Hidden Interfaces and High-Temperature Magnetism in Intrinsic Topological Insulator - Ferromagnetic Insulator Heterostructures

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New functionality often arises at the mesoscale at the interfaces. Generating exchange-induced ferromagnetism on the surface of a topological insulator (TI) with a ferromagnetic insulator (FMI) provides a clean approach for realizing many potential device applications exhibiting novel quantum functionality. Here we demonstrate a fundamental step towards realization of high temperature magnetization in combination of TI and FMI heterostructures through observation of magnetic proximity-induced via the exchange interaction. We have successfully introduced the ferromagnetic order onto the surface of epitaxial Bi_2Se_3 films employing exchange coupling through proximity with the ferromagnetic insulator EuS. Polarized Neutron Reflectiometry allows a unique insight into structures with the ability to access buried interfaces/structures enables us to efficiently discriminate the magnetism at the surface of TI from the magnetization distribution in FMI layer. This unique tool provides direct evidence that Bi_2Se_3-EuS heterostructures exhibit proximity-induced interfacial magnetization in the top 2 QL (~2 nm) layer of Bi_2Se_3. We show that such effects originate through exchange interaction, without structural perturbation at the interface.

The Bi_2Se_3 is spin polarized in the surface plane, accompanied by magnetic order in the immediate region of the interface and decaying into the TI layer. This interfacial ferromagnetism persists up to room temperature, even though the FMI (EuS) is known to order ferromagnetically only at low temperatures (< 17 K). The induced magnetism at the interface resulting from the large spin-orbit interaction and spin-momentum locking property of the TI surface is found to greatly enhance the magnetic ordering (Curie) temperature of the TI/FMI bilayer system. Due to the short range nature of the ferromagnetic exchange interaction, the time-reversal symmetry is broken only near the surface of a TI, while leaving its bulk states unaffected [1].

The TI ferromagnetism is observed reproducibly in a variety of bi-layer samples with different combinations of thicknesses, providing a mechanism to control this effect. These findings of locally-induced ferromagnetic order on the TI surface extending over macroscopic areas without impurity doping opens the door for an energy efficient topological control mechanism for future spin-based technologies. Work supported by U.S. DOE, Office of Science, BES

[1] F. Katmis, V. Lauter, F. Nogueira, B. Assaf, M. Jamer, P. Wei, B. Satpati, J. Freeland, I. Eremin, D. Heiman, P. Jarillo-Herrero, J. Moodera, “Achieving high-temperature ferromagnetic topological insulating phase by proximity coupling”, Nature 2016, in print.

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