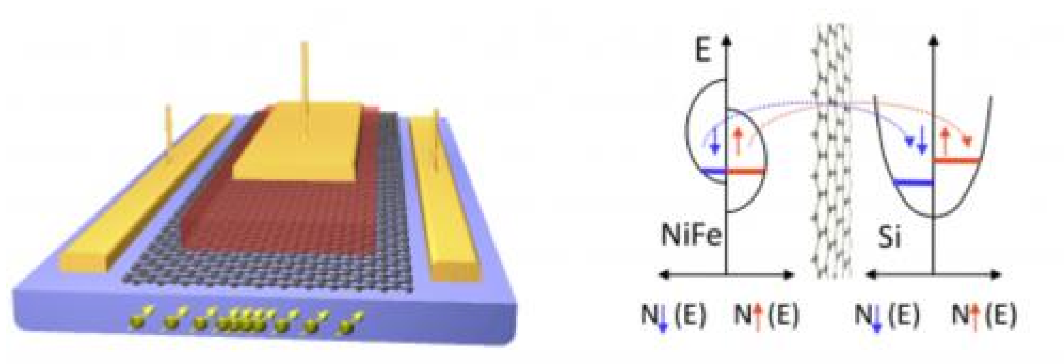
Researchers discover new route to spin-polarized contacts on silicon

October 22 2012



NRL scientists successfully used graphene, a single layer of carbon atoms in a honeycomb lattice (gray), as a tunnel barrier to electrically inject spin polarized electrons from a ferromagnetic NiFe contact (red) into a silicon substrate (purple). The net spin accumulation in the silicon produces a voltage, which can be directly measured. Spin injection, manipulation and detection are the fundamental elements allowing information processing with the electron spin rather than its charge. Credit: U.S. Naval Research Laboratory

(Phys.org)—Scientists at the Naval Research Laboratory have demonstrated that graphene, a single layer of carbon atoms in a honeycomb lattice, can serve as a low resistance spin-polarized tunnel barrier contact which successfully enables spin injection/detection in silicon from a ferromagnetic metal.

The graphene provides a highly uniform, chemically inert and thermally robust tunnel barrier free of defects and trap states which plague oxide barriers. This discovery clears an important hurdle to the development of future semiconductor spintronic devices, that is, devices which rely on manipulating the electron's spin rather than its charge for low-power, high-speed information processing beyond the traditional size scaling of Moore's Law.

The research results are reported in a paper published in *Nature Nanotechnology* on September 30, 2012.

Ferromagnetic metals, such as iron or permalloy, have intrinsically spin-polarized electron populations (more "spin-up" electrons than "spin-down", see figure), and are thus ideal contacts for injection and detection of spin in a semiconductor. An intervening tunnel barrier is required to avoid saturation of both semiconductor spin channels by the much larger metal conductivity - this would otherwise result in no net spin polarization in the semiconductor. However, the oxide barriers typically used (such as Al2O3 or MgO) introduce defects, trapped charge and interdiffusion, and have resistances, which are too high - all of these factors severely impact the performance. To solve this problem, the NRL research team, led by Dr. Berend Jonker, used single layer graphene as the tunnel barrier. This novel approach utilizes a defect resistant, chemically inert and stable material with well-controlled thickness to achieve a low resistance spin contact compatible with both the ferromagnetic metal and semiconductor of choice. These qualities insure minimal diffusion to/ and from the surrounding materials at temperatures required for device manufacturing.

The research team used this approach to demonstrate electrical generation and detection of spin accumulation in silicon above room temperature, and showed that the contact resistance-area products are 100 to 1000 times lower than achieved with oxide tunnel barriers on silicon substrates with identical doping levels.

These results identify a new route to low resistance-area product spin-polarized contacts, a key requirement for semiconductor spintronic devices that rely upon two-terminal magnetoresistance, including spin-based transistors, logic and memory, explains NRL's Dr. Berend Jonker.

In looking to the future, the NRL team suggests that the use of multilayer graphene in such structures may provide much higher values of the tunnel spin polarization due to band structure derived spin filtering effects which have been predicted for selected ferromagnetic metal / multi-layer graphene structures. This increase would improve the performance of semiconductor spintronic devices by providing higher signal to noise ratios and corresponding operating speeds, advancing the techological applications of silicon spintronics.

More information: DOI 10.1038/nnano.2012.161

Provided by Naval Research Laboratory