Tunneling effect in van der Waals Josephson junction

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Summary

We show that by exfoliating a layered dichalcogenide (NbSe2) 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 NbSe2 crystals.

Flake transfer and device fabrication

Junction fabrication process

(a) | (b)
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Layered 2H-NbSe2 flake is exfoliated onto PDMS substrate. (b) an optical photograph of a vDW junction composed of top and bottom NbSe2 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 NbSe2 thin flakes onto PDMS substrates.
- Dry-transfer a NbSe2 thin flake from PDMS to silicon substrate by micromanipulator platform, and the flake partially contacts with electrodes.
- Transfer another NbSe2 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 NbSe2 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 NbSe2 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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