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Electrical detection of current-induced spin polarization due to spin-momentum locking in the topological insulator Bi_2Se_3[1]

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Topological insulators (TIs) exhibit topologically protected metallic surface states populated by massless Dirac fermions with spin-momentum locking – the carrier spin lies in-plane, locked at right angle to the carrier momentum. An unpolarized charge current should thus create a net spin polarization whose amplitude and orientation are controlled by the charge current. Here we show direct electrical detection of this bias current induced spin polarization as a voltage measured on a ferromagnetic (FM) metal tunnel barrier surface contact [1]. The magnetization of the contact determines the spin detection axis, and the voltage measured at this contact is proportional to the projection of the TI spin polarization onto this axis. When the charge current is orthogonal to the magnetization of the FM detector contact, the TI spin is parallel (or antiparallel) to the magnetization, and a spin-related signal is detected at the FM contact proportional to the magnitude of the charge current. The voltage measured scales inversely with Bi_2Se_3 film thickness, and its sign is that expected from spin-momentum locking and opposite that of a Rashba effect [2]. Similar data are obtained for two different FM contact structures, Fe/Al_2O_3 and Co/MgO/graphene, underscoring the fact that these behaviors are due to bias current induced spin polarization in the TI surface states rather than the bulk, and are independent of the details of the contact. These results demonstrate simple and direct electrical access to the TI Dirac surface state spin system, provide clear evidence for the spin-momentum locking and bias current-induced spin polarization, and enable utilization of these remarkable properties for future technological applications.

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[2] S. Hong, V. Diep, S. Datta and Y.P. Chen, Phys. Rev. B. 86, 085131 (2012).

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