# $\mu$SR study of slightly pressurized organic superconductor $\kappa$-(ET)$_4$Hg$_{2.89}$Br$_8$, II

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The hole-doped organic superconductor $\kappa$-(ET)$_4$Hg$_{2.89}$Br$_8$, ($\kappa$-HgBr), where bis (ethylenedithio) tetrathiafulvalene is abbreviated as ET, is a key to bridge the knowledge gap between half-filled organics and doped cuprate systems. Both $\kappa$-HgBr and cuprate superconductors exhibit a peculiar metallic state at high temperature and pressure where their resistivity exhibits a linear temperature dependence, $\rho \propto T$; this is non-Fermi-liquid (FL) behavior. In $\kappa$-HgBr, this non-FL region gradually changes to the FL state by owing to pressure,[1,2)] similar to the change in metallic state from optimally doped to overdoped cuprates. A heat capacity study suggested that the enhanced antiferromagnetic fluctuations toward low-temperature cause the non-FL behavior of $\kappa$-HgBr.[3)] This evidence may locate the superconducting $\kappa$-HgBr state near the quantum critical point in between the FL and localized states; incoherent conductivity was observed in its non-FL state.[1,2)] In this region, low superfluid density was proposed by the macroscopic measurement.[4)]

Our zero-field $\mu^+$SR experiment indicated that the relaxation rate from a temperature of approximately 10 K down to 0.3 K is temperature-independent.[5)] This is consistent with a superconducting state that preserves time-reversal symmetry. Furthermore, we measured the transverse-field (TF) $\mu^+$SR on ARGUS at the RIKEN-RAL/ISIS muon facility. There was almost no change in the 10 mT of transverse-field-$\mu^+$SR time spectra at 0.3 K and above superconducting (SC) temperature $T_c = 4.6(3)$ K, indicating that the London penetration depth $\lambda_{\mathrm{bc}}$, is longer than the order of micrometer, that is, low superfluid density. To confirm this result, measurements using ano-ther geometric setup are necessary to minimize the sample misalignment and determine the absolute value of $\lambda_{\mathrm{bc}}$.

Further, we performed the $\mu^+$SR experiment at the M15 beamline at TRIUMF. The $\mu^+$ spin rotator was used so that the sample setup illustrated in Fig. 1 could be arranged. In all, 100 mg of the sample was used. The plate-like crystals we aligned so that the magnetic field is perpendicular to the conducting $bc$-plane. Using this setup on the M15 beamline, the crystal misalignment can be minimized, and larger TF 10 times higher than $H_{c1} = 25(5)$ Oe, which lies in the vortex solid regime[6)] can be applied.

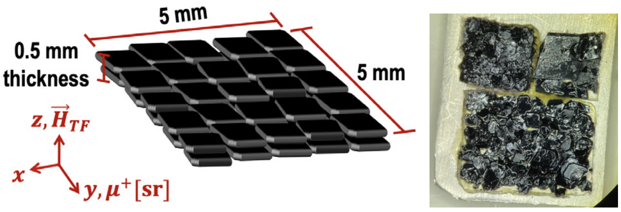

Fig. 1. Sample setup in the perpendicular mode $\mu^+$[sr] stand for the muon beam with a spin rotator. In the perpendicular mode, the TF is applied perpendicular to the plate-like conducting plane. The right panel displays a photograph of the sample setup on top of Ag plate of the cryostat sample holder.

Furthermore, the bulk SC state must be confirmed. Therefore, we first measure the TF-$\mu^+$SR upon zero-field cooling and compare the spectra above and below $T_c = 4.6(3)$ K. Figure 2 depicts the TF-$\mu^+$SR time spectra measured at 0.3 and 10 K under 50 mT, respectively. The spectrum measured at 0.3 K was clearly damped compared to that at 10 K owing to the bulk SC state. The spectra were analyzed by applying the Gaussian-type-damped cosine equation (represented by lines in Fig. 2) as,

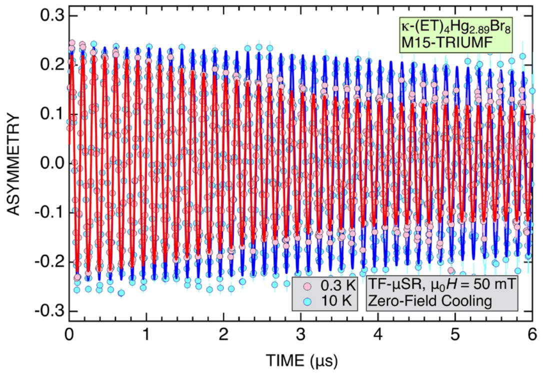

Fig. 2. TF-$\mu^+$SR time spectra upon zero-field cooling in $\kappa$-HgBr. The pink and cyan circles represent TF-$\mu^+$SR time spectra measured at 0.3 and 10 K, respectively. The red and blue solid lines represent the fitting lines for the 0.3 and 10 K data, respectively.

$$A(t) = A_1 \exp[-\sigma^2 t^2] \cos(\gamma_\mu B_1 t + \phi) + A_2 \cos(\gamma_\mu B_2 t + \phi), \quad (1)$$

where the first and second terms on the right-hand side

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describe muon components from the sample and background, respectively. The damping rate $\sigma$ at 0.3 K was determined as 0.53 $\mu\mathrm{s}^{-1}$. The next step is to measure the temperature dependence of the London penetration depth in the vortex state under the field cooling condition.

References

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