 1.5 K and at ambient pressure. Thus, the possibility of spin triplet and $d+id$-wave symmetry in κ-HgBr due to the expected triangular lattice in κ-HgBr becomes very low. The temperature dependence of London penetration depth measurement using TF-μSR is necessary for determining the SC gap symmetry, which will be discussed in the future work.

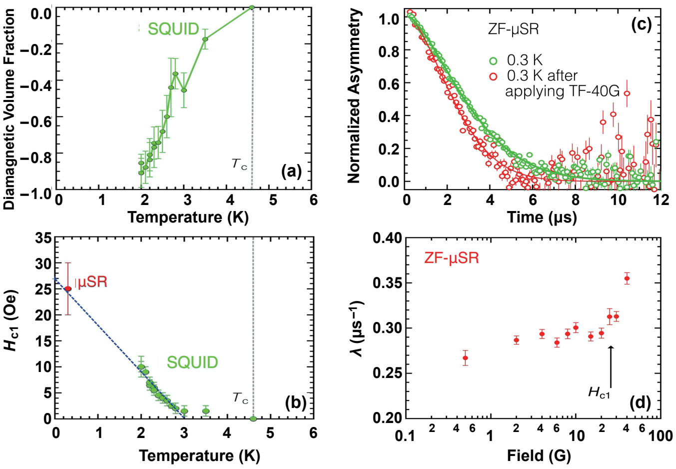

Fig. 1. (a) Temperature dependence of SC volume fraction measured by SQUID. (b) Temperature dependence of H_{c1} measured by SQUID down to 2 K compared with μSR measurement. (c) ZF-μSR time spectra before and after applying TF of 40 G. The solid lines are the exponential decay fitting lines. (d) Relaxation rate of ZF-μSR time spectra after applying several TF, from 2 to 40 G.

References

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