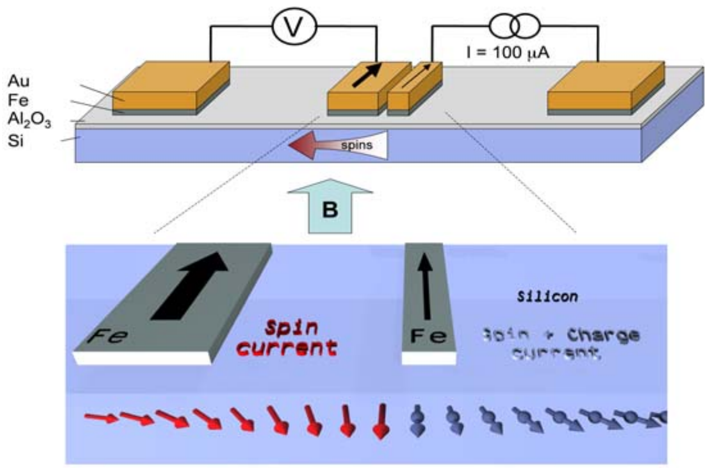
Generation, Manipulation and Detection of Pure Spin Currents in Silicon

The electronics industry to date has used size scaling (Moore's Law) to continuously increase the performance of existing electronics. However, size scaling cannot continue indefinitely, and new approaches must be developed. The *International Technology Roadmap for Semiconductors* has identified the use of the electron's spin as a new state variable that should be explored as an alternative to the electron's charge. The use of ***pure spin currents*** to process information is regarded as the "holy grail" of semiconductor spintronics, as it frees one from the constraints of capacitive time constants, resistive voltage drops and heat buildup which accompany charge motion.

NRL scientists from Codes 6361 and 6812 lead by Dr. Berend Jonker have generated, modulated and electrically detected pure spin currents in silicon (Si), the semiconductor used most widely in the electronics industry. Iron contacts on a 1 nm Al_2O_3 tunnel barrier on the surface of an *n*-type Si layer enable generation of a spin current which flows separately from a charge current. The spin orientation is electrically detected as a voltage at a second Fe/Al_2O_3 contact, and the relative magnetizations of these contacts allow full control over the orientation of the spin in the Si channel. They further showed that the spin in the Si could be uniformly rotated by an applied magnetic field, a process known as coherent precession. This was accomplished in a lateral transport geometry using lithographic techniques compatible with existing device geometries and fabrication methods. These results demonstrate that information can be successfully imprinted into the Si spin system, manipulated and read out as a voltage. The generation of pure spin currents, coherent spin precession and electrical detection compatible with "back-end" Si processing will greatly facilitate development of silicon-based spintronic devices.



Contact geometry used in this study. Spin-polarized electrons from the Fe/Al_2O_3 tunnel barrier generate a pure spin current flowing in the opposite direction. This spin current produces a voltage at a second magnetic contact that is sensitive to the relative orientation of the spin in the silicon. They further showed that the orientation of the spin in the silicon could be uniformly rotated by an applied magnetic field, a process referred to as coherent precession. The Al_2O_3 tunnel barrier is approximately 1 nm thick.

O.M.J. van 't Erve, A.T. Hanbicki, M. Holub, C.H. Li, C. Awo-Affouda, P.E. Thompson and B.T. Jonker, "Electrical injection and detection of spin-polarized carriers in silicon in a lateral transport geometry," *Applied Physics Letters* ***91****, 212109* (2007).

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