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SEMINAR ANNOUNCEMENT

Josephson Junctions with superconductor/topological insulator hybrid structures

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Abstract:

It is predicted that a unique quantum state, Majorana Zero Mode (MZM), can be formed in one-dimensional topological superconductors [1]. It is interesting from a fundamental physics point of view, and is also attractive for robust quantum bit (qubit) application (Majorana qubit) [2]. We could form the one-dimensional topological superconducting channel in narrow semiconductor nanowires with large spin orbit interactions (SOI) or helical edge channels in 2-dimensional topological insulators (2DTIs) when superconductivity is induced by contacting them with ordinary (s-wave) superconductor [3]. However, the MZM has not been confirmed experimentally. Despite the attractiveness, materials to study are usually very difficult to handle in practice, which makes the experimental study uneasy. In this talk, I will begin with a basic idea of the Majorana qubit followed by talking about how MZMs can appear in the hybrid structures and our experimental effort to study the quantum states and search for MZMs in InAs nanowires [4] and monolayer WTe2 which is a 2DTI [5]. Josephson junctions (JJs) are an interesting and useful device to study the quantum states formed in the normal region (N) sandwiched by the superconducting contacts (S). In a trivial case, the Andreev bound states (ABS) are formed that have a 2 periodicity as a function of the phase difference of the junction. We show that the energy spectrum can be measured in our InAs NW JJ devices using a microwave circuit resonator coupled with the junction (two-tone spectroscopy) [4]. The technique is similar to the one that is widely used to read out a qubit state in superconducting quantum computer (dispersive readout). An important requirement for the SNS JJ is that the SN interface has to be clean and transparent, and for that, the superconducting metal (Al) was deposited without breaking vacuum after growing the nanowires [8]. We have fabricated the resonator and the device in different substrates which are touched face to face to realize inductive coupling (Flip-chip method [4]). The advantage of the method is that it can be applied to various devices made of various materials. If the normal region becomes "topological", the bound state energy of the Majorana bound state should show 4 periodicity with crossing at zero energies.

We have also fabricated the SNS Josephson junctions in a monolayer WTe2. They should be formed in the helical edge channels in the 2DTI. The device fabrication has to be carried out carefully without exposing the WTe2 layer to air because the material can be easily degraded. The superconductivity can be induced in the monolayer WTe2 by the gate voltage. A formation of the Josephson junction was confirmed by the supercurrent at zero bias, magnetic effects and Schapiro response under microwave application [5]. However, the behavior was just "normal" without any signature of the topological junction. The observed magnetic field effect indicated a possibility of the edge channels, but detailed analysis with simulations revealed that the supercurrent flow was not uniform in the junction possibly because of any imperfection or non-uniformity of the monolayer flake.

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