# High electron density of Sn-doped GaN layer by halide vapor phase epitaxy


Kansuke Hamasaki[1]*, Kazuki Ohnishi[2], Shugo Nitta[2], Naoki Fujimoto[2], Hirotaka Watanabe[2], Yoshio Honda[2], Hiroshi Amano[2,3].
*lead presenter: hamasaki.kansuke.j5@s.mail.nagoya-u.ac.jp
1 Department of Electronics, Nagoya University, Japan
2 Institute of Materials and System for Sustainability, Nagoya University, Japan
3 Venture Business Laboratory, Nagoya University, Japan


To reduce the on-resistance of GaN vertical power devices, the resistivity of GaN substrates must be reduced. Currently, n-type GaN freestanding substrates with an electron density of $10^{18}$ $cm^{-3}$ grown by halide vapor phase epitaxy (HVPE) have been commercialized. These substrates were doped with Si or Ge. To further reduce resistivity, a method of high n-type doping should be established. To study high n-type doping, we focused on Sn atoms as novel donors because their ionization energy is shallow and their ionic radius is close to that of Ga atoms [1, 2]. However, Sn donors in GaN have not been studied well because there are few reports on the growth of Sn-doped GaN [1]. In particular, there are no reports on the HVPE growth. In this study, we attempted the HVPE growth of Sn-doped GaN with high carrier density.

A schematic diagram of Sn-doping by HVPE is shown in Fig. 1. HCl gas was reacted with Sn metal heated at 850 °C and $SnCl_2$ gas was generated as the Sn precursor. 10–16 µm thick Sn-doped GaN layers were grown on GaN/sapphire templates at 890–1080 °C for 30 min with other conditions fixed. Hall-effect measurements were performed at room temperature to measure carrier density and electron mobility. The measurements were performed on three Hall samples within each wafer.

The electron density was increased with lowering the growth temperature as shown in Fig. 2. The electron density reached (4.9–7.4) × $10^{19}$ $cm^{-3}$ when the growth temperature was 890 °C. This value was much higher than that of the commercialized substrates. From the theoretical calculated results shown as solid lines in Fig. 2, the compensation ratio $\theta$ was estimated to be 0.1–0.3. The sample with the highest carrier density showed the lowest resistivity of $1.6\times10^{-3}$ Ω·cm. These results show that the growth at low temperature is effective for high Sn-doping and Sn donors are promising for obtaining n-type GaN substrates with low resistivity.


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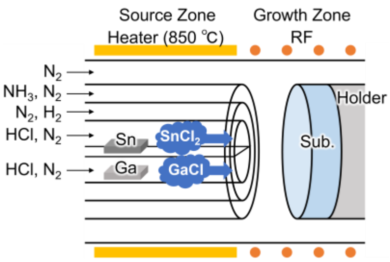


Fig. 1 Schematic diagram of Sn doping by HVPE.

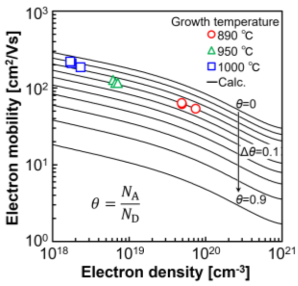


Fig. 2 Electron mobility as a function of electron density. Solid lines show theoretical calculated results for degenerate n-type GaN.


**References**

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