A Study of Boron Implantation into High Ge Content SiGe Alloys

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SiGe virtual substrates with Ge content in the range from 50 to 100% are a promising material for high-performance CMOS applications. Recently, MOS transistors with a three times mobility improvement in comparison to silicon devices were obtained using an HfO_2 high-k dielectric on pure Ge (1). While implanted dopant profiles are well-known in silicon for various implantation conditions, such profiles are scarce in SiGe alloys as well as in pure Ge.

We present an experimental and simulation study for introducing boron ions into high Ge content SiGe alloys and Ge. All simulations were performed with our technology computer-aided design tool MCIMPL–II (2). The multi-dimensional Monte Carlo simulator for ion implantation is based on a BCA method and uses the universal ZBL potential. In recent work, we extended the simulation capabilities from crystalline silicon to $Si_{1-x}Ge_x$ targets ($x \leq 0.5$) by adjusting the Lindhard correction parameter k_L of the empirical electronic stopping model as a function of the Ge content (3). In this work, the calibration has been extended to alloys with Ge content from 50% up to pure Ge.

Ge has a larger nuclear and electronic stopping power for ion-implanted dopants due to the heavier and electron-rich Ge atom. Therefore the implanted profile in Ge is shallower than in Si for any given energy. Figure 1 presents boron profiles in amorphous and crystalline Ge. The pre-amorphization was performed by an implantation of ^{72}Ge with an energy of 200keV and a dose of $10^{15}\mathrm{cm}^{-2}$. The boron implantation was performed with an energy of 20keV and a dose of $6 \cdot 10^{14}\mathrm{cm}^{-2}$. A tilt of 7° was used in the crystalline case. In Figure 2, the boron profiles in Si and $Si_{0.47}Ge_{0.53}$ were implanted with the same conditions as in crystalline Ge. The Ge content of 53% causes a steeper decline of the dopant concentration. The point responses in crystalline Si and Ge are shown in Figure 3. Boron is implanted with an energy of 10keV, a dose of $5 \cdot 10^{15}\mathrm{cm}^{-2}$, and the ion beam is 7° tilted in such a way that the lateral component of the incident direction is parallel to the direction of view. The penetration depth of boron ions in the $<100>$ direction is clearly reduced in Ge and the channeling tail is closely centered around the $<100>$ axis.

For the first time, boron implantation and channeling have been studied in high Ge content SiGe alloys and Ge by using a physics-based simulation approach.

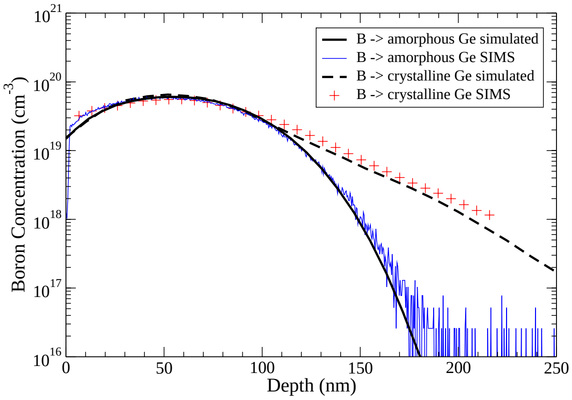

Figure 1: Simulated 20keV boron implants in amorphous and crystalline Ge compared to SIMS data.

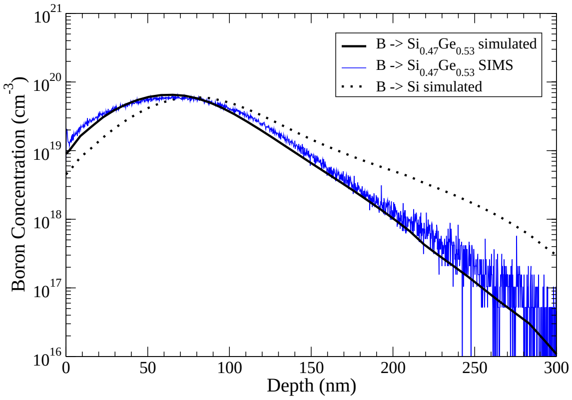

Figure 2: Simulated 20keV boron profile in $Si_{0.47}Ge_{0.53}$ compared to SIMS and to simulated boron profile in Si.

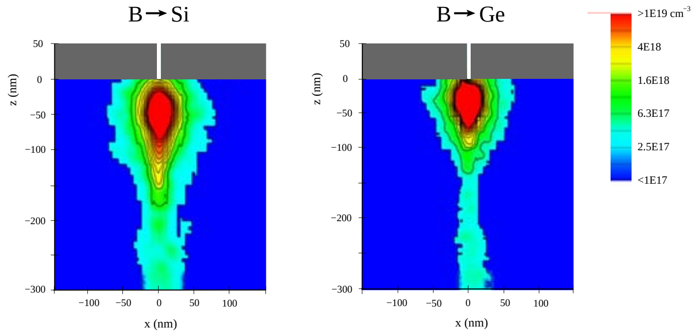

Figure 3: Simulated point responses for a 10keV boron implantation into crystalline Si and Ge.

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