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Giant supercurrent states in a superconductor-InAs/GaSb-superconductor junction

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Introduction

- Topological superconductivity could be realized in a 2D quantum spin Hall insulator (QSHI) with proximity to conventional s-wave superconductors.
- Topological superconductor can host Majorana Fermions.
- InAs/GaSb quantum well is a 2D QSHI.

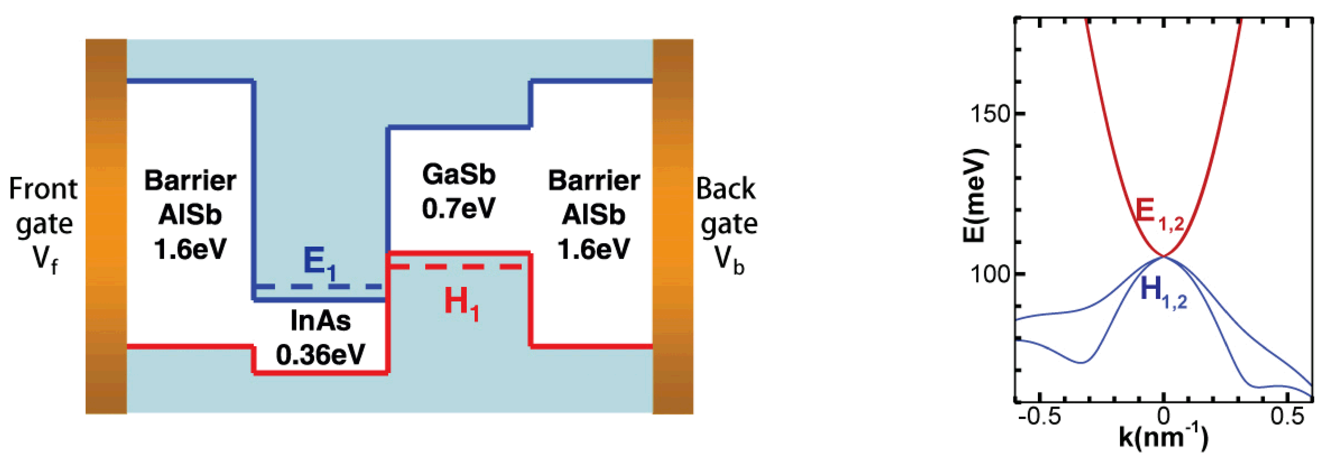

Fig. 1: (left) Energy band structure of InAs/GaSb quantum well bilayer. (right) Theoretic calculations demonstrate the Dirac cone structure in energy band where the quantum well width is at critical values. Figures credit: (left) Liu, et. al., Phys. Rev. Lett. 100, 236601 (2008). (right) K. Chang, unpublished.

Experiment

- InAs/GaSb quantum well wafers were grown by Molecular beam epitaxy (MBE) technique.
- A tantalum-InAs/GaSb-tantalum (superconductor-nonsuperconductor-superconductor) junction was fabricated at the CINT clean room on a wafer with critical quantum well width.
- Electrical transport measurement was performed in dilution refrigerators at T=30 mK and 90 mK.

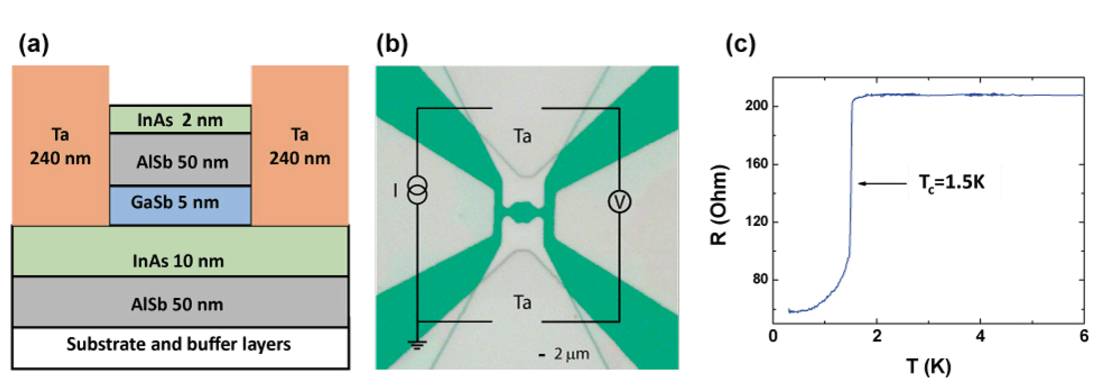

Fig. 2: (left) Layer structure of the Ta-InAs/GaSb-Ta junction. (center) Optical image of the sample. Two terminal electrical transport measurement setup is overlayed on top of the image. I and V are current sources and voltage meters, respectively. (right) Resistance versus temperature (T) of the junction shows a superconducting transition at T_c=1.5 K.

Results

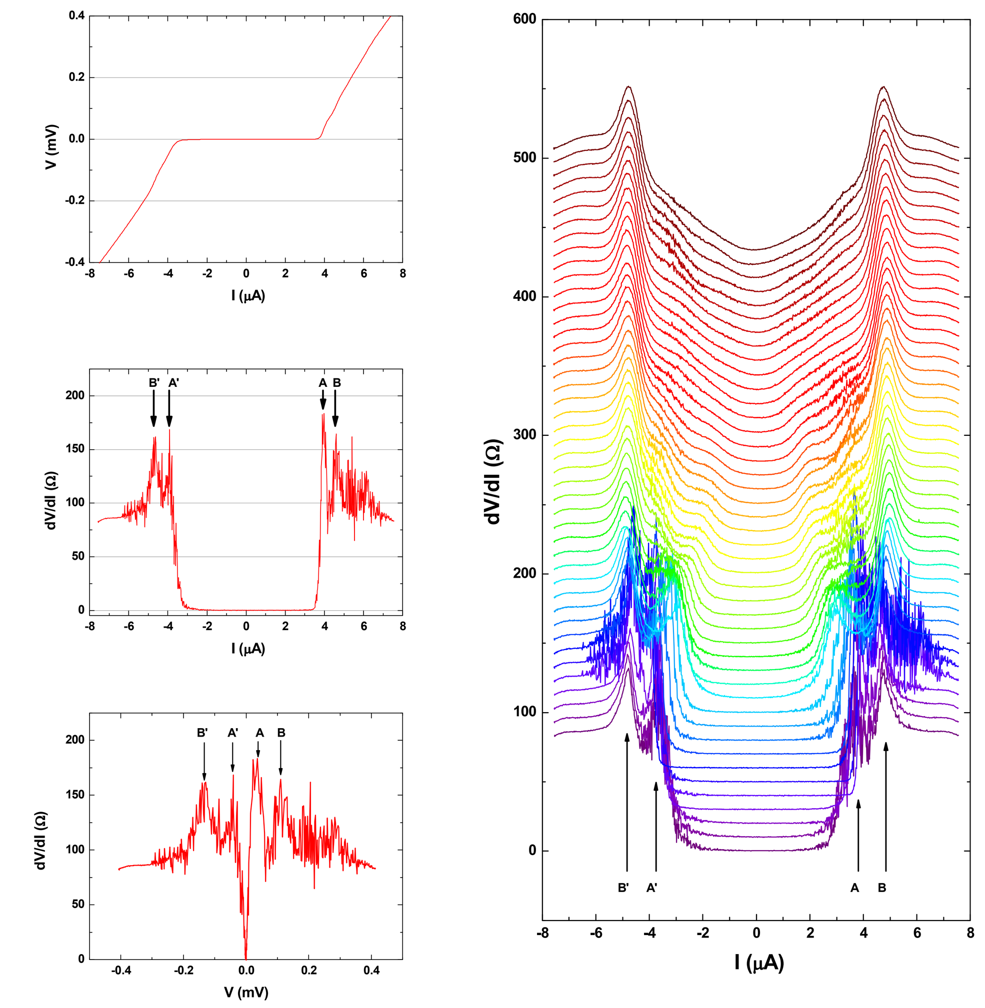

Fig. 3

- **Supercurrent in a long junction: L=2 μm**

Fig. 3: (top left) I-V, (middle left) dV/dI vs I, and (bottom left) dV/dI vs V at 90 mK and zero field for the junction. These figures clearly demonstrate a supercurrent region in near zero excitations. (right) dV/dI vs I traces at 90 mK for different magnetic fields. From bottom to top, field increases from -15 mT to 230 mT. Curves are shifted vertically for clarity.

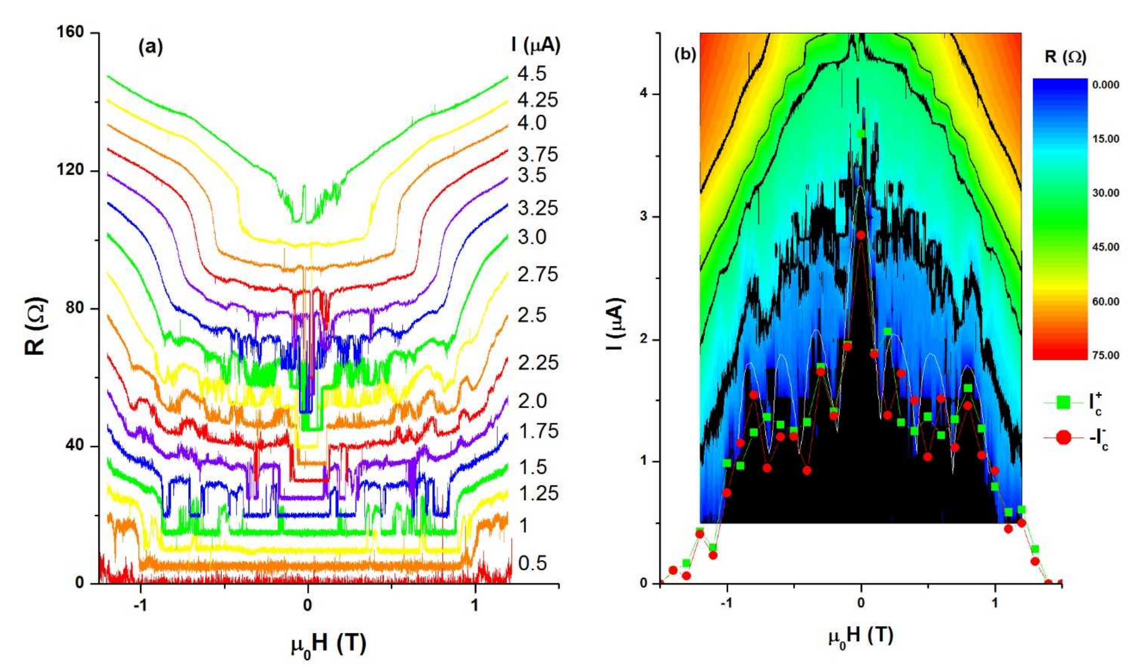

Fig. 4

- **Supercurrent can survive in high fields: $\mu_0 H_c$ ~ 1 T**

Fig. 4: Magnetic field dependence of R at T = 30 mK. (left) R(H) traces at fixed dc I excitations. Curves are shifted vertically for clarity. (right) A contour plot of R(H, I) based on data in left panel. The lower central black colored area shows the supercurrent region. Critical current values (I_c) from dc I-V measurements at given H fields agree with the supercurrent region in the contour plot. I_c^+ (green symbols) and $-I_c^-$ (red symbols) are absolute critical value of positive and negative excitation currents, respectively. A hand-drawn white line outlines the lobes.

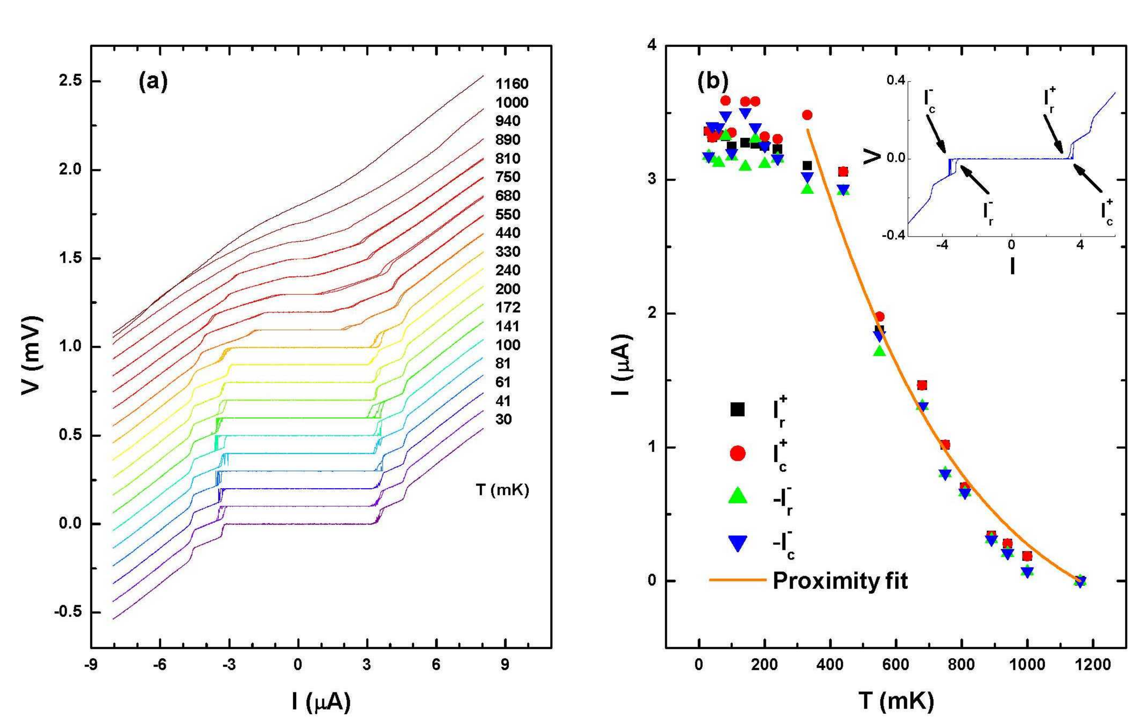

Fig. 5

- **Supercurrent can survive at high temperatures: T_c = 1.16 K**

Fig. 5: Temperature dependence of I-V in zero field. (left) Each I-V trace at a given temperature includes both up and down current scans. Curves are shifted vertically for clarity. (right) Inset: I-V trace at 141 mK is shown as an example to demonstrate the definition of I_c and I_r , which are critical current and retrapping current, respectively. Main plot: Temperature dependence of I_c and I_r . Solid line shows a fit based on proximity effect for high temperature data (T > 400 mK).

Conclusions

- Induced supercurrent in a LONG S-N-S junction.
- Both bulk and edge channels of the bilayer may attribute to the induced superconductivity.
- Supercurrent can be preserved in this junction in a surprisingly large temperature and magnetic field parameter space.
- Strong spin-orbital interaction, transparent junction interface, and long mean free path (~ 800 nm) could be the reasons for such giant supercurrent states.
- Induced superconductivity can be enhanced by applying a small magnetic field.

Acknowledgements

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