Low-Field Electron Mobility in Stressed UTB SOI MOSFETs for Different Substrate Orientations

E. Ungersboeck, V. Sverdlov, H. Kosina,
and S. Selberherr
Institute for Microelectronics, TU Wien,
Gußhausstraße 27–29, 1040 Wien, Austria
Phone: +43-1-58801/36022, Fax: +43-1-58801/36099,
E-Mail: ungersboeck@iue.tuwien.ac.at

Even though it is well known that ultra-thin body (UTB) SOI MOSFETs have a better scaling potential than bulk devices, the effect of stress on UTB MOSFETs has received less attention until recently (1). In the present work the origin of the stress induced effective electron mobility enhancement $\Delta\mu_{\mathrm{eff}}$ in UTB MOSFETs on (001) and (110) wafers is investigated. Since our simulations for stressed (001) wafers match well with experimental data (1,4) we are able to predict stress effects on UTB MOSFETs on (110) substrates.

By generalizing the empirical pseudopotential method for arbitrary stress conditions a pronounced change of the transport masses on (001) substrates with tensile stress along [110] was obtained (2). This effective mass change is present also in uniaxially stressed SiGe channels, whereas it is not observed in biaxially strained Si resulting from epitaxial growth of Si on SiGe. To investigate the stress induced mobility enhancement we are using a Monte Carlo algorithm developed for small signal response calculations (3), which is formally exact in the limit of small driving fields and allows to take anisotropic scattering, degeneracy effects and non-parabolic subband structures into account.

First, we simulate the surface mobility for substrate orientation (001) and (110). Results agree well with experimentally measured mobilities (see Fig 1). Next, two stress conditions are identified which will yield mobility enhancement on both substrate orientations, and the effect of stress on μ_{eff} at two different body thicknesses (T_{SOI}) are compared to each other.

On (001) substrates stress was applied in the channel direction [110] in order to benefit from two effects: stress induced valley splitting and the effective mass change. For T_{SOI}=20 nm, $\Delta\mu_{\mathrm{eff}}$ can be understood from a combination of the two effects yielding an anisotropic $\Delta\mu_{\mathrm{eff}}$ as compared to the unstressed system. At T_{SOI}=2.4 nm the strong quantum confinement induces an intrinsic valley splitting, thus the stress induced valley shifts have no further effect on the mobility. The larger $\mu_{\mathrm{eff}||}$ and smaller $\mu_{\mathrm{eff}\perp}$ parallel/perpendicular to the stress direction is a result from the effective mass change only and found in good agreement with experimental data (1).

On (110) substrates stress and channel direction were chosen to be [001]. Band structure calculations have shown that in this system the effective mass change is negligible, thus $\Delta\mu_{\mathrm{eff}}$ stems from the stress induced valley shift only. Simulations yield the experimentally observed (4) correct anisotropy at $T_{\mathrm{SOI}} = 20$ nm. In contrast to (100) substrates, when reducing T_{SOI} on (110) substrates stress induced $\Delta\mu_{\mathrm{eff}}$ decreases, as no effective mass change occurs.

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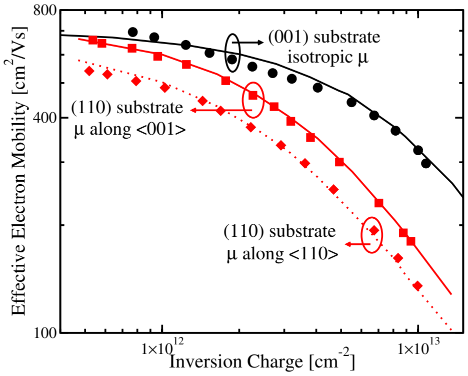

Figure 1: Simulated μ_{eff} for substrate orientation (001) and (110) compared to measurements (5,6) (symbols). The anisotropic μ_{eff} on (110) is given along ⟨001⟩ and ⟨110⟩.

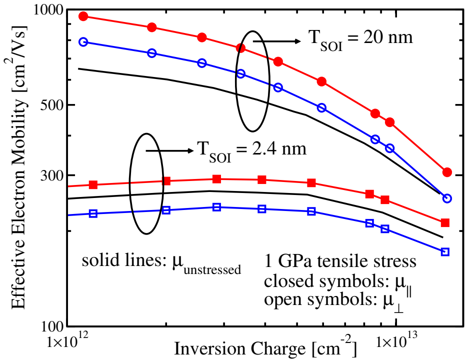

Figure 2: Simulated μ_{eff} for substrate orientation (001) for two body thicknesses. Stress and channel along [110].

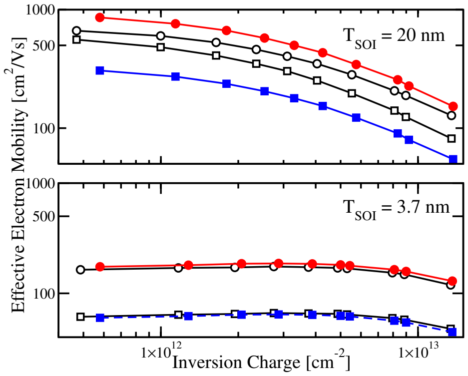

Figure 3: Simulated μ_{eff} for substrate orientation (110) for two body thicknesses. The anisotropic μ_{eff} is given along ⟨001⟩ (circles) and ⟨110⟩ (squares). Stress and channel along [001].