Microscopic Study of Quantum Phase Transition on Atomic-Layer Superconductors

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In two-dimensional (2D) superconductors, superconductor-insulator transition (SIT) is induced by magnetic fields through the breakdown of phase coherence of the superconducting order parameter at T = 0 [1]. The magnetic-field-driven SIT exhibits various behaviors depending on the degree of disorder because of sensitivity to disorder such as impurities or defects. Recent studies on weakly disordered films such as highly crystalline 2D superconductors, an anomalous metallic state is reported near the transition [2, 3]. However, because of the lack of microscopic investigation, the details of peculiar quantum phases such as the anomalous metallic state are not well investigated.

In this presentation, we will report on the magnetic-field- and disorder-driven quantum phase transition studied by both surface electron transport measurements and scanning tunneling microscopy (STM) on a striped-incommensurate phase, one of Pb atomic-layer superconducting films formed on the Si (111) substrates. In this 2D system, step density controlled by miscut angle of the substrates corresponds to the degree of disorder [4]. We found that electron transport measurements show the anomalous metallic state observed as a flat tail near T = 0 in the resistance-temperature curve, which has been thought due to quantum creep of vortices. On the other hand, STM exhibited individual stable vortices in the anomalous metal phase. Compared both results, the anomalous metallic state seems to be driven by infinitesimal current. We also detected a pseudogap by STM in insulating phase ($dR/dT < 0$ where R is resistivity) of the sample with higher step density, which implies the localization of Cooper pair due to quantum phase fluctuation under the high disorder.

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