TopoGraph: Engineering topological superconductivity in graphene

Main area: BSR10_Beyond CMOS switches and new computing paradigms based on GRMs
Keywords: graphene; van der Waals heterostructures; superconductivity; topological states; spin-orbit interaction, quantum Hall effect; Majorana zero modes; tunneling spectroscopy; supercurrent
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Abstract

The aim of the TopoGraph project is to engineer topological superconductivity and Majorana zero modes (MZMs) in graphene-based van der Waals heterostructures. While there is extensive research both in the field of graphene and in the field of topological materials, graphene as a platform for topological superconductivity has not yet received much attention. Majorana zero modes (MZM) are special excitations of topological superconductors with non-Abelian exchange statistics. This property, together with their topological protection against unwanted perturbations, make MZMs promising for practical implementations of topological quantum computation. This project will leverage the unique properties of graphene (long-range ballistic transport, clean interfaces with superconductors, tuneable properties through van der Waals engineering) to realize a new platform for topological superconductivity and MZMs.We will follow two different complementary routes to engineer MZMs: (a) enhance spin-orbit interaction in graphene by stacking it on high spin orbit 2D materials, and (b) use the peculiar quantum Hall phases in single or twisted bilayer graphene to induce quantum spin-Hall phases. We will then induce topological superconducting phases by coupling these structures to superconducting electrodes. The emergence of MZMs will be identified using tunnelling spectroscopy and current phase relation of Josephson junctions, both of which produce smoking-gun signatures of these excitations.To achieve these goals we will combine several cutting edge building blocks: high mobility graphene, induced spin orbit interaction, supercurrents in a quantum Hall states, crossed Andreev reflection and, tunnelling spectroscopy and on-chip detection of Josephson radiation. We will supplement our experiments with theoretical studies to interpret results, optimize device architectures, and to develop novel directions. The first demonstration of topological superconductivity in graphene would be a major milestone towards topological quantum computation, and would open up the field for graphene based devices. Graphene is expected to exhibit advantages over alternative platforms, which would make it a strong contender towards implementing topological quantum computation. The consortium is expert in all the aspects needed for the proposal: MZM measurements, high quality graphene and van der Waals heterostructures, Josephson effect in graphene, crossed Andreev reflection, and quantum Hall studies and Josephson radiation. Moreover, the consortium includes expert theory support from the developers of the first proposals towards MZMs in graphene.

Consortium

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