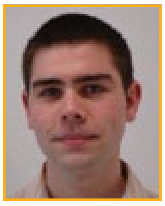
Topological superconductivity



Principal investigators

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Laboratories: NEEL, INAC

A wealth of new phenomena have been predicted to arise when superconductivity is induced by proximity in a topological insulator. This PhD work aims at investigating the coupling between superconductivity and topological insulators by means of quantum transport and low temperature scanning tunneling spectroscopy. We have developed state-of-the-art crystal growth of topological insulators that allows us to fabricate and investigate mesoscopic coherent devices, namely Josephson junctions, that show unusual behavior when irradiated by a radiofrequency field.

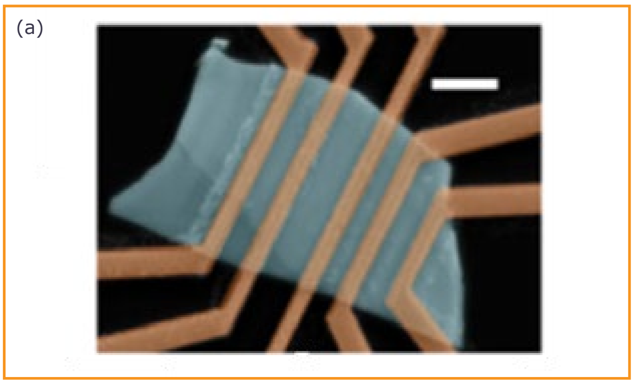
Description

Recently, the coupling between topological insulators and superconductivity has sparked a wide research interest, because it offers a new platform for the realization of novel quantum state of matter. Owing to the large spin-orbit interaction that modifies the band structure topology, TIs exhibit an insulating bulk state and gapless metallic surface states with linear dispersion.

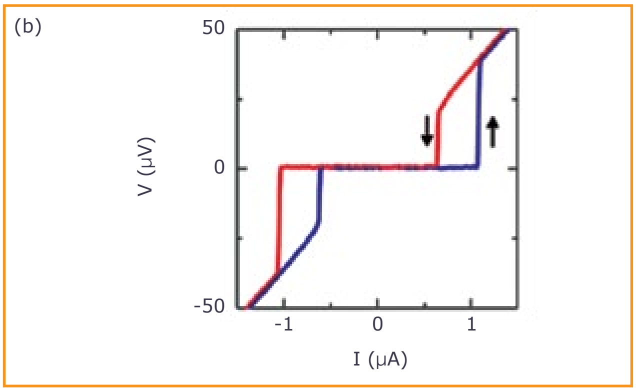
As a result, the entire crystal surface hosts a two dimensional electron gas of massless Dirac fermions akin to the electrons in graphene. When coupled to superconductivity, intrinsically or through proximity-effect, an unconventional superconductivity accompanied by new zero-energy modes that are called Majorana Fermions are expected to emerge at the surface of topological insulators.

In this context the project thesis aims at unveiling by means of quantum transport and cryogenic scanning tunneling spectroscopy the unconventional nature of the proximity-induced superconducting state in Bi-based topological insulators. We have developed an expertise in the state-of-the-art crystal growth of several topological insulators, namely Bi_2Se_3, $Cu_xBi_2Se_3$, $BiSbTeSe_2$, which allows us to have full control on the sample quality and fabrication.

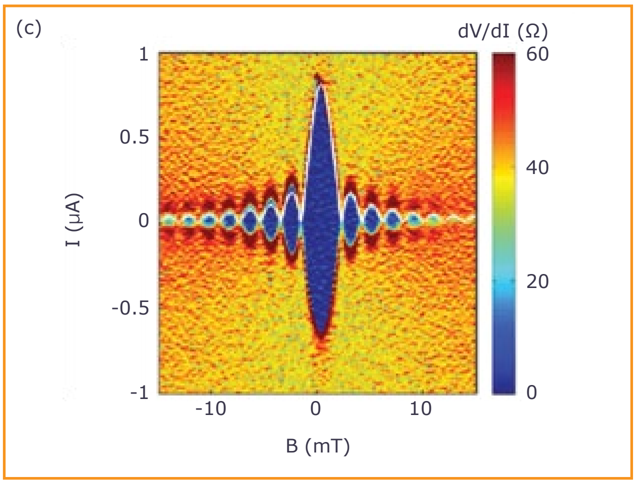
Our last grown $BiSbTeSe_2$ crystals exhibit full insulating behavior of the bulk at low temperature and only surface conduction. For the coupling with superconductivity we are currently focusing our effort on Josephson junctions made by exfoliation of such crystals (Fig. a). In particular we are interested in the behavior under radio frequecy irradiations where an anomalous sequence of Shapiro steps has been predicted and partially reported in other systems.



(a) Scanning Electron Microscopy picture of a Bi_2Se_3 flake contacted with superconducting electrodes (scale bar : 1 µm)



(b) I(V) characteristic of a Josephson junction on Bi_2Se_3.



(c) Colormap of the differential resistance plotted versus bias current and magnetic field B. The critical current oscillates with B as a result of quantum interferences (Fraunhofer pattern).

Collaboration : **Walter Escoffier, LNCMI-Toulouse.**

PhD Grants 2013

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