A comparative study of ion-implantation of As and B in GeSn epilayers grown on Si (001) by chemical vapor deposition.

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Recently, direct band gap GeSn alloy semiconductors with Sn concentration above 6-8% have attracted considerable attention as a tunable mid- and near-infrared materials of group IV for light emitting and detection applications with the advantage of monolithic integration on Si substrate and CMOS compatibility [1]. Due to the low miscibility of Sn and Ge, Sn-rich metastable GeSn alloys are typically grown under non-equilibrium conditions, such as by chemical vapor deposition (CVD) and molecular beam epitaxy (MBE). With these techniques, *in-situ* doping is somehow limited, in particular for the fabrication of devices with laterally selected doping regions. Alternatively, *ex-situ* ion implantation is a commonly used process for engineering the structure and precise control of different dopant species in materials.

The poor thermal stability of Sn-rich GeSn materials imposes a low thermal budget for dopant activation. At elevated annealing temperatures, phase separation into thermodynamically favored elemental Ge and β-Sn is ubiquitous. Recently, an annealing study of ion-implantation of As in Ge have shown a 60% substitutional occupation of As atoms in the Ge lattice for annealing temperatures below 200 °C and almost 100% substitutional occupation at higher temperatures [2]. In this work, the implantation of As and B in GeSn epilayers is investigated under different conditions.

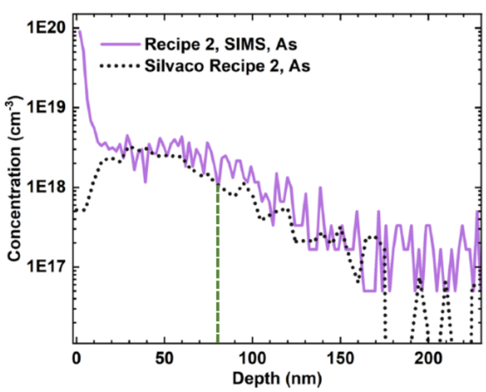

Figure 1 Arsenic doping profile with recipe 1 from SIMS compared with Silvaco simulation.

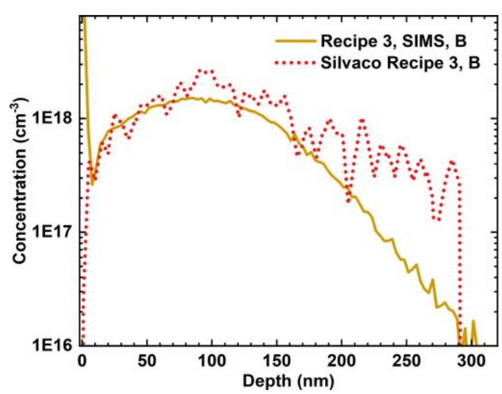

Figure 2 Boron doping profile with recipe 3 from SIMS compared with Silvaco simulation.

[1] K. P. Homewood and M. A. Lourenço, Nature Photonics **9**, 78–79 (2015).
[2] S. Decoster *et al.*, J. Appl. Phys. **111**, 053528 (2012).

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Table 1: Detail of doping parameters for As and B

Recipe #	**Dopant**	**Dose**	**Energy**	**Tilt**
1	As	$2 \times 10^{13}/cm^2$	150keV	7 degrees
2	B	$3 \times 10^{13}/cm^2$	30keV	7 degrees

The implantation parameters for As and B into GeSn epilayer are shown in table 1. The angle of tilt is to ensure that the dopant elements align to the lattice structure of GeSn for enhanced implantation. For both recipes, the implantation parameters were simulated using Silvaco to achieve a target depth of ~80 nm. At the target depth, the dopant has maximum concentration. After ion implantation, the samples were measured using SIMS. This was to compare the simulated doping profile with the actual. Figure 1 shows a comparison of the simulated versus the SIMS measured doping profile for both recipes. From the plot, it can be seen that the simulated doping profile is commensurate with the actual.