Spin Orbit Coupling in Two Dimensional Materials

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Introduction

The electrical isolation of atomically thin graphene in 2004 generated much excitement in the physics, nanotechnology, and engineering communities as it presented the opportunity to study an atomically thin two dimensional material [1]. This interest led to the discovery of rich physics such as the half-integer quantum hall effect [2, 3]. The success of graphene has prompted further interest in other atomically thin systems, including topological insulators [4] and more recently transition metal dichalcogenides such as MoS_2 [5-9]. Past studies of bulk transition metal dichalcogenides have revealed a diverse set of material properties, including metallic, semiconducting, and superconducting behavior [10]. However, as recent work demonstrating the indirect to direct bandgap transition in monolayer MoS_2 shows, the properties of these materials can significantly change when thinned to the atomic limit [5, 7]. With this motivation, we have studied spin orbit scattering in few-layer MoS_2 and few-layer $TaSe_2$ flakes to investigate the use of these materials in spintronics devices.

Experimental Results

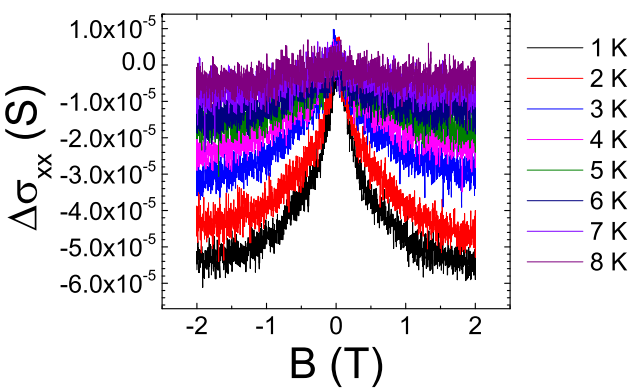

Fig 1: Differential magnetoconductance of $TaSe_2$

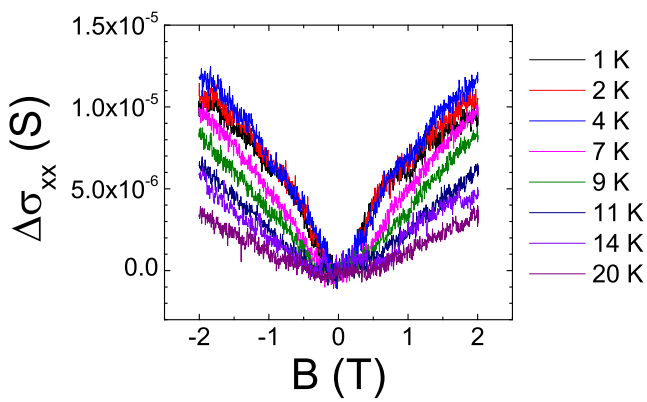

Fig 2: Differential magnetoconductance of MoS_2

Magneto-transport measurements of few-layer MoS_2 and $TaSe_2$ flakes exfoliated onto insulating substrates were performed using SCM2 at NHMFL, Tallahassee, FL. Figure 1 shows weak anti-localization in a $TaSe_2$ flake and indicates strong spin orbit coupling in $TaSe_2$. L_{so} is estimated to be about 20 nm at T~1K. Figure 2 shows weak localization in a MoS_2 flake and indicates the relatively weaker spin orbit coupling in MoS_2. L_{so} for the MoS_2 is estimated to be about 430 nm at T~1K.

Conclusions

Strong spin orbit coupling is observed in $TaSe_2$, whereas relatively weaker spin orbit coupling is observed in MoS_2. This variety of spin transport properties among the transition metal dichalcogenides allow for future studies of a wide variety of spintronics devices in the 2D material platform.

Acknowledgements

This work is supported by the Semiconductor Research Corporation (SRC) Global Research Collaboration (GRC), NSF Cooperative Agreement No. DMR-1157490, the State of Florida, and the U.S. Department of Energy.

References

[1] Novoselov, K.S., et al. *Science*, **306,** 666 (2004).
[2] Novoselov, K.S., et al. *Nature*, **438**, 197, (2005).
[3] Zhang, Y., et al. *Nature*, 438, 201, (2005).
[4] Teweldebrhan, D., et al. *Nano Letters*, **10**, 1209 (2010).
[5] Mak K.F., et al. *Phys. Rev. Lett.*, **105**, 136805, (2010).
[6] Radisavljevic, B., et al. *Nature Nano.*, **6**, 147, (2011).
[7] Splendiani, A., et al. *Nano Letters*, **10**, 1271, (2010).
[8] Liu, H., et al. *Electron Device Letters*, **33**, 546 (2012).
[9] Liu, H., et al. *ACS Nano*, **6**, 8563 (2012).
[10] Wilson, J., et al. *Advances in Physics*, **18**, 193 (1969).