Valley degeneracy and spin lifetime enhancement in stressed silicon films

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Recent advances in development of multi-core processor architectures and three-dimensional (3D) integration supported by continuous semiconductor device scaling continued to boost the performance of modern computers. However, in order to proceed with the performance enhancement beyond 3D integration completely new innovative approaches are mandatory. The electron spin attracts a significant attention [1] as a compliment or even a replacement of charge degree of freedom. Silicon is a perfect material for spin-driven applications because of the long spin lifetime at room temperature [1,2]. In gated silicon structures with lateral spin transport large spin relaxation is reported [3]. Due to the practical importance of such systems understanding the spin relaxation as well as finding ways to enhance the spin lifetime in ultra-scaled MOSFETs is urgently needed.

Mechanical stress is routinely employed to boost the electron mobility in silicon. Biaxial stress within the (001) plane lifts the degeneracy between the valleys, thus reducing the spin relaxation dominated by the electron-phonon intervalley scattering between the nonequivalent conduction band valleys [2]. However, because of the preserved degeneracy between the two [001] valleys, the spin relaxation due to these intervalley transitions remains large [4]. A much sharper increase of spin lifetime predicted in strained germanium [5] indicates that the complete degeneracy lifting between the valleys is essential.

We show that the degeneracy between the [001] valleys in silicon films and inversion layers can be efficiently removed by shear compressive strain, as is already employed for mobility enhancement in modern ultra-scaled MOSFETs. The subband structure in a silicon film as a function of shear strain (Fig.1, left) is found by the **k.p** method [6]. The degeneracy between the unprimed subbands is lifted which results in a sharp increase of the spin lifetime in silicon (Fig.1, right).

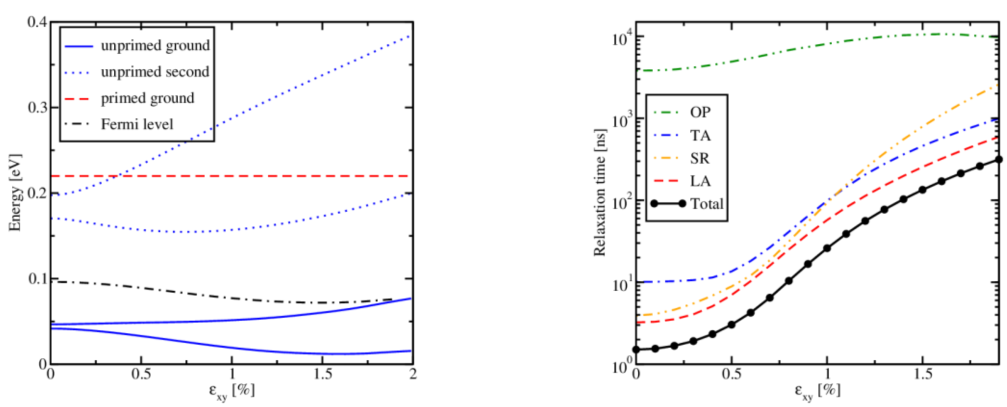

Fig.1: Subband structure (left) and spin lifetime (right) as function of shear strain in a 3nm thin silicon film. Contributions due to optical, acoustic, and surface roughness induced spin relaxation are included.

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