Effects of Si/N Ion Implantation on Defect formation and Doping of Gallium Oxide

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A new generation of power devices based on the wide-bandgap (WBG) semiconductor, Ga_2O_3, is expected to revolutionize the power electronics industry. Many promising β-Ga_2O_3-based devices have already been reported, such as Schottky barrier diodes, MOSFETs, and various solar-blind photodetectors [1 - 4]. So far, the development of Ga_2O_3-based transistors has been focused mainly on utilizing lateral geometry. On the other hand, the vertical geometry would allow for higher current drives without having to enlarge the chip size, simplified thermal management, and far superior field termination. However, for this geometry to be realized, both *n*-type and *p*-type doping should be achieved in Ga_2O_3, with *n*-type readily available [5, 6]. Contrarily, *p*-type doping in Ga_2O_3 is fundamentally challenging to be achieved due to the very flat valence band maximum (VBM) of O 2*p* in nature and self-compensation [7 - 9].

It was recently shown that *p*-type conductivity can be achieved even in undoped Ga_2O_3 layers with annealing in an oxygen atmosphere due to the β-Ga_2O_3 particular point defect chemistry and the large formation energy of oxygen vacancies [10, 11]. Such annealing increases the free hole concentration by three orders of magnitude due to the formation of VGa(-) - Vo (++) complexes, being a shallow acceptor center. However, the mobility was found to reduce, probably due to a greater number of acceptor scattering centers compared to the as-grown sample.

Another approach would be to use nitrogen as *p*-type dopant with subsequent post-annealing treatment as was shown in [6] where nitrogen and silicon were used to engineer a Ga_2O_3 transistor using ion implantation. Consequently, there is a need for a better understanding of the origin of the observed complicated behavior of Si and N elements in the Ga_2O_3 matrix, which results in different transport properties.

In this work, we aimed to identify structural defects caused by Si(N) implanted into the Ga_2O_3 matrix, their transformations and possible interaction with host intrinsic defects employing various experimental techniques: RBS/c, PIXE, HR XDR, XANES, TEM. The crucial task is the identification of the local surrounding of the mentioned above dopants and understanding the driving forces for phase transformations taking place upon implantation and subsequent annealing.

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