ELECTRON TRANSPORT MODELS FOR UNSTRAINED AND STRAINED Si AND SiGe

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The SiGe alloy is now widely used in silicon technology due to the possibility to improve the characteristics of semiconductor devices. For example, Ge implantation into the source/drain regions of MOSFET is performed for the substrate surface amorphization in order to prevent impurity channeling. Recently several authors reported the fabrication of n-MOSFETs with channel doped by Ge. Significant enhancement of device transconductance was shown for SiGe-channel MOSFET compared to conventional silicon-channel transistor. In addition, Ge implantation introduce additional scattering centers for hot electrons giving rise to carrier cooling and finally to the decrease of hot-carrier induced MOSFET degradation rate.

On the other hand, the realization of the high-quality Si/SiGe heterostructures combined with Si thechnology opens the possibility for various new device applications. One of the most prominent Si/SiGe-based heterostructure devices are Si-MODFET and heterojunction bipolar transistor with SiGe base.

Mechanical stress caused by the lattice mismatch produce the splitting of energy spectrum of Si and SiGe. Thus, electrons move from higher energy to lower energy valleys and their scattering rates are changed. The knowledge of electron transport properties in unstrained and strained Si and SiGe is necessary for the electric characteristics calculation of the above mentioned devices and their structure optimization. Electron transport in Si and SiGe has been studied in several experimental and theoretical works. However, there is still lack of information on high-field electron transport in these materials. In the present work we apply Monte Carlo simulation technique to investigate electron transport characteristics in Si and SiGe strained and unstrained semiconductors and to derive simple their analytical approximations suitable for implementation in device simulation programs.

We use the standard kinetic model of Si with nonparabolic ellipsoidal bands. Energy band structure of SiGe is assumed to be similar that of Si. Alloy scattering and bandgap reduction are accounted for in the case of SiGe. For strained materials the kinetic model was modified to take into account the intervalley scattering between energetically nonequivalent valleys. Calculations have been performed for electric fields up to $600kV/cm$ and Ge fraction up to 0.4. Some simulation results for unstrained SiGe - electron drift velocity and impact ionization coefficient - are presented in figure 1. It is seen that drift velocity as well as impact ionization coefficient are significantly reduced with the increase of Ge content (fig.1). Low-field electron mobility in undoped SiGe (fig.2) is significantly reduced with Ge fraction for any electric field orientation due to the increase of alloy scattering. In fig.3 the enhancement of drift velocity with X in strained pure Si grown on $Si_{1-x}Ge_x$ substrate is demonstrated. Contrary to earlier Monte Carlo simulations of Smith and Jones (1988) the nonmonotonic dependence of drift velocity in strained Si at high fields with Ge fraction is not observed in the present work. Empirical analytical approximations for electron kinetic coefficients are also presented in this work.

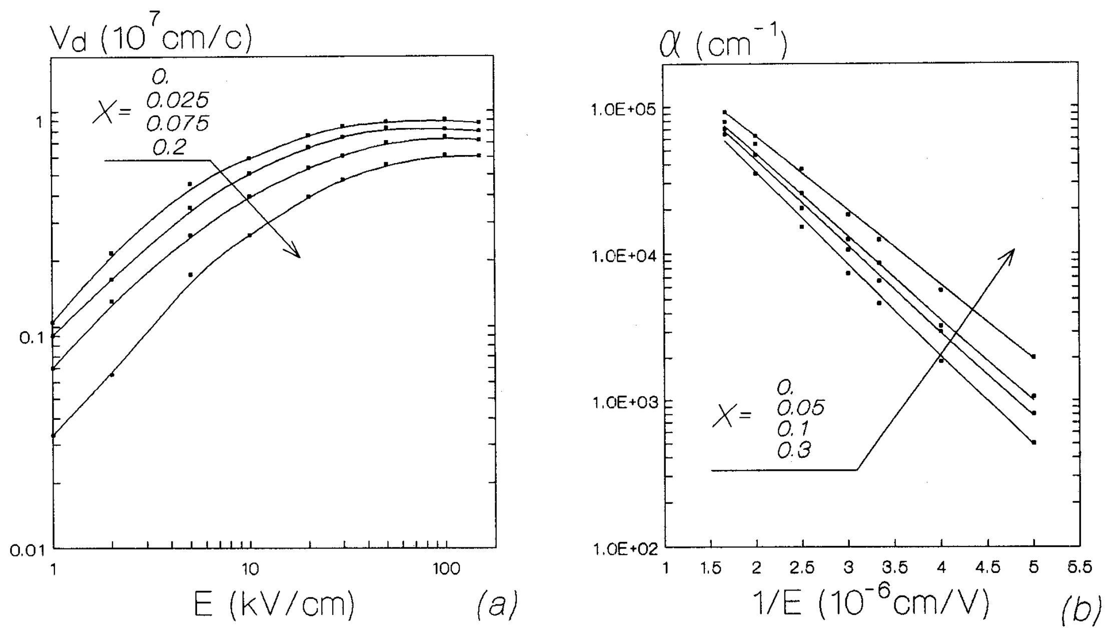

Fig.1. Electron drift velocity (a) and impact ionization coefficient (b) in unstrained $Si_{1-x}Ge_x$ alloy.

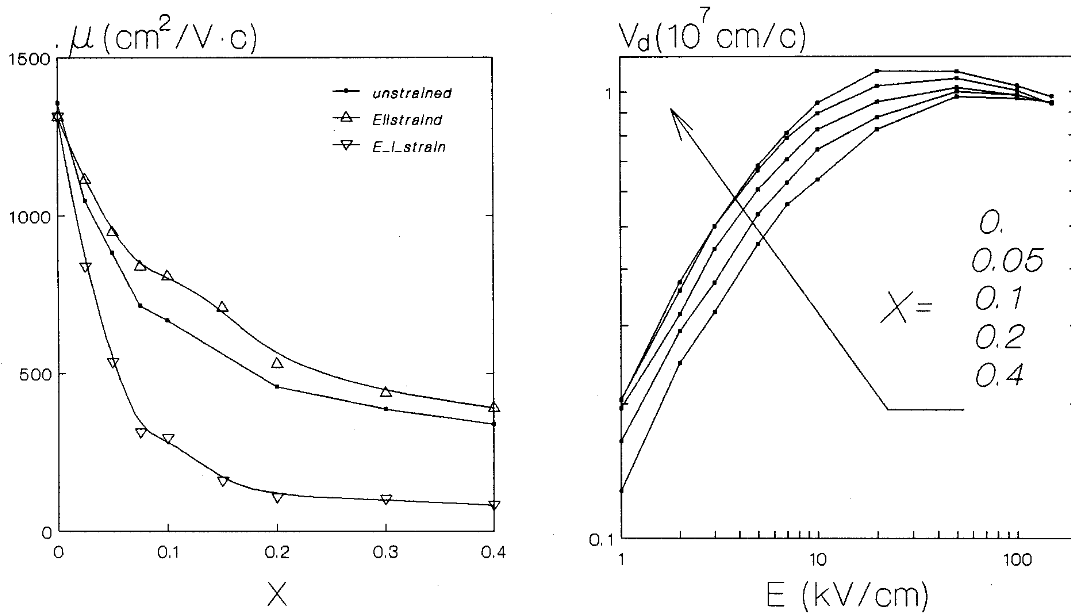

Fig.2. Electron mobility in unstrained and strained $Si_{1-x}Ge_x$ alloy grown on Si substrate.

Fig.3. Electron drift velocity in strained Si grown on $Si_{1-x}Ge_x$ substrate.