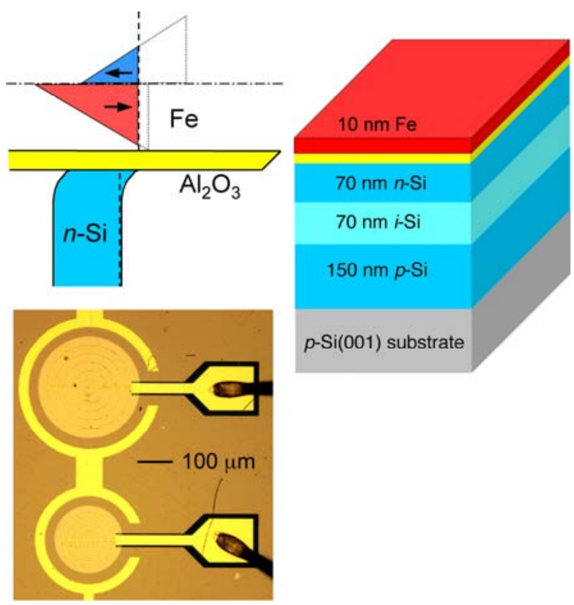
Efficient Electrical Spin Injection into Silicon

The electronics industry to date has relied upon the control of charge flow, and used size scaling to continuously increase the performance of existing electronics. However, size scaling cannot continue indefinitely (the “Moore’s Law Roadblock”), and new approaches must be developed. Basic research efforts have shown that *spin angular momentum*, another fundamental property of the electron, can be used to store and process information in solid state devices, an approach known as *semiconductor spintronics*. The *International Technology Roadmap for Semiconductors* has identified the electron’s *spin* as a new state variable which should be explored for use beyond CMOS. While much progress has been made in III-V semiconductors such as gallium arsenide, little progress has been made in silicon (Si), despite its overwhelming dominance of the semiconductor industry.

NRL scientists from Codes 6361 and 6812 lead by Dr. Berend Jonker have efficiently injected a current of spin-polarized electrons from an iron thin film contact through a nanometer thick Al_2O_3 tunnel barrier into Si, producing a large electron spin polarization. Efficient spin injection was confirmed by the emission of circularly polarized light from the Si, and analysis determined a lower bound of 30% for the Si electron spin polarization. For comparison, the spin polarization of electrons in common magnetic metals such as permalloy or iron is ~ 40- 45%. This approach injects spin-polarized electrons near the Si conduction band edge with near unity conversion efficiency and low bias voltages (~ 2 eV) compatible with CMOS technology, using a simple magnetic tunnel barrier compatible with "back-end" Si processing. This demonstration is a key enabling step for developing silicon-based spintronic devices which are expected to provide higher performance with lower power consumption and heat dissipation.



The illustration shows the surface-emitting LEDs used in this study. Efficient injection of spin-polarized electrons from the Fe/Al_2O_3 tunnel barrier contact is confirmed by the emission of circularly polarized electroluminescence from the silicon. The electron spin polarization in the silicon is approximately 30%. The Al_2O_3 tunnel barrier is approximately 1 nm thick.

B.T. Jonker, G. Kioseoglou, A.T. Hanbicki, C.H. Li and P.E. Thompson, “Electrical spin injection into silicon from a ferromagnetic metal / tunnel barrier contact,” *Nature Physics* ***3**, 542* (2007).

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