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Low Frequency Noise Mechanisms in Si and Pseudomorphic SiGe p-Channel Field-Effect Transistors

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Measurements of 1/*f* noise in Si and $Si_{0.64}Ge_{0.36}$ pMOSFETs are compared with theoretical models of carrier tunnelling into the oxide. Reduced noise in the heterostructure device as compared to Si is shown to be primarily associated with an energy dependant density of oxide trap states and a displacement of the Fermi level at the SiO_2 interface in the heterostructure relative to the Si control.

The device structure investigated in this work is shown in figure 1. Devices have an in-situ doped polysilicon gate and single high doped source-drain implants (BF_2 @ 5×10^{15} cm^{-2}, 50 keV). The SiGe device has a 2 nm Si cap, further details are given elsewhere (1).

For interpretation of the 1/*f* noise we assume a theory of Carrier Number Fluctuations (CNF) associated with tunnelling into the gate oxide, originally proposed by McWhorter (2) and now widely used.

Figure 2 shows measured values of $S_{I_{DS}}/I_{DS}^2$, extracted at 1 Hz, versus I_{DS} for Si and SiGe pMOSFETs. In the first instance we assume number fluctuations only (CNF). It is seen that the theory and experimental data agree at low currents but deviate substantially at the higher values. Next, we have attempted to correct for a possible mobility fluctuation term, using values of mobility obtained previously[1] and assuming that the mobility fluctuations are associated with scattering from a fluctuating number of oxide charges (CMF1), this theoretical form does not give agreement with experiment. A similar theoretical prediction by Pacelli *et al.* (3) also yields poor agreement. However, as pointed out by Martin and co-workers (4), the total effective mobility should be considered and it is not correct to ignore the fluctuations in interface roughness scattering which are driven by those in carrier number. Such a prediction is shown in figure 3, however, once again a poor agreement with experiment is found (CMF2). Finally, and for simplicity, we consider CNF only and, following Mathew *et al.* (5), assume that the density of trap states N_{ox} increases with hole energy. Allowing N_{ox} to vary gives an ideal fit and realistic profiles for N_{ox}. This picture accounts for the increased noise at high carrier densities, above that given by the simple carrier number theory with an energy independent density of trap states.

We have found evidence to suggest that the low 1/*f* noise in the heterostructure as compared to a silicon control, for the same gate overdrive, arises through a lower density of active oxide trap states, as a result of the band offset of strained SiGe relative to Si. The reduced low frequency noise of SiGe devices coupled with enhanced maximum voltage gain implies a promising future in analogue applications.

FIGURES

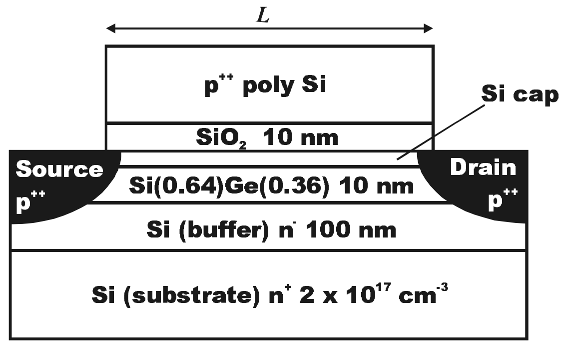

Figure 1. pMOSFET device structure. SiGe device has a Si cap thickness of 2 nm. The Si control has a Si layer in place of the SiGe layer.

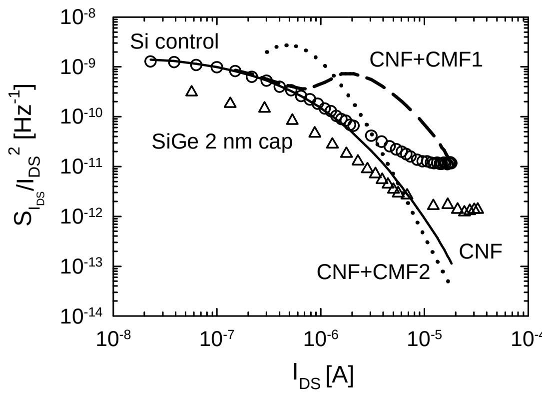

Figure 2. Normalized power spectral density of 1/*f* noise at 1 Hz plotted versus drain current, for Si and SiGe (2 nm Si cap) devices. V_{DS} = -50 mV. Comparison of Si data with theory: continuous line CNF (number fluctuations only), broken line CNF + CMF1 (scattering from oxide charge fluctuations), dotted line CNF + CMF2 (fluctuations in total mobility).

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