Novel Superconducting Microwave Devices from 2D Materials

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Abstract:

We have made some decent progress in our nano-device fabrication within CNF this year. Our research has been focusing on measuring electronic transport properties of 2D materials Josephson junction, as well as high-*Q* microwave devices for qubit control / readout.

Summary of Research:

The first project was observing Josephson effect in junction made from hBN-graphene-hBN heterostructure. Although several groups have reported large Josephson supercurrent in such devices before, our device was the first successful graphene JJ fabricated completely within Cornell University. The accomplishment is from the success in the following fabrication process:

1. EBL: we performed electron-beam lithography to write the planar junction with 800 nm width and 5 μm length using the Nabity Nano Pattern Generating System (Figure 1. (a)).

2. Etching: we performed reactive ion etching using Oxford 81 to etch through the 2D materials stack and expose the graphene on the edge to form a one-dimensional contact with deposited metal (Figure 1. (b)).

3. Deposition: we have developed a good sputtering recipe for superconducting niobium which yielded 8.5K critical temperature (Figure 1. (c)).

We measured the device in a dilution refrigerator, and found a gate tunable Josephson supercurrent with maximum as large as 1.5 microamperes (Figure 1. (d)). The success of this device paved the way for the development of future more novel mesoscopic 2D materials devices.

Recently, we have fabricated a new batch of Josephson junction at CNF with bilayer graphene and WSe_2 to study the effect of spin-orbit coupling in the superconducting proximity effect.

The microwave devices we fabricated are the 2D transmission line resonators. We deposited a layer of 70 nm niobium using our sputtering recipe, then we performed photolithography on it with DWL66. We found that DWL66 is particularly useful for checking designs before finalizing them on a photomask, and handling features that are too large to be written by EBL. We first performed etching using AJA ion mill. Details of the small structures of the device are shown in Figure 2. (a) and (b). The device quality factor was measured to be around 50000. The resonance phase and magnitude of the resonator are shown in Figure 2. (d). In the second batch, we performed etching using PT770 reactive ion etcher. The quality factor was improved by a factor of 6 (more data are still being collected on these newer devices).