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<td>Characterization of dielectrics and interfaces</td>
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1. Introduction

To date, solution processes have been developed due to the possibility of low-cost and large-area fabrication without using vacuum deposition techniques. Furthermore, solution-processed high-k oxide dielectrics enable the low leakage current, low operation voltage and easy process integration in thin-film transistors (TFTs) [1]. Among various high-k materials, Al₂O₃ is a promising candidate, especially due to its good chemical stability and low oxide/semiconductor interface traps density in a TFT device [2]. The changes in the solution-processed high-k materials resulting from bias-stress along with radiation damage have not been fully understood [3] and is a focus of this paper. In general, for a TFT, ionizing radiation could lead to device degradation by generating significant charges in the semiconductors and dielectrics [4]. Moreover, since the interruption of irradiation in conventional off-site radiation response measurements may cause a rapid recovery of the flat band voltage (VFB) shifts, the degradation caused by charge trapping/detrapping of the devices may be underestimated [5]. In this work, solution-processed and atomic layer deposited (ALD) Al₂O₃ thin films were fabricated for comparison. They were integrated into capacitors to fabricate the bias-stress stability along with radiation response by on-site measurements [6].

2. Sample Preparation, Results and Discussion

The solution-processed ~150 nm Al₂O₃ films were fabricated by spin coating on n-Si and annealed at 100°C. ALD Al₂O₃ films of ~40 nm were deposited at 100°C using Al(CH₃)₃ and H₂O as precursors. Al was deposited as the top electrode to form Metal Oxide Semiconductor (MOS) capacitors. The devices were irradiated by a 662-keV Cs¹³⁷ γ-ray radiation source under different positive/negative gate biases.

The plots of flat-band shift (ΔVFB) under gate bias-stress with/without radiation are shown in Fig. 1. A reversible behavior of ΔVFB is observed under both positive biased irradiation (PBI) and negative biased irradiation (NBI). This indicates that bias-stress dominates the device degradation in short term while radiation effect takes over in long term. Note that the radiation-induced ΔVFB is determined by the generation of oxide traps (ΔNox) and interface traps (ΔNit) at Al₂O₃/Si interface. Figs. 2 (a) and (b) present ΔNox of solution-processed Al₂O₃ capacitors under gate bias-stress with/without radiation. ΔNit were estimated by Eq. (1) [7]:

\[ ΔN_{it} = \frac{C_{ox}(ΔV_{FB} - ΔV_{mg})}{qA} \]

where Cox is oxide capacitance, ΔVmg – change in mid gap voltage, q elemental charge and A – area of device. Under PBI, the devices exhibit build-up of Si dangling bonds, which is related to the protons released by radiation. Under NBI, there is a negligible change of ΔNit. Furthermore, ΔNit of ALD Al₂O₃ capacitors is smaller than for solution-processed Al₂O₃ (Figs. 2 (c)-(d)). It has been reported that solution-processed low temperature Al₂O₃ contains a large amount of impurities such as hydroxyl and nitrate groups (also seen in Fourier Transform Infrared spectra of solution-processed samples in the full length paper), which can provide defect states in Al₂O₃ [8].

Figs. 3 (a) and (b) show the energy band diagrams of Al₂O₃ capacitors under PBI and NBI, respectively. When radiation passes through a gate oxide, electron/hole pairs are created [9]. Under PBI, the radiation induced electrons escape from the oxide within several picoseconds due to higher mobility relative to holes. The radiation induced holes in Al₂O₃ could cause negative ΔVFB. Furthermore, some of the radiation induced holes could transport towards the Al₂O₃/Si interface under PBI, and free hydrogen, in the form of protons [10, 11]. When the protons reach the interface by hopping transport, they react, breaking the Si-H bonds already there, forming H₂ and a trivalent Si defect and cause ΔNit to increase, as seen in Figs. 2 (a) and (b). Full analysis with ΔNit plots and discussion will be included in the full length paper.

3. Conclusion

The solution-processed and atomic layer deposited Al₂O₃ thin films were fabricated at low temperature. The effects of biased irradiation on Al₂O₃ based MOS capacitors were investigated by an on-site technique. It has been found that radiation can result in reversibility of ΔVFB of solution-processed Al₂O₃ MOS capacitors, which is further analyzed through calculating the radiation induced oxide (ΔNit) and interface (ΔNit) traps at Al₂O₃/Si interface. The results suggest that solution-processed Al₂O₃ thin films contain abundant precursor impurities compared to the ALD Al₂O₃ films.

References

Figure 1. Flat-band voltage shift ($\Delta V_{FB}$) of solution-processed AlO$_x$ capacitors induced by different positive/negative bias-stress as a function of (a) stress time, (b) stress time & total dose. $\Delta V_{FB}$ was extracted from capacitance voltage (C-V) curves measured from AlO$_x$ capacitors at 1 MHz.

Figure 2. Variation of interface traps ($\Delta N_i$) induced by different positive/negative bias-stress as a function of (a) stress time (solution-processed AlO$_x$), (b) stress time & total dose (solution-processed AlO$_x$), (c) stress time (ALD AlO$_x$) and (d) stress time & total dose (ALD AlO$_x$).

Figure 3. Energy band diagrams of solution-processed AlO$_x$ capacitors under (a) positive biased irradiation (PBI) and (b) negative biased irradiation (NBI).