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# Influence of ion implantation in SiC on the channel mobility in lateral n-channel MOSFETs

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As a consequence of the poor SiC/$SiO_2$ interface quality a distinct reduction of the electron mobility ($\mu_e$) in the inversion or accumulation layers of planar 4H-SiC n-channel MOSFETs and thus in the electrical performance of these devices can be observed [1]. Particularly the interfacial quality is determined by the high density of interface states ($D_{it}$) that dramatically limits $\mu_e$. Agarwal and Haney [2], however, have disclosed a speculative concept predicting that also bulk traps in SiC beneath the interface affect the $\mu_e$ in n-channel MOSFETs, much the same way as the interface traps at the SiC/$SiO_2$ interface. Thereby it was assumed that one very probable cause for the formation of these bulk traps is related to ion implantation of p-wells. Although this concept was offered with no concrete experimental evidence it attracted a great deal of attention within the scientific community [3]. If the aforementioned concept and particularly the formation of bulk traps as a result of ion implantation proves to be true, than structures in which the p-wells are grown by epitaxy should be consider so as to avoid ion implantation in the MOSFET channel region.

In this work a systematic analysis of the influence of ion implantation in SiC on $\mu_e$ in n-channel MOSFETs will be presented. For this purpose 4H-SiC epitaxial layers were first implanted with aluminum box profiles whereby the implantation dose was varied so as to achieve different p-type doping concentrations ($N_A$) of the p-wells ranging from $5\cdot 10^{15}$ $cm^{-3}$ to $5\cdot 10^{17}$ $cm^{-3}$. Subsequently, the later channel regions of the n-channel MOSFETs with the highest $N_A$ value were shallow implanted with different nitrogen doses ($N_D$) in the range of $5\cdot 10^{12}$ $cm^{-2}$ to $5\cdot 10^{13}$ $cm^{-2}$. Annealing after implantation was carried out in argon (Ar) atmosphere at 1700 °C for 30 min after capping the surface with a resist layer. Subsequently, all samples were oxidized at 1280 °C in $N_2O$ atmosphere resulting in oxide thicknesses ($d_{ox}$) between 25.5 nm and 27.5 nm.

In Fig. 1. the field effect mobilities ($\mu_{FE}$) that have been extracted from the experimentally observed transfer characteristics ($V_{DS}$=100 mV) at room temperature are presented for the MOSFETs with different $N_A$ but without additional nitrogen implantation in the channel region. Therein a contentious increase of the peak field-effect mobility ($\mu_{FE,max}$) that goes along with a decrease in the threshold voltage ($V_{Th}$) can be observed for decreasing $N_A$. $\mu_{FE,max}$ decreases from 26 $cm^2$/Vs for a $N_A$ equal to $5\cdot 10^{15}$ to 12 $cm^2$/Vs for a $N_A$ of $5\cdot 10^{17}$.

By counter doping the channel region of the MOSFET with the highest $N_A$ with nitrogen, the $\mu_{FE}$ values again rise from 12 $cm^2$/Vs to 26 $cm^2$/Vs (Fig. 2.). This fact can be interpreted in two different ways: Either that the ion implantation in itself does not alter the channel mobility by increasing the amount of bulk traps in SiC or, in case that bulk traps have been created as a consequence of ion implantation, that bulk traps do not affect the channel mobility to a significant extend. A conclusive line of argument will be presented so as to further substantiate the findings of Tilak et al. [3] that the increase in the peak $\mu_{FE}$ with decreasing $N_A$ or increasing $N_D$ is caused by a reduction in Coulomb scattering that is predominately induced by interface traps at the SiC/$SiO_2$ interface and not by bulk traps in SiC. The reduction of Coulomb scattering is thereby mainly attributed to the dependence of the bulk potential ($\phi_B$) from $N_A$ and $N_D$ and thus the equilibrium density of filled interface states when the inversion condition is reached (i.e. surface potential $\phi_S$ equals -$\phi_B$).

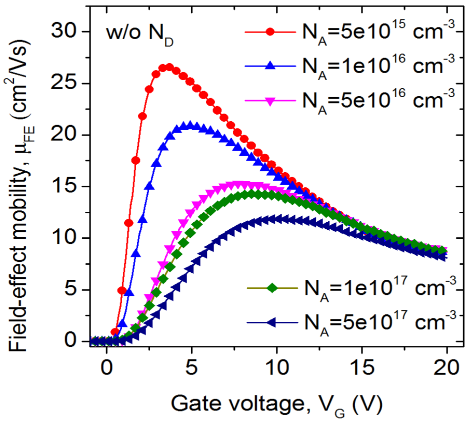

Fig. 1: $\mu_{FE}$ of MOSFETs with different p-well doping concentration $N_A$ as a function of $V_G$.

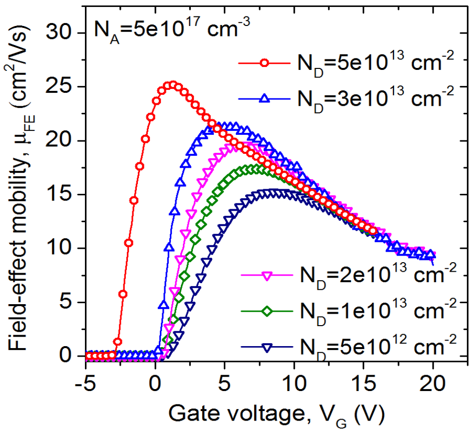

Fig. 2: $\mu_{FE}$ of depletion MOSFETs for constant $N_A$ and different channel implantation doses $N_D$ as a function of $V_G$.

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