Anisotropic Magnetoresistance in Graphene/ Insulating Ferromagnet van der Waals Heterostructures

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Principal Investigator(s): Daniel C. Ralph

User(s): Bozo Vareskic

Affiliation(s): Laboratory for Atomic and Solid State Physics, Cornell University

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Contact: dcr14@cornell.edu, bv227@cornell.edu

Primary CNF Tools Used: Veeco Icon AFM, CVC SC4500 even/odd-hour evaporator

Abstract:

Insulating van der Waals magnets are a promising platform for spintronic applications [1]. The insulating nature of these magnets eliminates current shunting observed in spin-torque bilayer devices with metallic magnets which would lead to more efficient spin-torque devices. Furthermore, the atomically clean interfaces of van der Waal heterostructures provide a novel system to study the nature of spin transparency at the interface of two dimensional materials. However, electrical readout of the magnetic state is challenging because insulating magnets do not exhibit anisotropic magnetoresistance (AMR). Previous studies have used tunneling magnetoresistance as a readout mechanism [2,3], but these methods are difficult to incorporate into a bilayer spin-torque device. In order to achieve electrical sensitivity to the magnetic orientation, we fabricate a heterostructure of graphene and insulating ferromagnet chromium tribromide ($CrBr_3$). Low temperature magneto-transport measurements reveal an angular dependence that is consistent with an AMR mechanism, suggesting that the graphene is magnetized by proximity to $CrBr_3$.

Summary of Research:

Flakes of graphene, $CrBr_3$, and hexagonal-boron nitride (h-BN) are mechanically exfoliated on a SiO_2/Si wafer with oxide thickness of 285 nm in an inert glove box environment. Monolayer graphene flakes and few layer $CrBr_3$ are identified by optical contrast. Thickness calibration is performed by a combination of atomic force microscopy (Atomic Force Microscope – Veeco Icon) and Raman spectroscopy. In order to avoid exposure to ambient oxygen and water, $CrBr_3$ flakes were always encapsulated by h-BN prior to removal from the glove box.

The heterostructure is assembled by a dry transfer technique [4] in the glove box. h-BN is initially picked up, followed by $CrBr_3$, and lastly, graphene. Figure 1 shows a schematic of the device. The h-BN and graphene encapsulate the $CrBr_3$ from above and below, respectively. The heterostructure is then dropped onto a set of prepatterned Hall electrodes (Figure 2). Metal was deposited using the CVC SC4500 even/odd-hour evaporator.

DC transport measurements were performed in a liquid helium fridge at 5 K, which is well below the Curie temperature (~34 K) of $CrBr_3$ [5]. An in-plane field of 0.9 T was applied, and the resistance was measured as the applied field angle was swept in the plane. The AMR is defined in the bottom of Figure 3. The angular dependence of the resistance is depicted in Figure 4 and fitted to the equation at the top of Figure 3. R_0, ΔR, and ϕ_0 are treated as free parameters.

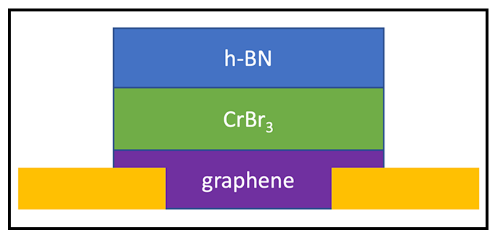

Figure 1: Schematic of monolayer graphene/chromium tribromide ($CrBr_3$) heterostructure. Insulating hexagonal boron nitride (h-BN) and graphene are used for top and bottom encapsulation, respectively, to prevent degradation of air sensitive $CrBr_3$.

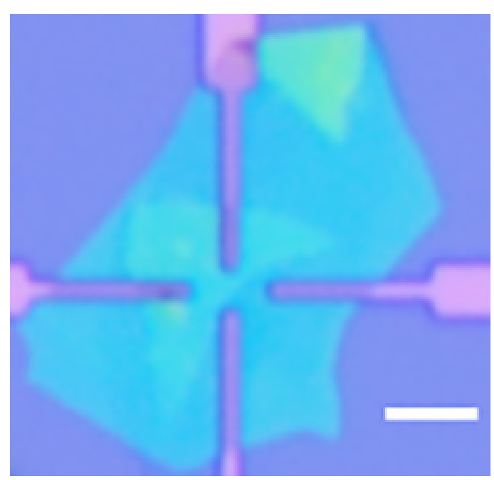

Figure 2: Micrograph of graphene/$CrBr_3$ heterostructure. Scale bar: 5 µm.

$$R = R_0 + \Delta R \cos(2(\phi - \phi_0))$$

$$\mathrm{AMR} = \frac{R(\phi) - R(\phi = \phi_0)}{R(\phi = \phi_0)}$$

Figure 3: Above: fitting equation used to describe the angular dependence of the magnetoresistance subject to an in plane magnetic field. ϕ is the in-plane angle of the applied magnetic field, and $\phi = \phi_0$ corresponds to angle at which the current the current is parallel to the field. Below: definition of the anisotropic magnetoresistance.

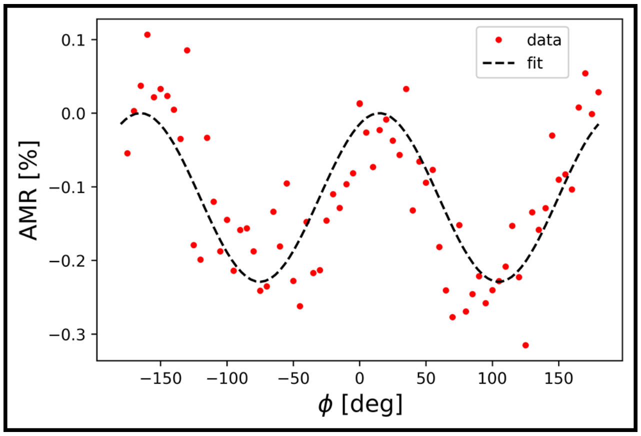

Figure 4: AMR of graphene/$CrBr_3$ heterostructure as a function of in-plane magnetic field angle. An in-plane field of B = 0.9 T was swept while applying a 1 µA current. Measurements were performed at T = 5 K. The fit is described by the top equation of Figure 3.

The periodicity of the AMR is consistent with that of conducting ferromagnetic systems described by the equation at the top of Figure 3. This suggests that the graphene is magnetized by the proximity effect. It is unlikely that the angular dependence of the magnetoresistance is due to spin Hall magnetoresistance since the spin-orbit coupling in graphene is relatively weak and graphene does not exhibit a spin Hall effect. Nonetheless, we can not rule out the possibility that spin-orbit coupling is induced in addition to ferromagnetism in graphene by the proximity effect.

References:

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