Summary of thesis: Superconductivity in Sr_2RuO_4 micro-ring

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A number of experiments and theories support that the superconductivity of Sr_2RuO_4 is in a spin-triplet equal-spin pairing with chiral *p*-wave state while some experiments cannot be explained within this scenario [1]. In a spin-triplet equal-spin pairing state, due to the spin degree of freedom of the Cooper pair, the fluxoid state accompanying a half of the flux quantum can be realized. This is called the half-quantum fluxoid (HQF). Although the observation of HQF in Sr_2RuO_4 micro-rings using magnetic torque has been reported [2], detection with other experimental technique is still desired. For a chiral state, the time-reversal symmetry is broken in the orbital section of the wave function, and the ground states are two-fold degenerate between states with clockwise and anticlockwise orbital angular momenta. With an analogy to ferromagnets, such chiral superconductors are expected to form domains of the degenerate ground states. Therefore, detection of the HQF and chiral domains strongly progress the understanding of spin and orbital information of the superconductivity in Sr_2RuO_4.

To achieve this goal, we micro-structured Sr_2RuO_4 single crystals using the focused ion beam technique and measured their transport properties down to 300 mK under magnetic fields applied using a tri-axial vector magnet. We observed magnetoresistance oscillations that is in good agreement with the Little-Parks oscillations for the conventional fluxoid state. To our knowledge, this is the first report of the Little-Parks oscillations using any bulk single crystals. We further investigated their transport properties with additional in-plane magnetic fields and observed splitting of magnetoresistance oscillation peaks. This suggest the unconventional fluxoid state, namely the HQF, is stabilized by the in-plane magnetic field [3].

In contrast, another Sr_2RuO_4 micro-ring shows magnetoresistance oscillations with unexpectedly large amplitude. Such behavior was previously reported in the same system [4, 5]. Hence, to search for its origin, we further investigated their current-voltage characteristics. Then, we found that the critical current also oscillates with magnetic field with the same period as the magnetoresistance oscillations. Such critical current

oscillations is known to occur in the superconducting quantum interference device (SQUID). A SQUID requires a pair of Josephson junctions in the ring. However, structural junction structures are not visible in scanning electron microscopy. In addition, other transport properties do not show behavior of structural junction structures. Therefore, the formation of Josephson junctions should originate from its superconducting state and most naturally attributable to domain boundaries separating different ground states [6].

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