Supplemental Material

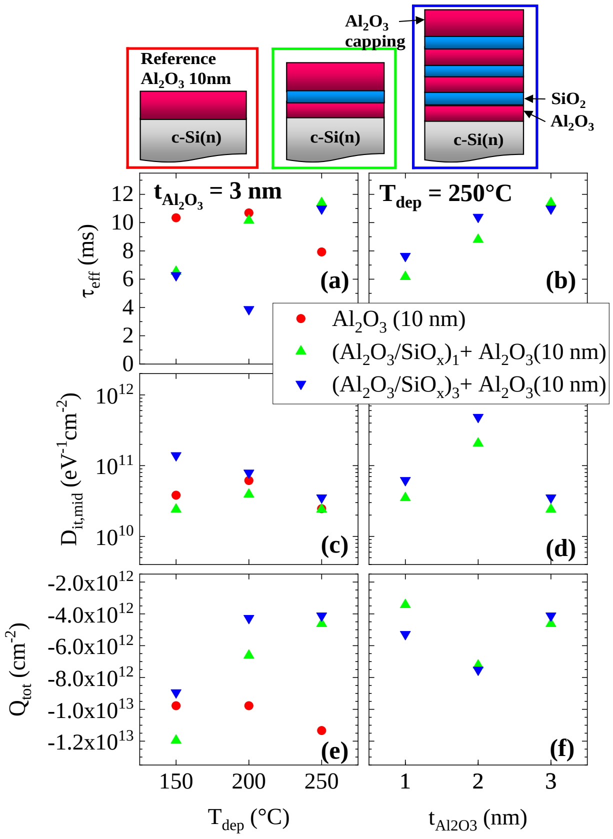

Figure 1: Study of Al_2O_3/SiO_2 multilayers for the Si surface passivation similar to those reported for MOSFETs [1]. The Figure shows the effect of ALD deposition temperature T_{dep} (left) and Al_2O_3 layer thickness t_{Al2O3} in the multilayer (right) on the Si surface passivation quality of the Al_2O_3/SiO_2 multilayers in terms of measured effective lifetime data, τ_{eff}, (a, b) as well as on the interface trap density at mid-gap, $D_{it,mid}$, (c, d) and the total effective density of fixed charges, Q_{tot}, (e, f) [2]. The results are shown for multilayers with single and triple multilayers (t_{SiO2} = 2 nm) and are compared to references coated only with a single Al_2O_3 layer of 10 nm thickness. Note that $\tau_{eff,}$, $D_{it,mid}$ and Q_{tot} are shown for optimal post-deposition anneal temperatures (forming gas), which was 450°C for the samples deposited at 150 °C and 200 °C, and 650 °C for the samples deposited at 250 °C. The passivation quality of the multilayers is for some variations on a similar level as for the Al_2O_3 single layers but not significantly better. The main reason is that most multilayers have a lower Q_{tot}. We studied further voltage stress V_{stress} on the interface properties (not shown). We found that with increasing V_{stress}, an increasing flat band voltage shift, V_{fb}, is obtained indicating a modification of Q_{tot}. A systematic analysis of the influence of V_{stress} on Q_{tot} revealed that while Q_{tot} is increasing with increasing V_{stress}, D_{it} starts to decrease after too high V_{stress}, which is confirmed by decreasing τ_{eff} using bias-QSSPC measurements.

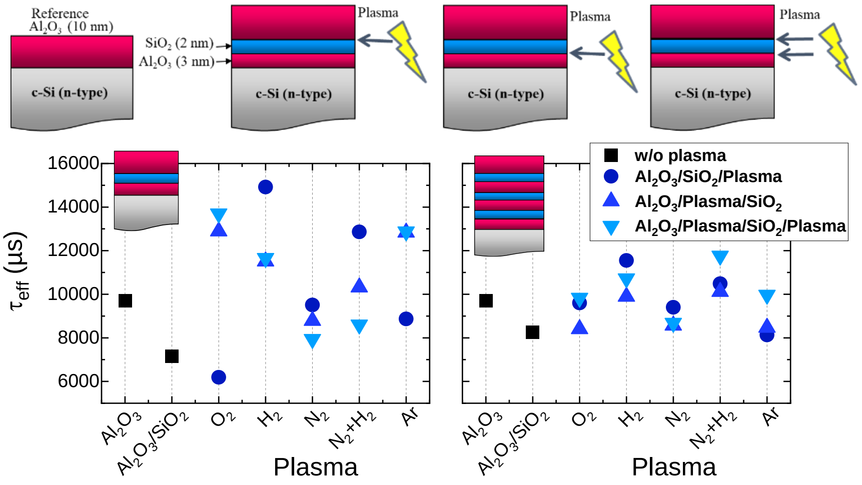

Figure 2: Influence of different plasma treatments (H_2, N_2, H_2/N_2, O_2 or Ar, 10s each) either after each SiO_2 or Al_2O_3 deposition, or after both, on the Si surface passivation quality in terms of τ_{eff} for single multilayers (left) and triple multilayers (right). The first two data points on the right of each graph correspond to Al_2O_3 single layer and Al_2O_3/SiO_2 multilayer reference samples, respectively, which were deposited without any plasma treatment.

The results reveal that especially the H plasma after the SiO_2 deposition results in a substantially improved surface passivation for the single multilayers (left), significantly better than that of the Al_2O_3 single layer references. In contrast, Al_2O_3 single layers do not show any beneficial effects if such plasma treatments were performed before or after the layer deposition (not shown). A detailed analysis with respect to the interface properties will be provided in the final paper.

References

[1] H. Kamata and K. Kita, "Design of Al2O3/SiO2 laminated stacks with multiple interface dipole layers to achieve large flatband voltage shifts of MOS capacitors," *Appl. Phys. Lett.*, vol. 110, no. 10, p. 102106, 2017, doi: 10.1063/1.4978223.

[2] H. Patel, C. Reichel, A. Richter, P. Masuch, J. Benick, and S. W. Glunz, "Effective charge dynamics in Al2O3/SiO2 multilayer stacks and their influence on silicon surface passivation," *Appl. Surf. Sci.*, vol. 579, p. 152175, 2022, doi: 10.1016/j.apsusc.2021.152175.