Band gap engineering in Ge via non-equilibrium thermal processing and Sn doping

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The incorporation of different functional optoelectronic elements on a single chip enables performance progress which can overcome the downsizing limit in silicon technology. For example, the use of Ge instead of silicon as a basic material in nanoelectronics would enable faster chips containing smaller transistors. As was shown recently, Ge can be used not only for fast electronics but also for optical devices e.g. LEDs and detectors. In order to fully exploit and boost further its unique properties, the alloying of Ge with Sn and ultra-doping with P for n-type conductivity have to be explored. To this day, both Sn and P impurity are introduced into Ge mainly *in-situ* during the growth process (e.g. using molecular beam epitaxy (MBE) or chemical vapour deposition (CVD)).

In this work, we report on the band gap modification of Ge by Sn alloying and P co-doping. The doping of Ge was be performed using ion beam implantation of P and Sn with a concentration far exceeding the solid solubility limit of Sn in Ge (>> 0.2%). The implanted Sn was alloyed with Ge using rear-side flash lamp annealing. According to both XRD and HRTEM fabricated layer is single crystalline for the Sn doping up to 6 %. After P-implantation and annealing fabricated GeSn layers are n-type with active carrier concentration above $5\times10^{19}cm^{-3}$. The GeSn alloy made by presented method enable the integration of innovative Ge-based devices in the mainstream of Si CMOS technology which can be used for the fabrication of three-dimensional (3D) large-scale-integration devices with modulated optoelectronic properties.