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Electrical detection of spin transport in lateral ferromagnet-semiconductor devices[1]

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A fully electrical scheme of spin injection, transport, and detection in a single ferromagnet-semiconductor structure has been a long-standing goal in the field of spintronics. In this talk, we report on an experimental demonstration of such a scheme. The devices are fabricated from epitaxial Fe/GaAs (100) heterostructures with highly doped GaAs as a Schottky tunnel barrier. A set of closely spaced Fe contacts on the top of an n-GaAs channel are used as spin injectors and detectors. Reference electrodes are placed at the far ends of the channel, allowing for non-local spin detection [1]. The electro-chemical potential of the detector is sensitive to the relative magnetizations of the injector and detector. In spin-valve measurements, a magnetic field is applied along the Fe easy axis to switch the relative magnetizations of injector and detector from parallel to antiparallel, resulting in a voltage jump that is proportional to the non-equilibrium spin polarization in the channel. A more rigorous test of electrical spin detection is the observation of the Hanle effect, in which an out-of-plane magnetic field is used to modulate and dephase the spin polarization in the channel. The magnitudes of the observed Hanle curves agree with the results of the spin-valve measurements. The dependence of the Hanle curves on temperature and contact separation is studied in detail and is consistent with a drift-diffusion model incorporating spin precession and relaxation. The spin polarization generated by spin injection (reverse bias at the injector) or spin accumulation (forward bias at the injector) is measured using the magneto-optical Kerr effect and is found to be in good agreement with the spin-dependent non-local voltage. Both the transport and optical measurements show a non-linear relationship between the bias voltage at the injector and the spin polarization in the channel. [1] M. Johnson and R. H. Silsbee, Phys. Rev. Lett. **55**, 1790 (1985).

[1]This work was done in collaboration with C. Adelmann, S. A. Crooker, E. S. Garlid, J. Zhang, S. M. Reddy, S. D. Flexner, C. J. Palmstrøm, and P. A. Crowell and was supported by the NSF MRSEC program and ONR.