



Probing mixed spin singlet-triplet Cooper pairs in 2D NbSe₂ under high magnetic fields

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Introduction

Superconductivity in two-dimensional (2D) materials has recently received much interest due to the unusually large in-plane upper critical field (H_{c2}). In atomically thin superconductors, the orbital limit is quenched and H_{c2} is paramagnetic-limited. The exceptionally large H_{c2} in 2D-NbSe₂ originates from the broken inversion symmetry and strong spin-orbit interaction (SOI). Such non-centrosymmetric superconductors are particularly interesting for the predicted mixed-parity Cooper pairs and for the realization of 2D topological superconductivity.

Experimental

We have prepared 2D NbSe₂ tunnel devices with two different tunneling barriers, AlO_x and few layer MoS₂. Depending on the type of device, we have transferred the mechanically exfoliated 2-3 layer NbSe₂ upon pre-patterned electrodes so that the final stacking would be Pt/AlO_x/NbSe₂ or Pt/NbSe₂/MoS₂/Au. Compared to our previous studies, we were able to achieve improved tunneling devices that provided cleaner spectral information under high in-plane magnetic field. The differential conductance of the tunneling device was measured under in-plane magnetic field up to 45 T at low temperature down to 300 mK at Cell 15 at the NHMFL.

Results and Discussion

Figure 1(a) and (b) shows the normalized differential conductance of NbSe₂/AlO_x/Pt and NbSe₂/MoS₂/Au, respectively, at 300 mK under in-plane magnetic field. The acquired superconducting gap ($\Delta(H)$) through fitting is summarized in Figure 1(c). In both type of devices, we observe a continuous decrease of $\Delta(H)$ under in-plane magnetic field, an indication of a second-order phase transition. This is in contrast to the well-known first-order transition in paramagnetic-limited BCS superconductors. The strong SOI in 2D-NbSe₂ results in an upper critical field limited by van Vleck paramagnetism, and the spin susceptibility remains largely unchanged from that in the normal state, unlike the case in conventional BCS superconductors. This gives rise to a second order paramagnetic-limited phase transition. The large spin susceptibility thus provides evidence of mixed-parity Cooper pairs in 2D-NbSe₂.

Conclusions

We have observed a paramagnetic-limited second-order phase transition under high in-plane magnetic field. This is a unique feature that strongly suggests the existence of mixed spin singlet-triplet Cooper pairs in 2D NbSe₂. This work will pave the way to study unconventional superconductivity, such as 2D topological superconductivity.

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References

[1] Sohn, E., *et al.*, submitted (2017).

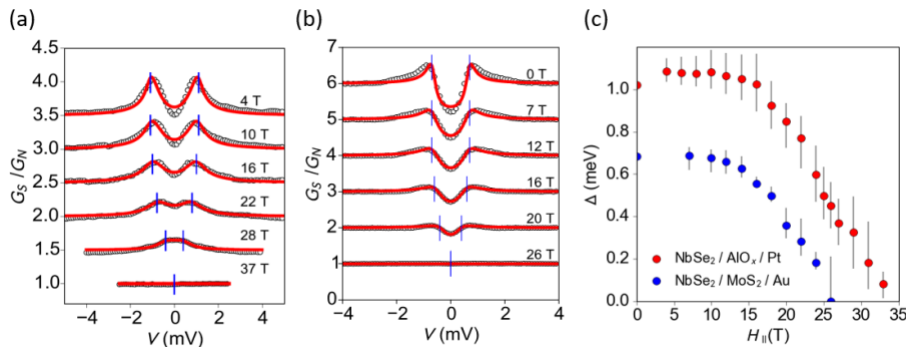


Fig.1 Normalized differential conductance of (a) NbSe₂/AlO_x/Pt and (b) NbSe₂/MoS₂/Au tunnel junction under in-plane magnetic field at 300 mK. The superconducting gap from the BTK fit (red solid line) is summarized in (c). A continuous second-order transition is seen in both devices.