Strained silicon-on-insulator for spintronic applications: Giant spin lifetime enhancement

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With CMOS feature size rapidly approaching ultimate limits, electron spin is attracting attention as an alternative to the electron charge. Silicon appears to be the perfect material for spin-driven applications. Room-temperature electrical spin injection into Si from a ferromagnetic contact has been successfully demonstrated [1]. Silicon is mostly composed of nuclei with zero spin and characterized by very weak spin-orbit interaction, favoring long spin lifetimes. The main spin relaxation mechanism in bulk Si at T = 300 K is phonon-mediated intervalley scattering [2, 3]. This process can be eliminated by partially lifting the valley degeneracy, either by applying stress or by confining the electrons. However, fast spin relaxation in electrically-gated Si structures [4] could become a challenge for spin-driven devices. Therefore, a deeper understanding of spin relaxation in SOI MOSFETs is urgently needed.

We discuss how shear strain, traditionally used to enhance the electron mobility, is also extremely efficient in boosting spin lifetimes in advanced (001) SOI MOSFETs with ultra-thin body. An accurate model of spin relaxation in strained films, taking into account the peculiarities of Si band structure and scattering mechanisms, has been developed [5]. We show that shear strain dramatically reduces spin relaxation, boosting the spin lifetime by an order of magnitude, see Fig. 1(a). The physical reason is the lifting of the degeneracy between the remaining two valleys in a confined electron systems, see Fig. 1(b). We note that the degeneracy between equivalent valleys was a longstanding problem in Si spintronics. Indeed, apart from causing a strong spin relaxation, valley degeneracy introduces unwanted competition between valley and spin quantum numbers, limiting device operation. Thus, lifting the valley degeneracy completely in a controllable way by means of standard stress techniques used by the semiconductor industry represents a major breakthrough in future employment of silicon for spin-driven applications.

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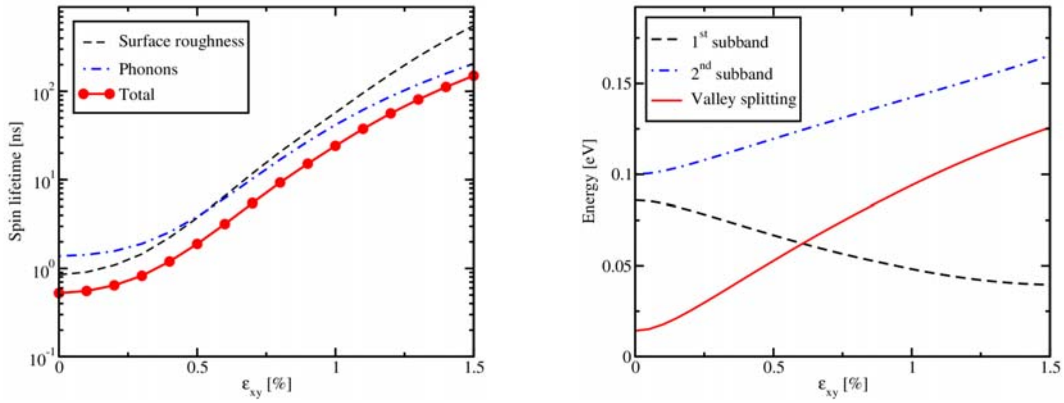

Fig. 1. (a) Spin lifetime *vs.* shear strain and (b) valley splitting *vs*. shear strain in a 2.1 nm thin Si film.

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