DC and microwave transport properties of topological insulator nanoribbon-superconductor hybrid junctions

ESR 11 Ananthu P. Surendran, MC2, Chalmers University of Technology, Sweden

Hybrid material systems with a conventional superconductor in proximity to a semiconductor with strong spin-orbit coupling (the direction of spin of the particle is correlated to its direction of motion) or an unconventional metal have recently attracted a vast interest due to their potential to host exotic phenomena, which are not otherwise accessible. One such strange phenomenon to emulate and study are Majorana fermions, particles that are their own anti-particles, which may come in handy for developing a fault-tolerant topological quantum computer in the future.

During this project, we looked at hybrid devices with bismuth selenide (Bi2Se3) topological insulator (TI) nanoribbons, synthesized by physical vapor deposition, placed in proximity to aluminum superconducting electrodes forming an Al-Bi2Se3-Al junction as shown in the figure below. We expect to see the Majorana physics manifest as peculiar properties of a part of the Andreev Bound States (ABS) carrying the supercurrent in these devices, and we characterized them using DC and microwave techniques. In these measurements, we demonstrated deviations from what one expects for the typical junction made from conventional materials, pointing towards the presence of non-trivial transport modes in our devices. The high transparency values (ranging from 0.65–0.85) that we have in our junctions are among the best that has been achieved on TI-based junctions. We also uncovered signatures of non-trivial transport modes in the dissipation measurements performed on an RF-SQUID with integrated topological junction coupled to a quarter wavelength coplanar waveguide resonator (see Fig (f)).

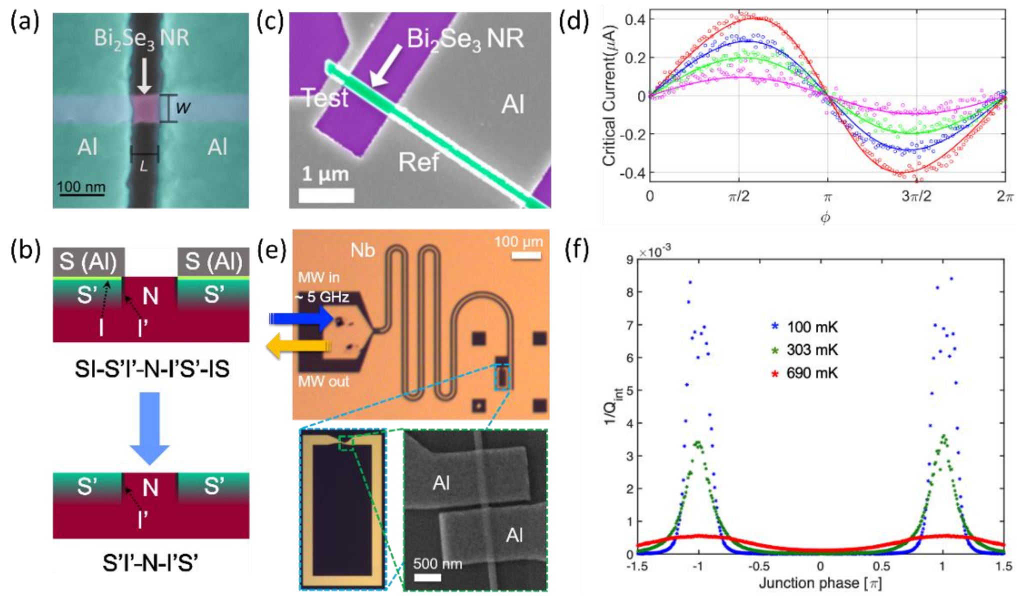

Fig. (a) SEM image of a typical Al-Bi_2Se_3-Al junction. (b) Schematic cross section of a S-TI-S junction. (c) SEM image of a representative asymmetric DC-SQUID used for extracting the current-phase relation (CPR) of the junction. (d) Extracted CPR for an Al-Bi_2Se_3-Al junction showing deviations from conventional sinusoidal CPR typical for low transparency (tunnel) junctions. (e) Device layout used for microwave measurements showing an RF-SQUID with integrated topological junction coupled to a quarter wavelength coplanar wave guide resonator. (f) Phase bias dependence of the dissipative part of the junction admittance. The single peak in the dissipative part of junction admittance at a phase bias of π indicates that the bound state spectrum in our TI Josephson junctions is dominated by highly transparent modes.