Spin Diffusion in Silicon from a Ferromagnetic Contact

J. Ghosh[1], V. Sverdlov[1], and S. Selberherr[1]

[1]Institute for Microelectronics, TU Wien, Gußhausstraße 27–29/E360, 1040 Wien, Austria

Spin current generation in silicon and other semiconductors by purely electrical means is paramount for building spintronic devices. Recently, a robust spin injection into a semiconductor from a ferromagnetic metal contact has been performed at room temperature [1], but the spin accumulation signal obtained with the three-terminal measurement setup is reported to be higher than the theoretical prediction [1]. An evidence that the presence of an interface space charge may boost the spin injection by an order of magnitude has been presented [2]. It is noticed that the interface charge accumulation helps the spin current to increase only close to the interface, while at a distance of about the Debye screening length (λ_D) away, the value of the spin current is similar to the one at charge neutrality [3]. In this paper we consider a contact between a semiconductor ferromagnet and silicon and investigate the influence of charge accumulation at the interface on the spin injection in the silicon side. We assume that the density of states for the up(down)-spin electron in the ferromagnet (*P*: bulk spin polarization) is equal to the corresponding density of states in the semiconductor multiplied by 1±*P*. We define *K* as the ratio of the doping level in the ferromagnet to that in silicon. The flow of charge current assists spin accumulation at the interface. First, we preserve charge neutrality under *K*=1 and compare the spin current injection efficiency (α_0) with the analytical predictions [4], and we obtain a good agreement (Fig. 1). Then *K* is increased (decreased) to introduce the charge and the spin accumulation (depletion) at the interface. However, in this case, α_0 at a distance λ_D away from the interface (Fig. 2) is only slightly affected. So, an introduction of space charge at the junction between a ferromagnetic and a non-magnetic semiconductor does not increase the spin injection efficiency.

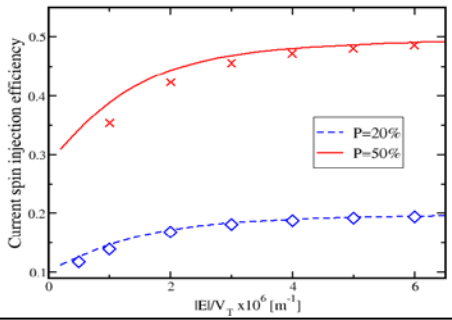

Fig 1: α_0 versus the electric field. Doping: 10^{16} cm^{-3} kept throughout. Lines: Theory

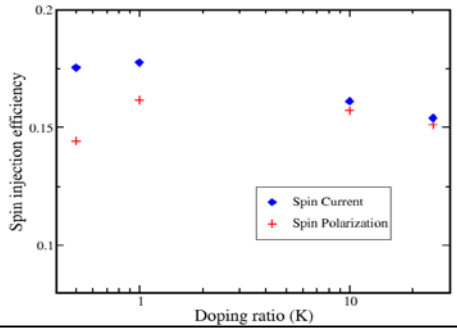

Fig 2: Spin injection efficiency for P=20%, applied voltage 310 mV, channel length 4 μm.

This work is supported by the European Research Council through the grant #247056 MOSILSPIN.

References:

[1] R. Jansen, *Nature Mater.* **11**, 400 (2012).
[2]M.R. Sears and W.M. Saslow, *Phys.Rev.B* **85**, 014404 (2012).
[3]J. Ghosh, V. Sverdlov, T. Windbacher, and S. Selberherr, *J.App.Phys.* **115**, 17C503 (2014).
[4]Z.G. Yu and M.E. Flatte, Phys. Rev. B **66**, 235302 (2002).

Corresponding author: Joydeep Ghosh, Institute for Microelectronics, TU Wien, Gußhausstr. 27–29, 1040 Wien, Austria. Tel.: +43-1-58801-36060, Fax: +43-1-58801-36099, Mail: ghosh@iue.tuwien.ac.at.