Electrical characterization of atomic layer deposited La_2O_3 films on $In_{0.53}Ga_{0.47}As$ substrates

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The effect of La_2O_3 atomic-layer-deposition (ALD) conditions on the electrical properties of metal/La_2O_3/$In_{0.53}Ga_{0.47}As$ MOS capacitor has been investigated. It is shown that by controlling the growth temperature of ALD, near ideal capacitance-voltage (*C-V*) characteristics with lower interface state density (D_{it}) values can be obtained.

In order to achieve scaling requirements of the semiconductor industry, the implementation of high electron mobility channels, in particular $In_{0.53}Ga_{0.47}As$, in MOS field effect transistors (MOSFETs) is expected to be actively used for future generations of semiconductor devices. Recently our studies have shown improved interface property using La_2O_3 as high-k materials at gate insulator [1]. On the other hand, developing a suitable ALD process is required for 3D-channel devices at industrial level. In this study, we report on methods and guidelines for improving ALD-La_2O_3/$In_{0.53}Ga_{0.47}As$ interface properties.

MOS capacitors were fabricated on *n*-$In_{0.53}Ga_{0.47}As$ substrates (Si-doped at 2 x 10^{16} cm^{-3} and epitaxially grown on InP substrate). After oxide removal HF (20%) and treating the substrates using $(NH_4)_2S$ solutions, La_2O_3 layers (80 cycles) were deposited at substrate temperature of 150 and 180°C using La($^iC_3H_7$-C_5H_4)$_3$, (La(^{i}PrCp)$_3$) and H_2O liquid sources. Next, TiN(45nm)/W(5nm) films were deposited by in-situ RF magnetron sputtering as the gate electrode. Post-metallization anneals (PMA) was carried out in forming gas (FG) (N_2:H_2=97%:3%) ambient for 5 minutes.

Figure 1 shows *C-V* characteristics of ALD-La_2O_3 (80 cycles)/InGaAs capacitors deposited at (a) 150 and (b) 180°C annealed in FG at 320°C. Samples fabricated at a growth temperature of 150°C exhibit superior *C-V* response with reduced frequency dispersion in all bias conditions. At 180°C growth temperature, samples show large hysteresis (Fig. 1 (b)). Figure 2 (a) shows hysteresis of samples fabricated at 150 and 180°C as a function of PMA temperature. From Fig. 2, small hysteresis is obtained for growth temperatures less than 150°C samples. Increasing substrate temperature during grow, could result in formation of unstable AsOx species. These oxide species are unstable and change to elemental As upon annealing, which increase hysteresis at high growth temperature [2]. Figure 2 (b) shows peak D_{it} values in depletion condition as a function of PMA temperature for various growth temperatures. D_{it} values of all samples were estimated by the conductance method. The lowest value of 6.3 x 10^{11} $eV^{-1}cm^{-2}$ is achieved for capacitor at PMA temperature of 320 - 370°C, and growth temperature of 150°C.

In conclusion, we found that ALD growth temperature has a major effect on electrical properties of ALD- La_2O_3/InGaAs. Near ideal *C-V* characteristics and low D_{it} values were obtained at growth temperature below 150°C.

References
[1] D.H. Zadeh, et al., Solid-State Electron., vol. 82, pp. 29-33 (2013).
[2] R.P.H Chang, et al., Appl. Phys. Lett., vol. 33, pp. 341-342 (1978).

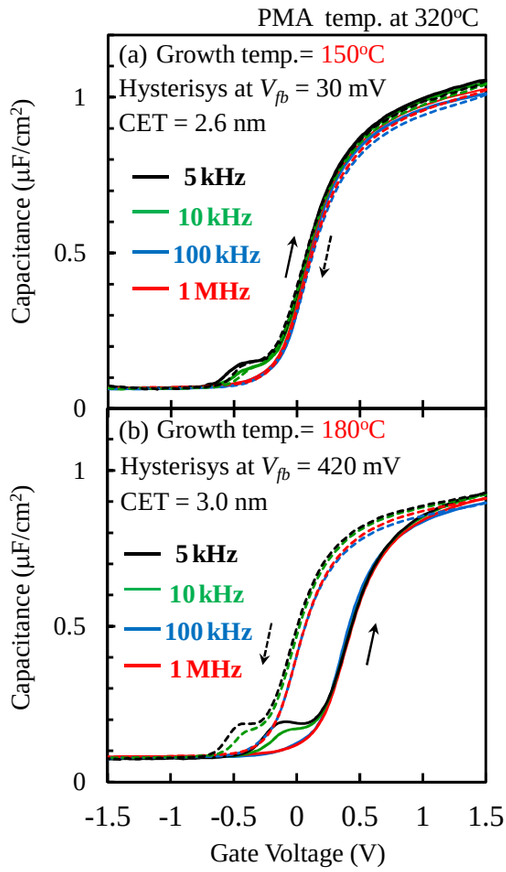

Fig. 1 *C-V* characteristics of TiN/W/ALD-La_2O_3 (80 cycles)/InGaAs capacitors deposited at (a) 150°C and (b) 160°C annealed in FG at 320°C.

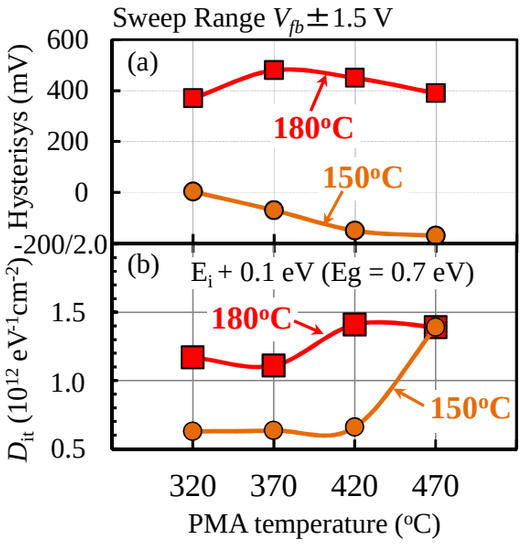

Fig. 2 (a) Hysteresis at V_{fb} and (b) D_{it} values at E_i+0.1eV as a function of PMA temperature.