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BCS-BEC CROSSOVER IN A 2D SUPERCONDUCTOR

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Gate-induced superconductivity using field effect transistor devices has a strong advantage over the conventional bulk superconductivity owing to its controllability. To realize the gate-induced superconductivity, researchers have nowadays established two methods; one is to use gate dielectrics which enables high density carrier accumulation, which is sufficient to achieve superconductivity in semiconductors. The other is to use channel materials with huge lattice parameters, which enable the effective high band-filling with a rather low carrier density. The former was realized by ionic gating first on $SrTiO_3$ followed by many 2D materials [1]. The latter was achieved in 2018 [2] on magic angle twisted bilayer graphene.

In this presentation, we focus on the ion-gated superconductors and report our challenge to approach the Bose-Einstein condensation (BEC) region, where preformed pairs are formed at high temperatures and condense at lower temperature. BEC in superconductivity is believed to be realized in the low carrier density limit. However, most of superconductivity is realized in high carrier densities and classified as the Bardeen-Cooper-Schrieffer (BCS) condensation, in which the condensation and paring occurs simultaneously. The crossover from BCS to BEC has been a long-time challenge in materials science of superconductors.

By controlling the gating protocol in Li intercalated layered compound, Li_xZrNCl, we have succeeded in controlling x from 0.28 to 0.004, and established the phase diagram by simultaneous experiments of resistivity and tunneling spectra under the ionic gating. T_c exhibits dome-like behavior, and more importantly, a wide pseudogap phase was discovered in the low doping regime. Furthermore, in the low carrier density limit, T_c scales as $T_c/T_F = 0.12$, where T_F is the Fermi temperature, which shows fair agreement with the theoretical prediction in the 2D limit of BEC [3].

References

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