Joule spectroscopy and heating in hybrid superconductor-semiconductor devices

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Hybrid superconductor-semiconductor devices have been intensively studied in the past decade owing to prospects of applications in quantum technologies. Crucially, towards this goal, an impressive improvement in the quality of materials has been achieved in recent years. Nonetheless, fabricated devices arguably still show a great deal of variability, each being effectively unique. Here, we demonstrate that Joule heating can be used as a powerful tool for the characterization of such devices. Concretely, we show that the transition of the superconducting leads to the normal state by the Joule effect can be used as a spectroscopical signature in transport of the superconductivity of each lead separately and in a single measurement, thus readily providing a “fingerprint” of each device. We demonstrate the potential of the technique by obtaining detailed information of devices based on hybrid epitaxial Al-InAs nanowires. In particular, we study full shell wires, also in the Little-Parks, and uncover different sources of inhomogeneities such as disorder in the parent superconductor (differences in the superconducting coherence lengths of the leads and discontinuous covering from the epitaxial shell), and the inverse superconducting proximity effect. Our work also brings to light important bottlenecks for heat dissipation in hybrid superconducting devices, which can lead to substantial temperatures even for moderate currents/voltages. This underscores the importance of heating effects in hybrid devices, a topic which has been so far largely overlooked [1].

References

[1] A. Ibabe, M. Gomez, G. O. Steffensen, T. Kanne, J. Nygard, A. Levy Yeyati, E. J. H. Lee, arXiv:2210.00569.