

## Dopant Redistribution in High Temperature Grown Sb-doped Ge Epitaxial Films

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### Introduction

The development of Ge-based materials potentially allows Si-compatible high-speed devices. Our group has demonstrated the formation of n<sup>+</sup>-Ge for device application by *in-situ* doping of Sb using molecular beam epitaxy (MBE)<sup>[1]</sup>. It was found that heating the substrate at  $\geq 350^\circ\text{C}$  remarkably improves the crystallinity of Sb-doped Ge layer. However, the high temperature heating during deposition reduces the dopant density, thus deteriorating the performance of fabricated devices. The underlying mechanism behind this behavior were unknown, while dopant distribution in the deposited layer is one of the crucial factors that govern its electrical properties<sup>[2]</sup>. Therefore, we investigated the mechanism of dopant redistribution during the growth of Sb-doped Ge epitaxial films.

### Experiment and Results

An epitaxial Ge layer (~100 nm) with high Sb dopant concentration ( $T_{\text{dop.}}: 350^\circ\text{C}$ ) was deposited on p-Ge (100) substrate using MBE. Here, various substrate heating conditions ( $T_{\text{sub.}}: 300\text{--}550^\circ\text{C}$ ) were implemented during the deposition (Fig.1). Then, the samples were characterized by secondary ion mass spectrometry (SIMS) for the Sb depth profiling in epitaxial Ge layer.

The epitaxial growth of Sb-doped Ge layer was confirmed for the deposition with  $T_{\text{sub.}} \geq 350^\circ\text{C}$ . In

Figure 2, Sb depth profiles (obtained by SIMS) show the reduction of Sb concentration for the samples that heated at high temperatures. As a result of the experiment in which the deposition rate of Ge was changed, it was proven that the decrease of Sb concentration was caused by the re-evaporation of Sb. Here, interstitial Sb atoms near the surface are easy to move and cause re-evaporation, while substituted Sb atoms are less likely to be removed from the layer. On our further investigation, diffusion of Sb from deeper region also confirmed, and will be covered in the main report.

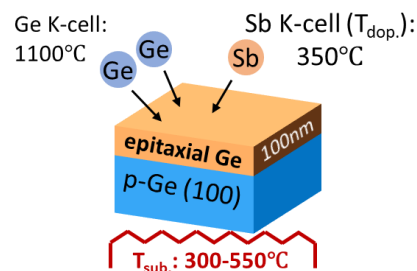


Figure 1. Schematic of experiment.

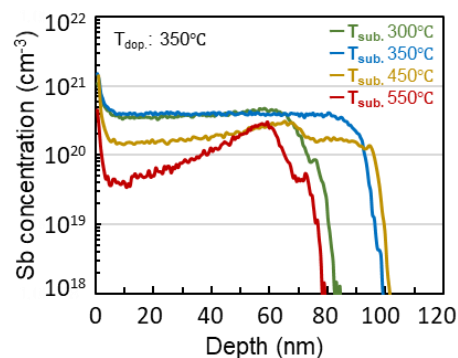


Figure 2. Depth profiles of Sb-doped Ge deposited at various substrate heating ( $T_{\text{sub.}}: 300\text{--}550^\circ\text{C}$ .) show different distribution of dopant throughout the layer.

[1] R.H.Saputro et al., ECS Trans. 102, 147 (2021).

[2] D.V.Yurasov et al., J. Appl. Phys. 118, 145701 (2015).