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Monte Carlo simulation of electron mobility in silicon-on-insulator structures

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Abstract

A Monte Carlo simulator has been used to study the electron mobility in different silicon-on-insulator structures at room and lower temperatures. Electron mobility behaviour in single-gate SOI MOSFETs is compared to that in double gate devices. The role of volume inversion is analysed. In addition, the electron mobility in strained silicon-on-SiGe-on-insulator inversion layer is also studied.
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1. Introduction

For many years, silicon-on-insulator (SOI) devices have been considered as a serious alternative for the fabrication of future integrated circuits [1]. Many reasons have contributed to this status: easy complementary metal-oxide-semiconductor (CMOS) processing, excellent device scalability, tremendous cost/performance advantages over Si and Si/SiGe technologies, very good device and circuit performance, strong radiation tolerance, etc. [2–5]. Today, the many critical physical limitations of conventional silicon technology as device dimensions become ever smaller, mean that the time for SOI technology is approaching. For this reason, a lot of research has been carried out in recent years to foresee the actual properties of these new devices. The goal of this paper is to review electron mobility in a particular kind of SOI device: ultrathin SOI devices. Here, the silicon layer sandwiched between the two oxide layers is very thin, and the presence of two Si–SiO_2 interfaces in such proximity greatly modifies the transport properties of the electrons confined in such a structure. In addition to the advantages mentioned above, ultrathin SOI devices specifically present other benefits, as described below. Several structures will be considered: single-gate transistors, symmetrical double-gate transistors, and strained silicon-on-SiGe-on-insulator devices.

2. Electron distribution, quantum effects

To accurately evaluate the electron distribution in these structures we must previously self-consistently solve the Schroedinger and Poisson equations. To solve Poisson's equation we have considered a non-uniform adaptive mesh, employing an iterative-Newton scheme. The actual band-bending through the whole structure and the finite height of the barrier at the Si–SiO_2 interfaces have been considered. A simple non-parabolic band model for the silicon has been taken into account assuming $\alpha = 0.5\ eV^{-1}$, α being the parameter of non-parabolicity [6]. This limits our study to low-electron energies (below 0.5 eV) [7].

The reduction of the silicon film thickness sandwiched between the two oxide layers causes important effects on electron distribution and on electron transport properties:

(a) *Subband modulation effect*. The size quantization in the (1 0 0) silicon inversion layer produces a redistribution of the carriers between the two subband ladders which arise from the split of the degeneracy of the six

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