Increment of Spin Lifetime by Spin Injection Orientation in Stressed Thin SOI Films

Joydeep Ghosh, Viktor Sverdlov, and Siegfried Selberherr
Institute for Microelectronics, TU Wien
Gußhausstraße 27-29/E360, A-1040 Wien, Austria
{ghosh|sverdlov|selberherr}@iue.tuwien.ac.at

The scaling of CMOS devices is about to reach fundamental limits, and this prompts the development of new technologies in semiconductor industry. Spin-based electronics or spintronics is considered as one of the alternatives in ‘beyond CMOS’ research. Silicon, the main element of microelectronics, appears to be the perfect material for spin-driven applications. Purely electrical spin injection in silicon from a ferromagnetic contact at room temperature has been successfully demonstrated [1]. However, a large spin relaxation in electrically-gated silicon structures as experimentally observed [2] could become an obstacle in realizing spin driven devices. Therefore, a deeper understanding of the fundamental spin relaxation mechanism in SOI MOSFETs is urgently needed. Stress has been traditionally used to enhance the electron mobility, and it has been demonstrated that, when spin is injected perpendicular to the film, shear strain due to tensile stress in [110] direction is also extremely efficient in boosting the spin lifetime (τ) in advanced (001) SOI MOSFETs with ultra-thin body [3]. It has also been mentioned that spin flip scattering processes between the two un-primed [001] valleys are primarily responsible for spin relaxation in the film [4]. The physical reason for the enhancement of τ by shear strain lies in an ability to lift completely the degeneracy between the remaining two valleys in a confined electron systems by uniaxial stress. This significantly suppresses the main component of spin relaxation due to intervalley scattering (Figure 1). We demonstrate a further reduction of the spin relaxation at any fixed stress, when the spin injection direction (denoted by polar angle θ) is gradually drawn towards in-plane ($\theta=\pi/2$), given by $\frac{1}{\tau(\theta)} \propto 1 + \cos^2\theta$. This allows to further increase τ by a factor of two for the in-plane injection orientation as shown in Figure 2 at any stress value.

This research is supported by the European Research Council through the Grant #247056 MOSILSPIN.

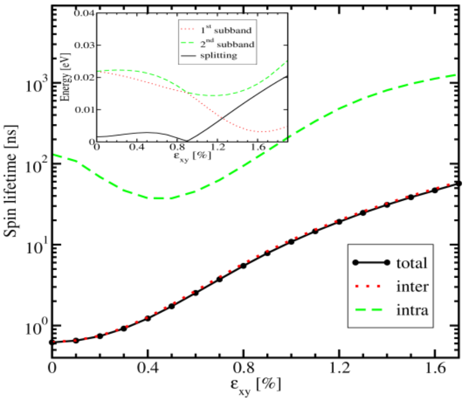

Figure 6 Variation of the spin lifetime with stress with its components. Thickness t=4.34nm, T=300K, electron conc. $N_S=1.29\text{x}10^{12}$ cm^{-2}.

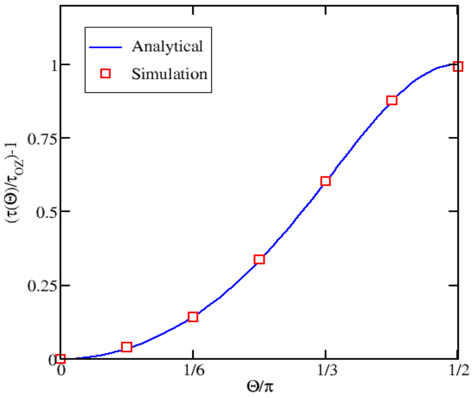

Figure 2 Dependence of the spin lifetime τ with spin injection orientation θ at any fixed stress point. τ_{OZ}: τ(θ=0).

[1] R. Jansen, *Nature Materials* **11**, p. 400, 2012.
[2] J. Li, I. Appelbaum, *Appl. Phys. Lett.* **100**, 162408, 2012.
[3] D. Osintsev *et al.*, *Solid-State Electronics*, 2015.
[4] J. Ghosh *et al.*, *Microelectronic Engineering* **147**, 2015.