Cooper Pair Injection into a 2D Semiconductor

Raziel Itzhak
R. Itzhak[1,2], D. Panna[1], A. Kumar[1], S. Bouscher[1], N. Suleymanov[1], B. Minkovich I[1]. Goykhman[2], and A. Hayat[1].
[1]*Technion – Israel Institute of Technology, Haifa, Israel*
[2]*Institute of Applied Physics, The Hebrew University of Jerusalem, Jerusalem, Israel*
iraziel@campus.technion.ac.il

Superconductor-semiconductor hybrid devices are attractive for various technological applications and fundamental studies in condensed matter physics. They have become a vibrant field of research for quantum gates, superconducting qubits, and quantum light sources of entangled photons. The key physical phenomenon exploited in hybrid systems is the proximity effect, which imparts the superconducting properties from superconductor (S) to normal material (N) when brought into intimate contact. However, the main challenges for realizing proximity-based S-N devices stem from the limited penetration depth of the induced order parameter inside normal materials. Recent advancements in 2D materials and vdW heterostructures open new avenues in developing novel functionalities and integration with modern nanophotonic and nanoelectronics semiconductor technologies [1]. Specifically, the attractiveness of employing 2D materials for the realization of proximity-based devices (e.g. quantum LED [2]) stems from their ability to operate at the fundamental limit of few-atom thickness, providing unprecedented proximity to the superconductor surface with increased light extraction efficiency. Here, we report for the first time on Cooper pairs injection from bulk superconductor Nb into a single-layer optically active 2D semiconductor, WS2, using an Nb-WS2 heterojunction, evidenced by Andreev reflection in the conductivity spectra. To understand the key parameters governing the device performance, the conductivity spectra were fitted to an extended BTK model, which was also developed in this work. Our findings highlight the great potential of 2D semiconductors' integration with superconductors for hybrid proximity-based devices in applications such as quantum light sources for quantum-photonic integrated circuits.

References

[1] Trainer, D. J., Wang, B., Bobba, F., Noah, S., Xi, X., Zasadzinski, J., Nieminen, J., Bansil, A., & Iavarone, M. ACS Nano, Vol. 14, No. 3, 2020, p. 2718-2728.
[2] A. Hayat, H.-Y. Kee, K. S. Burch, and A. M. Steinberg, Phys. Rev. B 89, 094508, (2014)

Figures

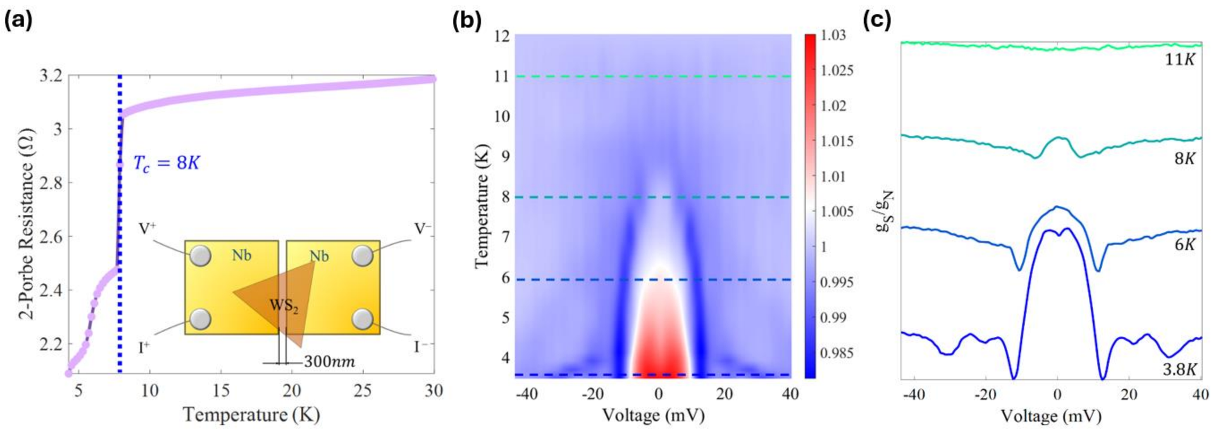

Figure 1:(a) 2-Probe resistance measurement of the Nb pad. An inset represents a schematic of the device configuration. **(b)** Normalized differential conductance measurement of Nb-WS2-Nb interface for temperatures below and above T_c. **(c)** Differential conductance for a selected number of temperatures exhibiting Andreev reflection and attenuation of the central conductivity feature at elevated temperatures.