Pronounced Scaling of the Tunnel Spin Polarization of Fe/MgO/silicon Contacts with MgO Thickness

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The discovery of giant tunnel magnetoresistance in crystalline Fe/MgO/Fe magnetic tunnel junctions greatly accelerated the development of practical spintronic applications. Inspired by this success, crystalline MgO has also widely been used in semiconductor spintronic devices. Indeed, it has been shown that a charge current across a FM/MgO/semiconductor tunnel junction results in spin injection into the semiconductor[1-4]. With this approach, we recently demonstrated the creation of a giant spin accumulation in Si using Fe/MgO tunnel contacts[4]. However, some important questions remain, such as how the tunnel spin polarization (TSP) varies as a function of the MgO thickness and what is the role of symmetry-based spin filtering due to coherent tunneling in Fe/MgO tunnel contacts on Si. Here we report on these two aspects[5].

The Fe/MgO contacts were deposited on a Si substrate having a 70 nm-thick heavily-doped Si(001) channel and a MgO thickness (t_{MgO}) varying from 0.75 nm to 2.3 nm. The spin current produced by a charge current across the Fe/MgO/Si tunnel junction was measured using the standard 4-terminal nonlocal geometry. The TSP was extracted from the magnitude of the nonlocal spin-valve and Hanle signals. As shown in Fig. 1, the TSP depends sensitively on t_{MgO}, increasing from values below 1 % at small thickness, to values in the 90 to 95 % range for t_{MgO} above 2 nm. Such a near-perfect spin polarization of the tunnel current indicates that symmetry-based spin filtering due to coherent tunneling occurs in Fe/MgO tunnel contacts on Si, despite the significant lattice mismatch. The unexpected drop of the TSP below 1 nm of MgO is attributed to the lower crystalline quality of thin MgO layers, as supported by TEM. The scaling of the TSP can be well described (Fig. 1) by assuming coherent spin-dependent tunneling, but excluding the first 0.7 nm of MgO, which has lower quality. The pronounced scaling of the TSP with MgO thickness, as revealed here, has important implications for achieving large magnetoresistance in Si-based devices.

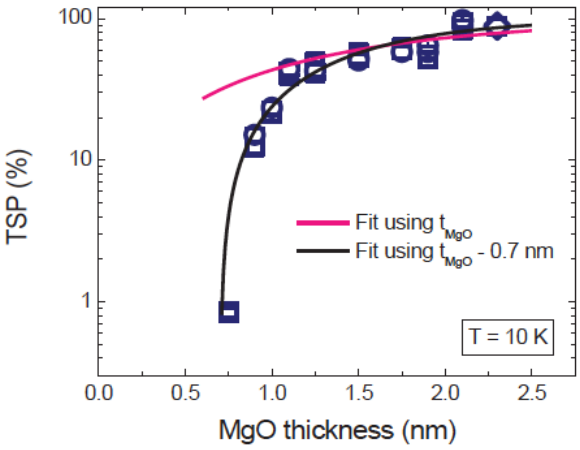

Figure 1: Scaling of the TSP of Fe/MgO tunnel contacts on Si with MgO thickness. The black solid line is a fit assuming coherent tunneling, but excluding 0.7 nm of MgO.

References:

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