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Electrostatically Manipulated Ballistic Spin Currents[1]

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Two decades ago Datta and Das published a remarkable paper [1] concerning spin polarized ballistic electron currents in a semiconductor channel and the Rashba spin orbit interaction. They predicted that the source-drain conductance of a spin-injected Field Effect Transistor (spin FET) would oscillate periodically as a function of monotonically increasing gate voltage. We have observed Datta Das oscillations using spin-FETs with ferromagnetic metal electrodes as source and drain [2]. The channel is composed of a high mobility InAs single quantum well heterostructure with strong spin-orbit interaction. The source-drain length is less than the electron mean free path at T=1.8 K. Using the nonlocal geometry, diffusive carriers are removed at a remote ground and the channel conductance is dominated by a current of spin polarized ballistic electrons. A conductance that oscillates as a function of gate voltage is observed. The oscillation amplitude is calibrated from the lateral spin valve magnetoresistance. The spin-orbit interaction parameter is determined from beats in Shubnikov-de Haas data. Thus, the fit to theory has no adjustable parameters other than a small phase factor. Finally, we compare the temperature dependence of the oscillation amplitude with that of the carrier mean free path. The importance to Spintronics, which proposes the use of both spin and charge as state variables, is the demonstration that carrier spin orientation can be modulated by voltage, a parameter normally associated with charge.

[1] S. Datta and B. Das, Appl. Phys. Lett. v. 56, 665 (1990).
[2] H.C. Koo, J.H. Kwon, J. Eom, J. Chang, S.H. Han and M. Johnson, Science v. 35, 1515 (2009).

[1]In collaboration with H.C. Koo, J. Eom, S.H. Han and J. Chang. I acknowledge support from ONR.