Giant Spin Accumulation in Si Non-local Devices with Fe/MgO Tunnel Contacts

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Silicon, owing to its compatibility with the existing complementary metal-oxide semiconductor technology and its long spin coherence, is one of the most suitable candidates to develop spin-based semiconductor devices. Over the past years, spin transport in Si using ferromagnetic (FM) tunnel contacts in the non-local (NL) spin-valve geometry was reported by several groups [1-5]. However, the observed NL spin signals were rather small and the extracted contact tunneling spin polarization (a few %) was much lower than expected [1-4]. Although some enhancement was recently reported by using Heusler alloys as a tunnel contact [5], achieving large spin signals in Si is still a major challenge.

Here, we observed NL spin signals in Si that correspond to a giant spin accumulation of more than 10 meV, demonstrating that large carrier spin polarization can indeed be created in Si spintronics devices. The four-terminal lateral spin-transport devices have a 70 nm-thick phosphorus-doped n-type Si(001) channel and Fe/MgO(001) FM tunnel contacts grown by molecular beam epitaxy. Each device has two FM contacts for spin injection and detection, and two nonmagnetic outer electrodes for 4-terminal current and voltage measurements. The FM contacts all have a length of 40μm, a width that varies from 0.4 to 2.4 μm, while the gap between injector and detector contact is between 0.4 and 1.2 μm. Clear NL spin-valve signals and Hanle-type spin precession signals were observed. Interestingly, for a constant current density, the magnitude of the NL spin signal was larger when the wider contacts FM2 were used as the injector. The data for devices with different dimensions can all be consistently described by numerical calculations of spin injection and spin diffusion, provided that the contact size is explicitly taken into account. From these findings, we deduce a tunneling spin polarization of the Fe/MgO contact of ~ 53 % and a spin accumulation as large as 17 meV in the Si channel at 10 K [6].

References

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