# Two-Dimensional Diffusion Process Simulation of Si-Implanted $Ga_2O_3$

In Ki Kim, and Sung-Min Hong

*School of Electrical Engineering and Computer Science, Gwangju Institute of Science and Technology (GIST), Gwangju, Cheomdangwagiro-123, South Korea*
*smhong@gist.ac.kr*

Gallium oxide ($Ga_2O_3$) is a promising material for power electronics devices and UV detectors owing to its wide bandgap (~ 4.9 eV) [1]. The free electron concentration of $Ga_2O_3$ can be controlled in bulk growth process such as Molecular Beam Epitaxy or mist-Chemical Vapor Deposition process [2]. However, the ion implantation and the thermal annealing are required to form ohmic contacts of source and drain regions with selective and high concentration doping [3]. A simulation model of the dopant diffusion in $Ga_2O_3$ is required to predict the dopant distribution after the annealing process. In this work, we report two-dimensional simulation of Si dopant diffusion as a function of time at 1100 °C annealing temperature in $O_2$ and $N_2$ ambient. A diffusion model reported in [4] is adopted in the simulation and implantation profiles of dopant and damage are calculated from Stopping and Range of Ions in Matter (SRIM) simulation. The simulation is conducted in a 500 nm × 2000 nm $Ga_2O_3$ region. Figure 1 (a) and (b) show the profile of implanted Si into $Ga_2O_3$. The implantation profile along the vertical direction is calculated for $3.24\times10^{13}$ $cm^{-2}$/30keV, $5.72\times10^{13}$ $cm^{-2}$/60keV, and $8.1\times10^{13}$ $cm^{-2}$/90keV with the SRIM simulation. The implantation window is open from -700 nm to 700 nm in the lateral position. Subsequently, the diffusion simulation is carried out during 60 s at 1100 °C temperature in either $O_2$ or $N_2$ ambient. In Figs. 2 and 3, the dopant profile is shown at three representative time instances, 20 s, 40 s, and 60 s. In the $O_2$ ambient simulation, the peak concentration of Si decreases to below $4.7\times10^{18}$ $cm^{-3}$ from $1.85\times10^{19}$ $cm^{-3}$, as shown in Fig. 2. Otherwise, almost no redistribution of Si is occurred in the $N_2$ ambient as shown in Fig. 3. In conclusion, the dopant diffusion of Si-implanted $Ga_2O_3$ has been simulated. Since the generated vacancy type is different according to the ambient, the Si redistribution is significantly affected by the ambient.

Acknowledgement: This work was supported by the National Research Foundation of Korea grant funded by the Korea government (NRF-2019R1A2C1086656 and NRF-2020M3H4A3081800) and the GIST Research Institute grant funded by the GIST in 2021.

[1] S. J. Pearton et al., Appl. Phys. Rev., **5**, 011301 (2018).

[2] M. J. Tadjer et al., ECS J. Solid State Sci. Technol., **8**, Q3133 (2019).

[3] M. H. Wong et al., IEEE Elect. Dev. Let., **40**, 3 (2019).

[4] R. Sharma et al., AIP Adv., **9**, 085111 (2019).

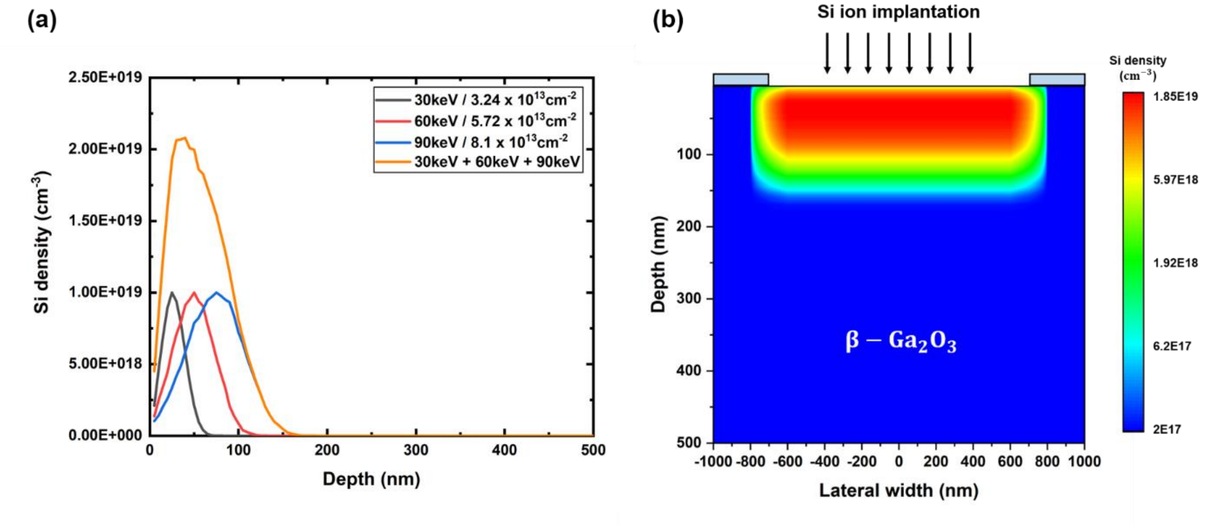

*Fig.1: Implantation profile of Si. (a) Implanted Si profile as a function of depth calculated from the SRIM simulation. (b) Two-dimensional implantation profile of Si. The implantation window is open from -700 nm to 700 nm in the lateral position.*

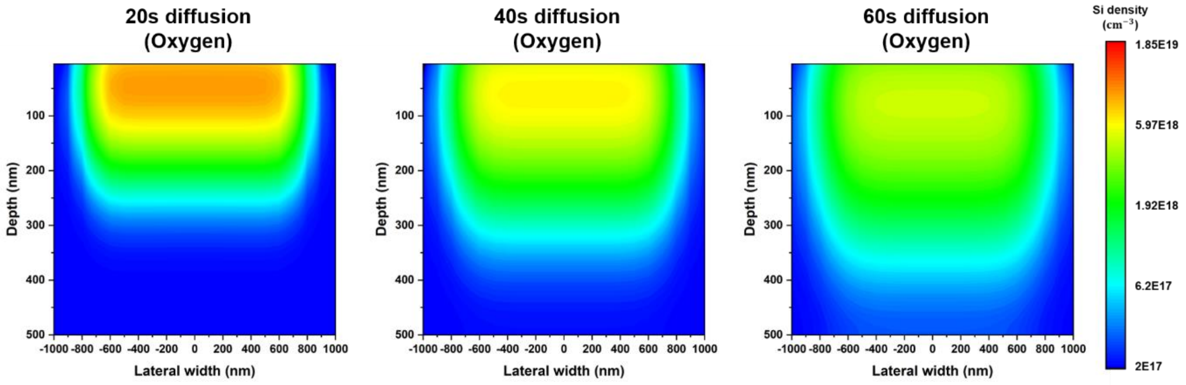

*Fig.2: Simulated two-dimensional Si profile after annealing at 1100℃ temperature (20 s, 40 s, and 60 s) in the $O_2$ ambient.*

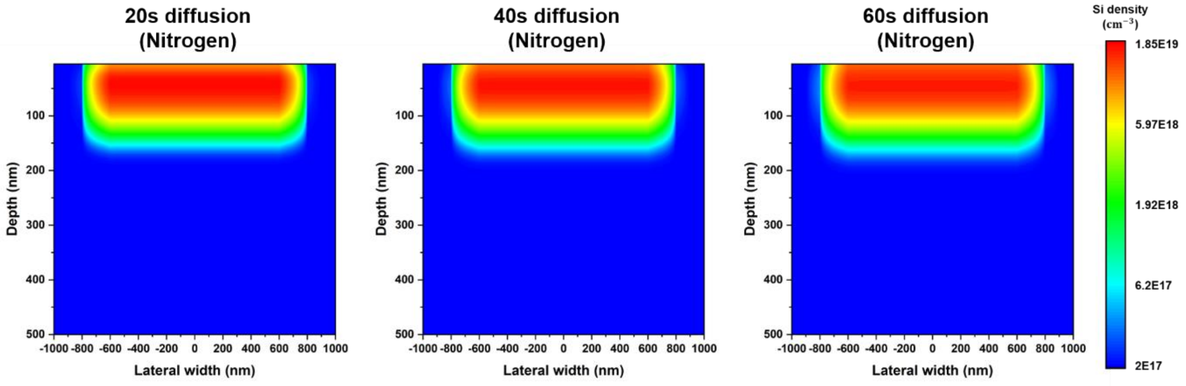

*Fig.3: Simulated two-dimensional Si profile after annealing at 1100℃ temperature (20 s, 40 s, 60 s) in the $N_2$ ambient.*