Fully *in-situ* fabrication of proposed Majorana devices

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A novel approach to quantum information processing based on exotic Majorana zero modes (MZM) in solid-state matter holds great promise for fault-tolerant quantum computation. Since large-scale error corrections are a bottleneck of conventional solid-state qubits, there is considerable research interest in these so-called Majorana qubits. MZMs reside at the interface between a quasi-1D topological insulator (TI) and a superconductor (SC). Signatures of those elusive modes have already been realized based on Josephson irradiation [1] as well as Shapiro response [2] measurements in TI-SC hybrid devices.

Here, we present Majorana signatures in low-temperature experiments based on Shapiro response measurements. The full suppression of the first Shapiro step at low frequencies indicates a signature of Majorana excitations in our hybrids, too. The three-dimensional topological insulator Bi_2Te_3 thin films were grown by molecular beam epitaxy. Our TI-SC hybrid devices are fabricated under ultra-high vacuum conditions, yielding a very high interface quality. We have shown the interface transparency and the characteristic $I_C R_N$ product of *in-situ* defined Josephson junctions to be superior compared to *ex-situ* fabricated devices.

Next to highly transparent interfaces, thin films must be confined to nanostructures for Majorana devices. Selective area growth permits the fabrication of TI nanoribbons under vacuum conditions. A subsequent passivation layer encapsulates the whole quasi-1D structure, protecting the delicate surfaces from oxidation as the sample is removed from the chamber to ambient conditions. Measurements on as-grown nanoribbons show flux-periodic Aharonov-Bohm oscillations, indicating transport mediated by surface states.

A combination of both processes, the selective growth of TI nanoribbons as well as the *in-situ* fabrication of superconductive electrodes has been established. This novel preparation technique not only allows for high-quality Josephson devices, but ultimately enables the fabrication of highly complex TI-SC hybrids comprised of networks of quasi-1D topological nanostructures. The highly scalable process paves the way towards *in-situ* fabrication of proposed qubit architectures and might be key for exploiting topological insulators for topological quantum computation.

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