首届致远学术节
学生科研成果展示

Tunneling effect in van der Waals Josephson junction

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Summary

We show that by exfoliating a layered dichalcogenide ($NbSe_2$) superconductor, the van der Waals (vdW) contact between the cleaved surfaces can instead be used to construct a Josephson junction. This artificially created vdW interface provides sufficient decoupling of the wavefunctions of the two $NbSe_2$ crystals.

Flake transfer and device fabrication

Junction fabrication process

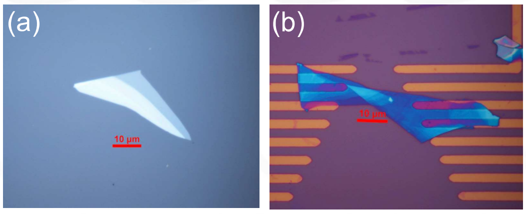

Figure 1 | $NbSe_2$/$NbSe_2$ vdW Josephson junction. (**a**) Layered 2H-$NbSe_2$ flake is exfoliated onto PDMS substrate. (**b**) an optical photograph of a vdW junction composed of top and bottom $NbSe_2$ flakes. The Au/Ti electrodes (with 9nm of Au and 2nm of Ti) were fabricated on silicon substrate first, and then two flakes were dry-transferred to desired positions.

- Fabricate the Au/Ti electrodes (with 9nm of Au and 2nm of Ti) on silicon substrates by photolithography.
- Exfoliate $NbSe_2$ thin flakes onto PDMS substrates.
- Dry-transfer a $NbSe_2$ thin flake from PDMS to silicon substrate by micromanipulator platform, and the flake partially contacts with electrodes.
- Transfer another $NbSe_2$ flake onto silicon substrate, with one end partially overlapping the first flake, another end contacting electrodes.

PPMS transport measurements

Josephson effect in the vdW junction

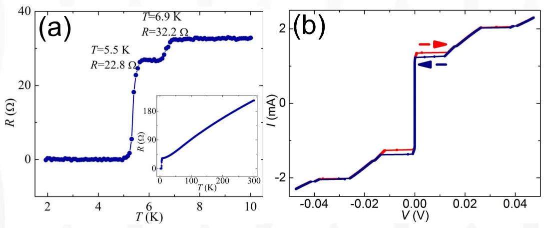

Figure 2 | Electrical characteristics of a vdW Josephson junction. (**a**) Temperature dependence of the four-point resistance R for a $NbSe_2$ junction device from 1.9 to 10 K. (**b**) Current–voltage (I–V) curve measured by sweeping the current at 2 K. Arrows indicate the sweep direction of the current.

Figure 2a shows the temperature dependence near the superconducting transition of the resistance for a $NbSe_2$ junction. We observed two significant drops near the transition temperature. Figure 2b presents the current–voltage characteristics of the vdW junction under current biasing at 2 K; it is clear from the hysteresis of the I–V curve that its behavior is typical of an underdamped Josephson junction. This means that the vdW interface introduces sufficient discontinuity in the superconducting order parameter for the Josephson effect to be observed.

Superconducting density of states

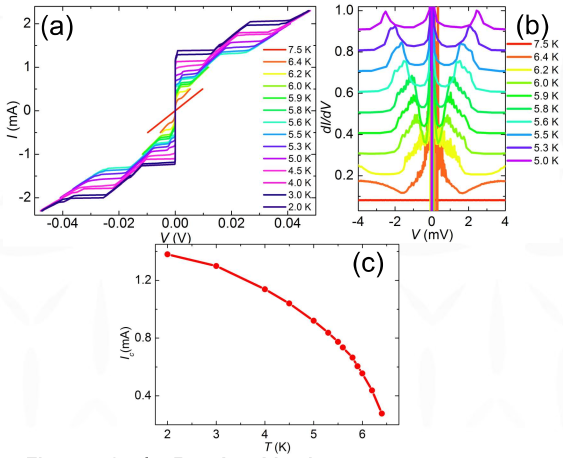

Figure 3 | Relationship between temperature and superconductivity. (**a**) I-V characteristics measured at different temperatures. (**b**) Variation in differential conductance dI/dV with respect to V measured at different temperatures. (**c**) Critical current I_c versus T.

To determine the superconducting density of states, I–V curves were measured at different temperatures, and the results obtained were numerically differentiated to obtain dI/dV as a function of bias voltage. As shown in Fig 3b. The temperature dependence of the critical current I_c of the Josephson junction is plotted in Fig 3c. The temperature dependence of symmetric Josephson junction critical current can be calculated through Ambegaokar–Baratoff theory.

References

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