Gate-controlled two-dimensional superconductors approaching BCS-BEC crossover

Gate-control of two-dimensional (2D) superconductivity via electric field has been attracting enormous interests as represented by SrTiO$_3$, transition metal dichalcogenides, and magic-angle twisted bilayer graphene [1]. In this presentation, we demonstrate that the gate-control of electrochemical intercalation processes (Fig. 1a) offers a new opportunity to study exotic phenomena in 2D superconductors [2]. We achieved the superconductivity in the low carrier-density limit of layered nitrides (ZrNCl and HfNCl) by the intercalation of lithium. The superconducting critical temperature $T_c$ is enhanced up to 25 K as the system approaches the non-doped semiconducting phase (Fig. 1b). Such behavior is distinct from other superconductors with dome-shaped phase diagrams. The strongly coupled, low carrier density superconductors are promising candidates to observe a crossover from the Bardeen-Cooper-Schrieffer (BCS) limit to the Bose-Einstein condensation (BEC) limit, which has been studied in ultra-cold Fermi gas system [3]. We searched its features by combining transport measurements and tunneling spectroscopies, and the systematic development of the pseudogap phase was detected. This work sheds new light on the study of BCS-BEC crossover in condensed matter systems, and the exploration of novel 2D superconductors.

References

Figure 1: (a) Schematic of the device for intercalation. Lithium ions are intercalated to the crystal driven by a gate voltage $V_G$. (b) Phase diagram of layered nitrides. Red circles and blue diamonds indicate $T_c$ of HfNCl and ZrNCl, respectively. $T_c$ shows the highest value in the vicinity of the semiconducting phase ($x = 0$).