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Calibration for the Monte Carlo Simulation of Ion Implantation in Relaxed SiGe

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Strained silicon/relaxed SiGe CMOS devices have significant performance enhancements compared to pure silicon devices. We have extended our Monte Carlo ion implantation simulator MCIMPL–II to $\mathrm{Si_{1-x}Ge_x}$ targets in order to study the formation of shallow junctions. The simulator is based on a binary collision approximation (BCA) and can handle arbitrary three-dimensional device structures consisting of amorphous and crystalline materials (1), (2). For $\mathrm{Si_{1-x}Ge_x}$ crystals the lattice parameter depends on the germanium fraction x and can be calculated by a quadratic approximation with sufficient accuracy for the crystal model (3). The selection of the target atom species for the next found collision partner is defined by probability x for germanium and 1 - x for silicon, respectively.

SiGe has a larger nuclear and electronic stopping power for ion implanted dopants due to the heavier and electron-rich germanium atom (4). The germanium content generates a significantly higher backscattering probability which can be derived from the scattering integral which is calculated by the simulator to determine the scattering angle of a nuclear collision event (5). The Lindhard correction parameter of the empirical electronic stopping model is adjusted by a linear function of the germanium content to adopt the strength of the electronic stopping for each dopant species (6).

Figure 1 shows the successful calibration by comparing simulated arsenic implantations into $\mathrm{Si_{1-x}Ge_x}$ up to a germanium fraction of 50% with SIMS measurements. All implantations were simulated with an energy of 60 keV, a dose of 10^{11} $\mathrm{cm^{-2}}$, a tilt of 7°, and a twist of 15°. The figure demonstrates the effect of the germanium content which produces a non-linear shift towards shallower profiles with increasing germanium fraction in the alloy. Additionally, a stronger decline of the profiles compared to silicon can be observed which is caused by the larger electronic stopping power of germanium. Figure 2 points out that boron implants in $\mathrm{Si_{1-x}Ge_x}$ targets with different composition show qualitatively the same characteristics as arsenic implants. All implantations were simulated with an energy of 50 keV, a dose of 10^{15} $\mathrm{cm^{-2}}$, and a tilt of 7°.

Finally, the excellent properties of $\mathrm{Si_{1-x}Ge_x}$ alloys for forming shallow vertical junctions will be demonstrated with a two-dimensional application in the paper. We present the simulation result of arsenic source/drain and extension implants for a 100 nm gate n-MOSFET structure on a $\mathrm{Si_{0.75}Ge_{0.25}}$ substrate.

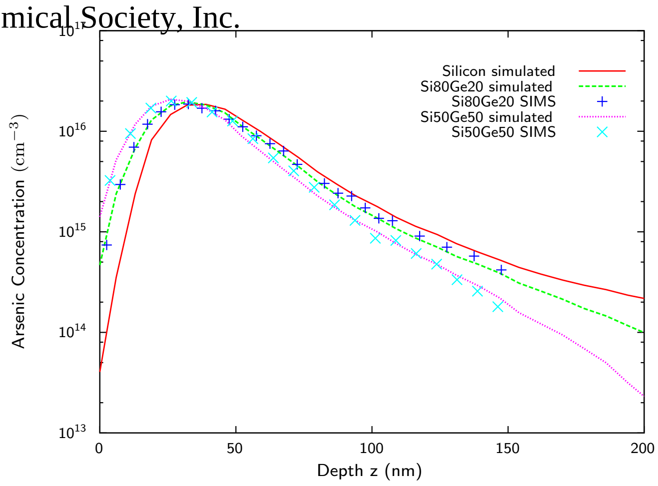

Figure 1: Simulated 60 keV arsenic implantations in $\mathrm{Si_{1-x}Ge_x}$ targets with x = 0, 20%, 50% compared to SIMS measurements

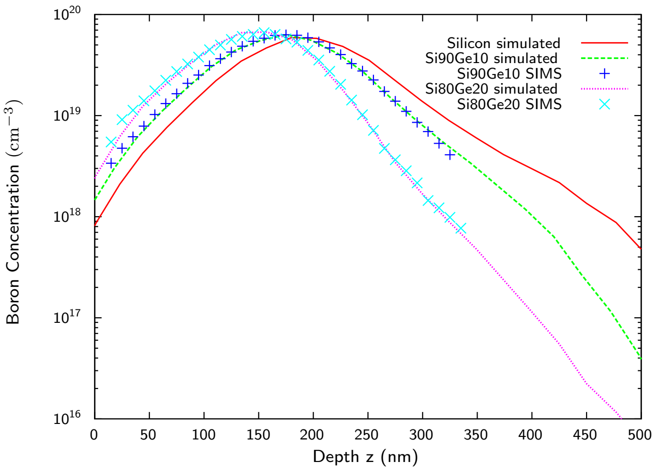

Figure 2: Simulated 50 keV boron implantations in $\mathrm{Si_{1-x}Ge_x}$ targets with x = 0, 10%, 20% compared to SIMS measurements

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