# Fabricating Heavy Metal/Ferromagnetic Bilayers for Spin Torque Applications


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### Abstract:

**Magnetic devices are leading contenders for future non-volatile memory and logic implementations. Applications for magnetic devices will require the development of efficient mechanisms for reorienting their magnetization. Spintronic devices use spin currents to exert a torque on the ferromagnetic layer, causing its magnetization to reorient. When a charge current flows through a metal with a strong spin-orbit coupling, the Spin Hall Effect creates a spin current transverse to the charge current direction. This spin current applies a torque to an adjacent ferromagnet. Topological insulators, which have surface states with large in spin-orbit coupling effects, are promising options for spin current sources. Previous research has shown that the topological insulator bismuth selenide ($Bi_2Se_3$) efficiently generates spin currents. However, due to the high resistivity of $Bi_2Se_3$, much of the charge current in a $Bi_2Se_3$/Permalloy devices flows through the low resistivity Permalloy (Py) and does not contribute to the torque. This issue can be resolved by using an insulating ferromagnet. We are working to develop a new method capable of measuring spin torques acting on insulating ferromagnets by using waveguide spin pumping and a Magneto-Optical-Kerr-Effect (MOKE) microscope. We will present initial measurements of Pt/Py test devices from the MOKE microscope.**


### Introduction:

In previous research [1], samples consisted of 8 nm of $Bi_2Se_3$ and 8 nm of Py patterned into strips 10-80 $\mu$m long and 2.5-24 $\mu$m wide, with an oxidized aluminum cap to prevent oxidation of the Py layer. Although the sample geometry produced measureable spin torques, on average $Bi_2Se_3$ was twenty-five times more resistive than Py. As a result, much of the current shorted through the Py layer and did not contribute to the spin torque.

Our current research involved new sample geometry where we deposited a hafnium oxide insulating ferromagnetic layer in addition to transmission waveguides. The hafnium oxide insulating ferromagnetic layer should prevent the current from shorting the Py layer, while the transmission waves guides should provide a general spin torque measurement.

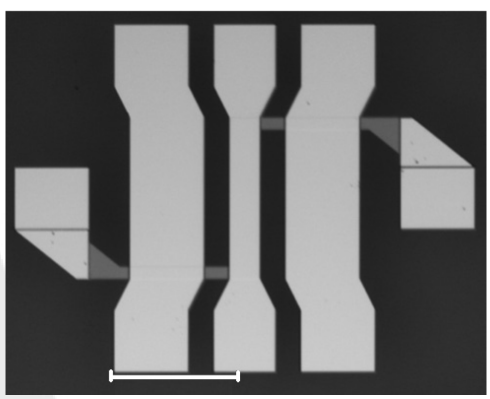

*Figure 1: Device schematic.*

To measure the vector components (‖, "in-plane") and (⊥, "perpendicular") of the spin torque, we also fabricated MOKE devices. The polarized light reflecting from our magnetic sample will image the scanned area and provide these vector components.

### Experimental Procedure:

To make these devices, we began by depositing 6 nm of Pt and 6 nm of Py on a two-inch sapphire wafer. We also deposited 2 nm of aluminum oxide to prevent the Py from oxidizing. We then employed optical lithography and ion milling techniques to pattern the Pt/Py bilayers. We made electrical contacts from 3 nm of Ti and 150 nm of Pt in a symmetrical geometry, so that when samples were contacted using a ground-signal-ground highfrequency probe, the currents travelling in the contacts did not produce a net Oersted field acting on the sample.

To pattern the transmission waveguide devices, we used atomic layer deposition to deposit 18 nm of hafnium oxide to prevent current from entering the ferromagnetic layer, and deposited 3 nm of Ti and 150 nm of Pt for the actual waveguide devices.

## Results and Conclusions:

Preliminary resistance measurements were taken on the devices to test the sample geometry. From these measurements, the sample geometry will be reconstructed where needed in order to prevent the current from shorting through the Permalloy layer and not contributing to the spin-torque.

## Future Work:

In the near future, more measurements will be taken on the devices. One set of measurements will use radio frequencies to measure the components of the spin torque produced while the MOKE will measure an overall spin torque for the device.

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## References:

[1] Spin-transfer torque generated by a topological insulator; A. R. Mellnik, J. S. Lee, A. Richardella, J. L. Grab, P. J. Mintun M. H. Fischer, A. Vaezi, A. Manchon, E.-A. Kim, N. Samarth, and D. C. Ralph. Nature 511, 449-451, (24 July 2014). doi:10.1038/nature13534.