Physics of nm-Scale Superconductors and Magnets

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Primary CNF Tools Used: Heidelberg Mask Writer - DWL66FS, JEOL 6300, AJA Sputter Deposition

Abstract:

We have been actively using the Heidelberg Mask Writer - DWL66FS to make spin torque ferromagnetic resonance and second harmonic Hall devices for spin-orbit torque generation study. JEOL 6300 electron beam writer has been employed to make non-local devices for spin transport study.

Summary of Research:

In the past year, one of our research focuses is to study unconventional spin-orbit torque generation in exotic material systems, consisting of a spin-orbit coupled material and a ferromagnet. The ferromagnet serves as a sensitive spin detector, whose magnetization state is subject to the perturbation induced by spin current generated in the spin-orbit coupled material. Two different techniques were employed to study spin-orbit torque generation in these systems. Since the device dimension is in the order of microns (Figure 1a, b), a photolithography recipe is developed to fabricate those devices. To begin with, spin torque ferromagnetic resonance is the mostly commonly used technique to measure spin orbit torque generation. The device made with the Heidelberg Mask Writer - DWL66FS at Cornell NanoScale Facility is shown in Figure 1a. The device consists of a T shaped bar made of the target material systems and a symmetric Ground-Signal-Ground contact that produces no net Oersted field when the applied high frequency current travels through. Moreover, second harmonic Hall measurement is another technique that Ralph group has pioneered to measure spin-orbit torque generation. The second harmonic Hall measurements are performed on Hall devices (Figure 1b), with external magnetic field rotated in the device plane. To make the Hall devices, Hall bars with three Hall crosses are first exposed with DWL 66fs. Then an ion mill step is followed to remove the material that is not protected by the photoresist. Finally, a second step exposure is performed to align contacts to the Hall crosses. Contacts made of Pt are deposited in the AJA sputter system for both spin torque ferromagnetic resonance and second harmonic Hall devices.

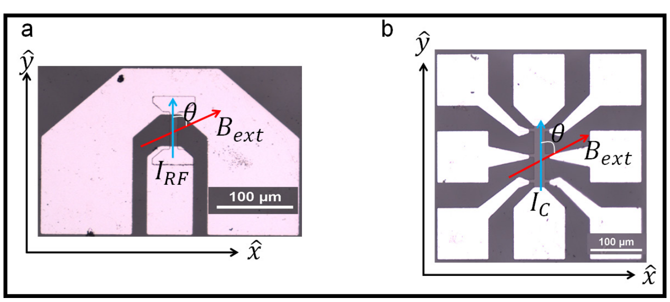

Figure 1: Devices for spin orbit torque generation study. a) Spin torque ferromagnetic resonance devices made with the Heidelberg Mask Writer - DWL66FS. b) Hall devices made with the DWL66FS. Mark alignments were used for the second step exposure.

The other project we have been actively working on at the Cornell NanoScale Facility is the non-local spin transport in magnetic materials. Magnetic materials such as ferrimagnets [1,2] and antiferromagnets [3,4] have been shown to have the capability of carrying spin information over long distance. To study spin transport in magnetic insulators, non-local devices shown in Figure 2 [5] consisting of an injection channel and a detection channel that are separated by various distances are made with electron beam lithography. To achieve sub-micron down to 200 nm of distances between the two channels, electron beam lithography tool JEOL 6300 is used to expose features as small as 200 nm.

Conclusions and Future Steps:

We have successfully measured spin-orbit torque generation in spin-orbit coupled materials and spin transport in magnetic insulator in the devices fabricated at the Cornell NanoScale Facility. Our future steps include: 1. Study spin-orbit torque generation in the same material with various orientations. 2. Study the distance dependence of spin transport in the magnetic insulators.

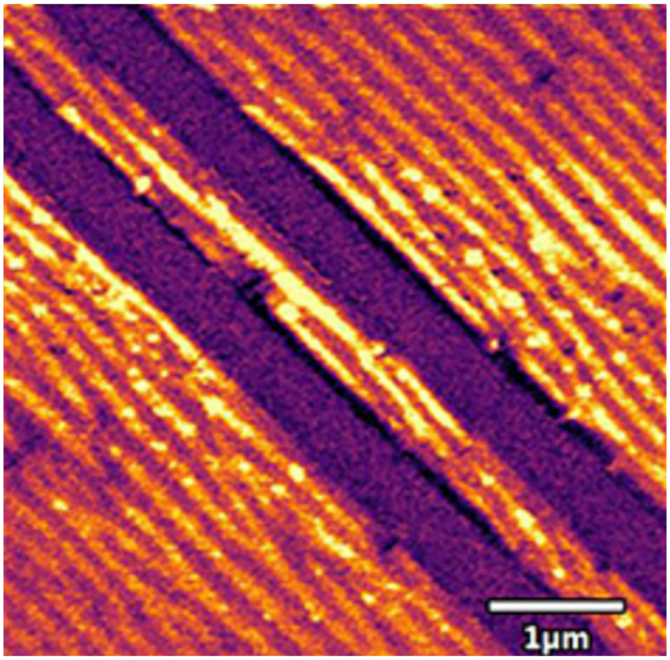

Figure 2: Non-local devices for long distance spin transport study. The channel width and spacing between two channels are 500 nm.

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