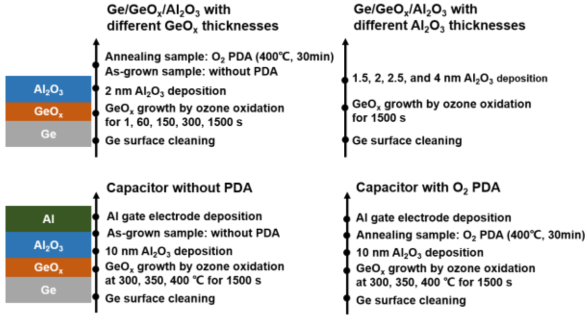

Fig. 1. Procedure for all the samples.

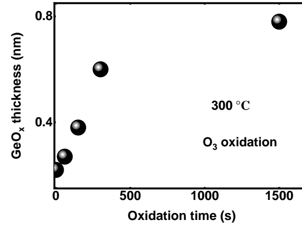

Fig. 2. GeO_x thickness for different ozone oxidation time at 300 °C.

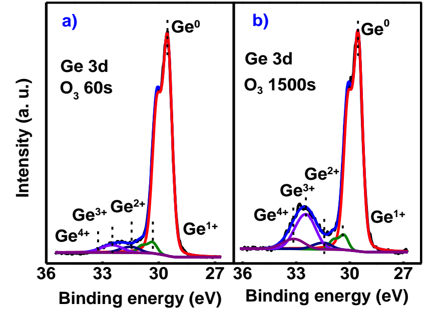

Fig. 3. XPS of Ge 3d with Ge surface ozone passivation for (a) 60 s and (b) 1500 s.

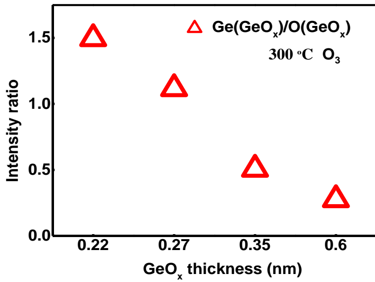

Fig. 4. The areal intensity ratio of $Ge(GeO_x)$ vs $O(GeO_x)$ for different GeO_x thicknesses.

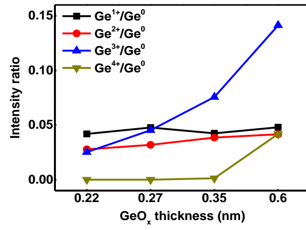

Fig. 5. The areal intensity ratio of various Ge oxidation states from GeO_x (Ge^{1+}, Ge^{2+}, Ge^{3+}, and Ge^{4+}) vs Ge^0 from Ge substrate for different GeO_x thicknesses.

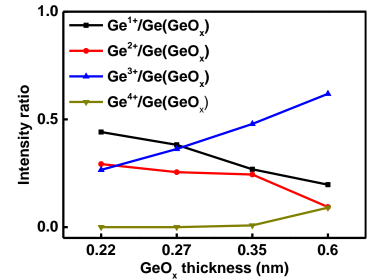

Fig. 6. The areal intensity ratio of various Ge oxidation states from GeO_x (Ge^{1+}, Ge^{2+}, Ge^{3+}, and Ge^{4+}) vs total Ge content (Ge^{1+} + Ge^{2+} + Ge^{3+} + Ge^{4+}) for different GeO_x thicknesses.

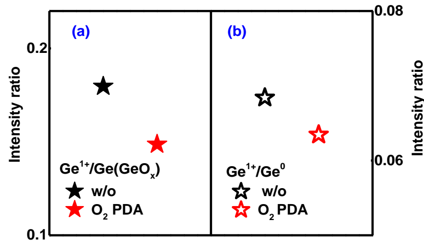

Fig. 7. The areal intensity ratio of (a) $Ge^{1+}/Ge(GeO_x)$ and (b) Ge^{1+}/Ge^0 for the as-grown and O_2 annealing samples.

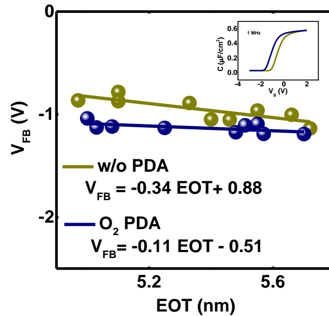

Fig. 8. V_{FB} versus *EOT* plots of $Ge/GeO_x/Al_2O_3/Al$ structure for the samples without and with O_2 annealing. The inset is the *C-V* plots for the without and with O_2 annealing samples.

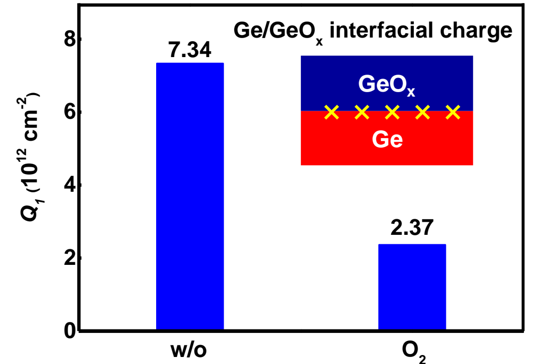

Fig. 9. Charge distribution **in** the $Ge/GeO_x/Al_2O_3$ gate stack of Ge MOS capacitor for the samples without and with O_2 annealing.

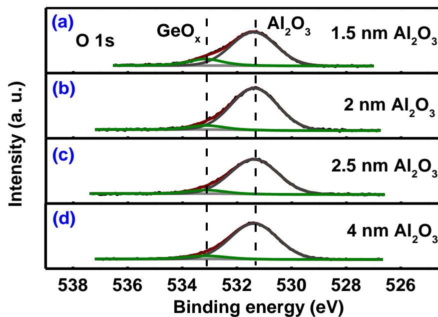

Fig. 10. O 1s spectra of GeO_x/Al_2O_3 structure for various Al_2O_3 thicknesses: (a)1.5 nm, (b) 2 nm, (c) 2.5 nm, and (d) 4 nm.

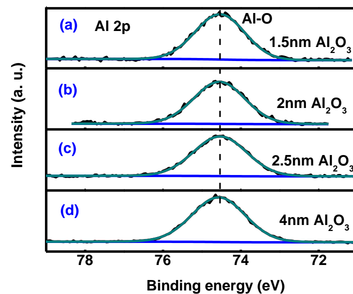

Fig. 11. Al 2p spectra of GeO_x/Al_2O_3 structure for various Al_2O_3 thicknesses: (a)1.5 nm, (b) 2 nm, (c) 2.5 nm, and (d) 4 nm.

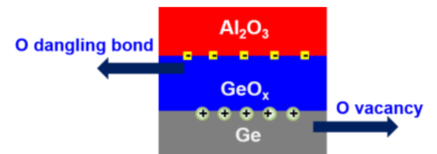

Fig. 12. The sketch of the interfacial defect in GeO_x/Al_2O_3 gate stack.