

Coulomb scattering model for ultrathin silicon-on-insulator inversion layers

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A Coulomb scattering model for ultrathin silicon-on-insulator inversion layers has been developed. This model simultaneously takes into account (i) screening of charged centers by mobile carriers, (ii) the distribution of charged centers inside the structure, (iii) the actual electron distribution, (iv) the charged center correlation, and (v) the effect of image charges. We have used this model in a Monte Carlo simulator for single-gate silicon-on-insulator inversion layers and have calculated electron mobility curves in these devices taking into account phonon, surface roughness and Coulomb scattering for different values of the silicon slab thickness sandwiched between the two oxide layers. © 2002 American Institute of Physics. [DOI: 10.1063/1.1477623]

The electronic properties of quasi-two-dimensional electrons in silicon inversion layers are significantly affected by the insulator semiconductor interface.^{1,2} This is so to the extent that the main limitations to electron mobility in these physical systems are closely related to inherent phenomena in the insulator semiconductor interface, such as: (i) the Coulomb scattering of electrons by fixed charges in the oxide bulk or by trapped charges right at the Si-SiO₂ interface, and (ii) the interface-roughness scattering of electrons due to the deviation of the Si-SiO₂ interface from an ideal plane. The importance of these phenomena is reflected by the fact that they are responsible for the significant decrease in electron mobility in silicon inversion layers compared to its value in the bulk, both at low inversion charge concentrations (Coulomb scattering) and at high ones (interface roughness scattering).

It seems clear that these effects are important in physical systems where electrons are simultaneously affected by two of these interfaces. This is the case of the electron gas contained in an ultrathin silicon-on-insulator (SOI) inversion layer.³

In the Coulomb scattering models for bulk silicon inversion layers it has been shown that Coulomb scattering strongly depends on factors such as (a) the electron distribution of electrons in the inversion layers, (b) the geometrical distribution of external charged centers, (c) the screening of charged centers by mobile carriers, (d) the charged-center correlation, and (e) image charges.^{1,4,5} On the other hand, we know from the self-consistent solution of Poisson and Schrödinger equations in ultrathin SOI devices,^{3,6} that the mutual influence of the two Si-SiO₂ interfaces means that the electron distribution in ultrathin SOI devices strongly differs from that found in bulk inversion layers. This, *a priori*, would lead to a different screening effect, a different relative position between carriers and charged centers, and as a consequence, a very different Coulomb scattering effect on the electron mobility.

We have improved the previous Coulomb scattering model in order to make it valid for SOI inversion layers. Figure 1 shows the semiconductor structure we have consid-

ered in our study. The model developed is valid both for single-gate silicon-on-insulator devices (SGSOI) and for double-gate silicon-on-insulator (DGSOI) devices.

Let ρ_{ext} be the external charge density responsible for the Coulomb scattering.⁴ As a consequence of this charge density, the electrostatic potential responsible for the confinement of the carriers is spatially modified, and its perturbation V obeys the Poisson equation:²

$$\nabla[\epsilon(z)\nabla V(\mathbf{r},z)] = 2\epsilon_{\text{sc}}\sum_i S_i g_i(z) \int V(\mathbf{r},z_2) g_i(z_2) dz_2 - \rho_{\text{ext}}(z), \quad (1)$$

where \mathbf{r} is the coordinate parallel to the interface and z is the coordinate perpendicular to it. $\epsilon(z)$ is the position-dependent permittivity overall and ϵ_{sc} the permittivity of the semiconductor. The first term of the right-hand member of Eq. (1) is the induced charge responsible for the screening. $g_i(z)$ is the square of the electron envelope function in the i th subband, and $\xi_i(z)$, and S_i the screening parameter.^{4,5}

Multiplying Eq. (1) by $e^{-i\mathbf{Q}\cdot\mathbf{r}}$ and integrating over \mathbf{r} , one obtains the following equation for the Fourier transform of the electrostatic potential perturbations, $V(\mathbf{Q},z_1)$:

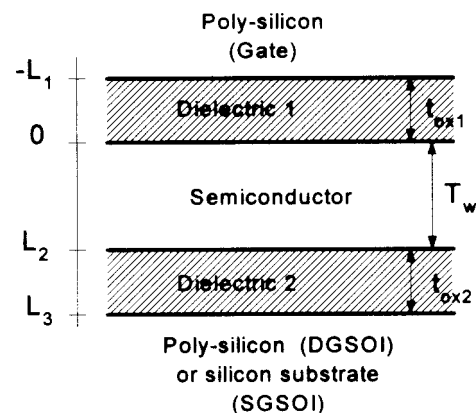


FIG. 1. Schematics of the silicon-on-insulator structure considered in the study.

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