Silicon for spintronic applications: Strain-enhanced valley splitting

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Spin as a degree of freedom is promising for future nanoelectronic devices and applications. A recently proposed concept of a racetrack memory is based on controlled domain wall movement by spin-polarized currents [1]. Spin-controlled qubits may form a basis for upcoming logic gates. Silicon is composed of spin-zero nuclei and is characterized by small spin-orbit coupling, making it attractive for future spintronic applications. However, the conduction band of silicon contains six equivalent valleys, which is a source of potentially increased decoherence unless valley splitting is made larger than the spin Zeeman splitting. Recent experiments on point contacts demonstrated that a valley splitting larger than the spin splitting can be achieved by laterally confining a gated Si-SiGe electron system [2]. Here we propose an alternative way to enhance the valley splitting by introducing strain. Uniaxial stress is already used to boost the performance of modern MOSFETs, and its application to increase the valley splitting comes at no extra cost.

In order to analytically demonstrate strain-enhanced valley splitting, we have adopted the two-band **k·p** model for the conduction band [3, 4] to describe it in the presence of shear strain. The good agreement of the analytical two-band **k·p** model with numerical pseudo-potential band structure calculations is shown in Fig. 1(a). With this model the subband structure for an infinite square well can be calculated and the values of the quantization wavevectors obtained from a graphical solution as in Fig. 1(b). For small strain η the valley splitting is linear. We will show results for arbitrary strain values and different Si film thicknesses.

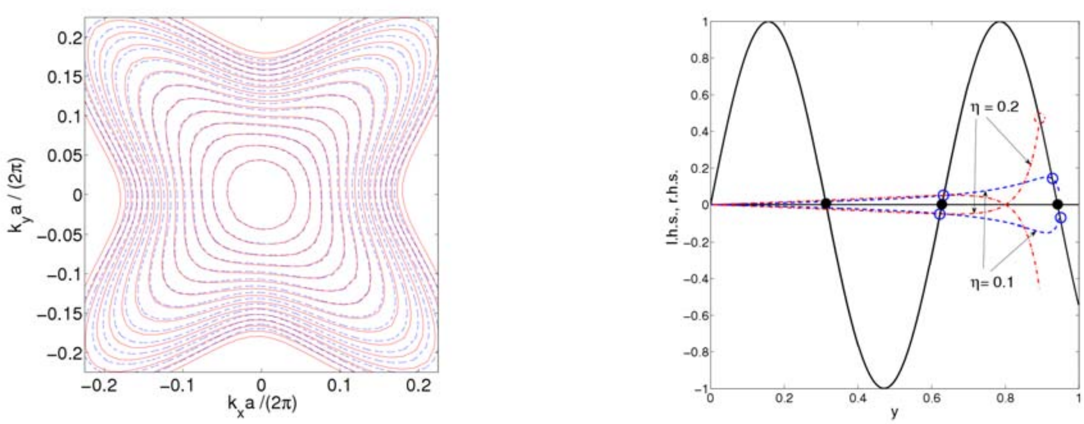

Fig. 1. (a) Two-band **k·p** theory (dashed) *vs.* pseudopotential calculations (solid), for 50 meV contour line spacing with tensile [110] and compressive [-110] stress of 150 MPa. (b) Graphical solution for the lifting of valley degeneracy (solid circles at η = 0) by non-zero shear strain.

1. S. Parkin *et al.*, *Science* **320**, 191 (2008).
2. S. Goswami *et al.*, *Nature Physics* **31**, 41 (2007).
3. V. Sverdlov *et al.*, *ESSDERC* 2007, p. 386; E. Ungersboeck *et al.*, *IEEE T-ED* **54**, 2183 (2007).
4. J. C. Hensel *et al.*, *Phys. Rev.* **138**, A225 (1965).