PC3-4

Thermoelectric study of the anomalous metallic state in amorphous superconducting thin films

*Koichiro Ienaga[1], Taiko Hayashi[1], Yutaka Tamoto[1], Shin-ichi Kaneko[1], Satoshi Okuma[1]

Department of Physics, Tokyo Institute of Technology[1]

The superconductor-insulator transition in a two-dimensional electron system is known as a quantum phase transition [1]. This transition is driven by magnetic field or disorder and has been studied in disordered superconducting thin films [2]. On the other hand, an unusual metallic phase intervening between the superconducting phase and the insulating phase has been reported in various thin-film systems including amorphous, granular, and highly crystalline films [3]. This state is called an anomalous metal and shows characteristic features reminiscent of superconductivity, e.g., residual resistivity much smaller than the normal resistivity just above the transition temperature, and giant positive magnetoresistance. Many theoretical models for the metallic state have been constructed assuming the existence of Cooper pairs and superconducting vortices [3]. However, whether the vortices are really present in the metallic phase has not been completely verified from resistivity measurements.

In this study, we performed a Nernst measurement using a dilution refrigerator. We studied an amorphous Mo_xGe_{1-x} thin film with a thickness of 12 nm prepared by rf sputtering. The field-induced superconductor-metal-insulator transition was observed in the zero-temperature limit from the magnetoresistance measurement. We measured Nernst signals by sweeping the field at high temperatures just below the transition temperature, and found vortex Nernst signals in wide field ranges corresponding to the thermal vortex liquid phase [4]. With decreasing temperature, the field range where the vortex signals are observable decreases but remains finite toward zero temperature, indicating the existence of a quantum vortex liquid state. Moreover, the observed quantum vortex liquid state is located within the anomalous metallic phase defined by the magnetoresistance. These results strongly suggest that the metallic ground state is induced by mobile vortices due to quantum fluctuations.

[1] M. P. A. Fisher, G. Grinstein, and S. M. Girvin, Phys. Rev. Lett. **64**, 587 (1990): M. P. A. Fisher, Phys. Rev. Lett. **65**, 923 (1990).
[2] A. M. Goldman and N. Marcovi´c, Physics Today **51**, 39 (1998).
[3] A. Kapitulnik, S. A. Kivelson, and B. Spivak, Rev. Mod. Phys. **91**, 011002 (2019).
[4] K. Behnia and H. Aubin, Rep. Prog. Phys. **79,** 046502 (2016).

Keywords: Nernst effect, two-dimensional superconductor, anomalous metal, quantum vortex liquid