# Exploiting topological matter for Majorana physics and devices

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Topological insulators (TIs) are semiconductors with a bandgap in the bulk, but metallic states at the surface. At the surface a band inversion induced by strong spin-orbit interactions leads to the so-called Dirac states. Majorana excitations are predicted to arise in TI surface states in proximity to conventional s-wave superconductors (SCs). Furthermore, topologically protected Majorana zero modes (MZMs) promise to obey non-Abelian exchange statistics and therefore to facilitate fault-tolerant quantum computing [1].

Josephson junctions were fabricated from s-wave superconductor (Nb) and 3-dimensional topological insulators, typically $Bi_xSb_{2-x}Te_3$ alloys, as test vehicles on the search for Majorana modes. Induced superconductivity in Josephson junctions with weak links of 3D TI films is expected to be mediated partly by Majorana bound states.

In $Bi_xSb_{2-x}Te_3$ alloys the bandgap and the position of the Fermi level at the sample surface can be controlled by the composition. However, serious challenges arise due to large bulk carrier concentration and the high sensitivity towards surface oxidation. Thus, *in-situ* fabrication of the TI/SC interface as well as TI surface passivation is required to obtain a high contact transparency and a high mobility in the surface layer, respectively. A molecular beam epitaxy process presented in this work combines selective growth and stencil lithography [2] to resolve both issues. The *in-situ* prepared Josephson junctions show a high interface transparency and large $I_C R_N$ product of 325 µV, indicating a strong proximity effect and a large superconductive gap. The Shapiro response of radio frequency measurements indicates the presence of gapless Andreev bound states (also known as Majorana bound states) and proves a high interface transparency.

The *in-situ* fabrication process can be adapted to complex layouts. We will present the first experiments focused on *in-situ* processing of nanowire devices and qubit structures. Thus, our approach paves the way towards networks of functional Majorana devices for the proposed topological qubit layouts.

1. F. Hassler, Lecture Notes of the 44th IFF Spring School on "Quantum Information Processing", Verlag des Forschungszentrums Jülich (2013).
2. P. Schüffelgen, D. Rosenbach, L. Chuan, T. Schmitt, M. Schleenvoigt, *et al.* "Boosting transparency in topological Josephson junctions via stencil lithography", ArXiv: 1711.01665 (2017).