In-situ and *Ex-situ* Si Doping of β-Ga_2O_3

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Primary CNF Tools Used: DISCO Dicing Saw, Oxford ALD FlexAL

Abstract:

Recently, there is great interest in the material β-Ga_2O_3, which has an ultra-wide bandgap of ~ 4.8 eV. β-Ga_2O_3 is of interest for its application for radio frequency (RF), high power electronics, and solar-blind UV detectors. β-Ga_2O_3 substrates can be grown from the melt, which will make scaling-up production favorable. Additionally, the facile n-type doping of β-Ga_2O_3 is achieved due to the availability of shallow donors. In this work, we demonstrate controllable *in-situ* and *ex-situ* Si doping of β-Ga_2O_3, by MOCVD and ion-implantation respectively.

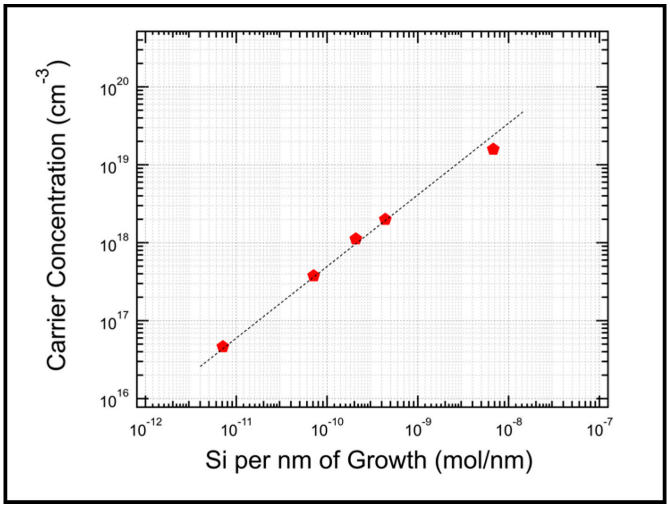

Figure 1: Demonstrated in-situ *Si doping concentration from mid × 10^{16} to low × 10^{19} cm^{-3} by controlling the molar flow of Si per nm of MOCVD β-Ga_2O_3 growth.*

Summary of Research:

In this work, Fe doped β-Ga_2O_3 substrates were acquired from Novel Crystal Technology and then subsequently diced into a square geometry for Hall effect measurements, typically 5 × 5 or 10 × 10 mm.

In-situ Si doping was performed during the metal organic chemical vapor deposition (MOCVD) growth in an Agnitron Agilis 100 system. Figure 1 shows the controllability of *in-situ* Si doping by tuning the moles of Si per nm of β-Ga_2O_3 growth at a chamber pressure of 15 Torr. Doping is controlled over three orders of magnitude from mid × 10^{16} to low × 10^{19} cm^{-3} with competitive mobilities. Even higher *in-situ* doping up to 1×10^{20} cm^{-3} can be achieved by increasing the chamber pressure for 40 Torr to increase the cracking efficiency of the Si precursor, silane.

Ex-situ Si doping was performed by ion-implanted of unintentionally doped (UID) β-Ga_2O_3 grown by plasma-assisted molecular beam epitaxy (MBE). Prior to ion implantation, a 20 nm SiO_2 cap was deposited on the sample via atomic layer deposition (ALD) in order to tailor the Si implant profile. After ion implantation, the samples were annealed under a controlled ultra-high purity nitrogen ambient in order to activate the dopants. The best anneal condition was found to be 950°C for five minutes for implant concentrations between 5×10^{18} to 1×10^{20} cm^{-3}, achieving greater than 80% activation with mobilities all recovered to greater than 70 $cm^2/V \cdot s$ for all conditions.

This work has laid the groundwork for current device processing by enabling high channel mobilities via *in-situ* doping and ohmic contacts via *ex-situ* ion implantation.