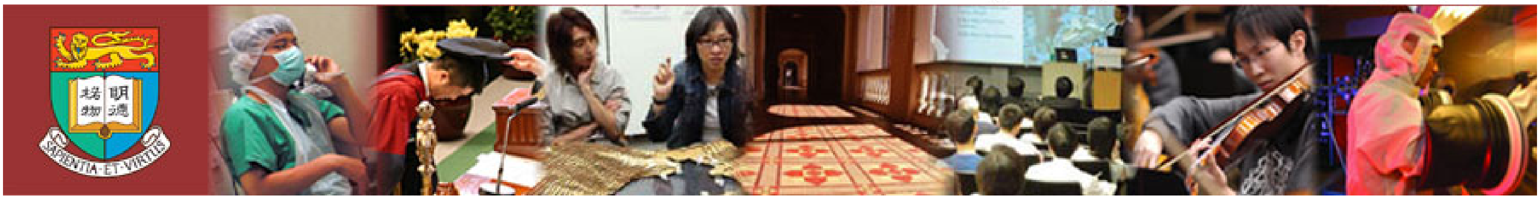

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Charge-Trapping Characteristics of Niobium-Doped La_2O_3 for Nonvolatile Memory Applications

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I. INTRODUCTION

Metal-oxide-nitride-oxide-silicon (MONOS)-type flash memories with discrete traps in dielectric as charge-trapping layer (CTL) have been widely studied in recent years. Among various high-k dielectrics, La_2O_3 seems to be a promising candidate due to its high dielectric constant (k ~ 25). However, the shortage of La_2O_3 is obvious. It cannot provide large memory window due to its low trap density [1], [2]. Doping niobium into La_2O_3 may help to increase the trap density and thus overcome the problem of La_2O_3. Niobium (Nb) oxide also has high- k value (k ~ 40), but it has a strong tendency to diffuse into the blocking layer of the device, leading to severe leakage problem [3]. In this work, based on MONOS capacitors, the charge-trapping characteristics of La_2O_3 with and without niobium doping are studied.

II. EXPERIMENT

MONOS capacitors were fabricated on p-type silicon substrate. After the standard RCA cleaning, 3-nm SiO_2 tunneling layer (TL) was grown on the substrate by thermal dry oxidation. Then, LaNbO with different contents of niobium was deposited on the wafer by co-sputtering of La_2O_3 and Nb targets. Nb was set as 0 W and 10 W to produce samples with different contents of niobium, denoted as LaO and LaNbO samples respectively. Following that, Al_2O_3 blocking layer (BL) was deposited. Then, the two samples received post-deposition annealing at 900°C in N_2 for 30 s. Subsequently, aluminum was evaporated and patterned as electrodes. Finally, the samples received forming-gas annealing. Their electrical characteristics were measured by HP4284A LCR meter and HP4156A semiconductor parameter analyzer.

III. RESULTS AND DISCUSSION

Fig. 1 shows the 1-MHz C-V hysteresis characteristics of the MONOS capacitors under various sweeping voltages. The LaNbO sample has much larger memory window than the LaO sample, indicating that niobium doping increases the trap density of the CTL, thus increasing its charge-trapping efficiency. Moreover, the LaNbO sample can endure higher voltage, while the LaO sample breaks down at 12 V. This phenomenon also shows higher trap density of the LaNbO sample because higher charge trapping efficiency makes it harder for carriers to tunneling through .

Fig. 2 shows the P/E characteristics of the MONOS capacitors. It is found that much larger V_{FB} shift is obtained for the LaNbO sample than the LaO sample under the same operating conditions. This is due to the different charge trap density of the two samples. Large number of charge traps in the LaNbO sample can trap more carriers, leading to larger V_{FB} shift. Furthermore, the V_{FB} shift of the LaO device hardly increases as the program voltage increases, while that of the LaNbO one increases significantly. In this phenomenon, different charge trap density, especially for deep-level traps, plays an important role. Deep-level traps do not trap carriers at low programming voltage due to insufficient energy for the carriers, but make it possible to trap more carriers at high voltage, thus preventing the saturation of V_{FB} shift.

Fig. 3 shows the retention characteristics of the LaNbO sample. It is programmed at 10 V for 1s and measured at room temperature. Up to 96% of charges are retained after 10 years. This value is much better than memory devices based on other CTL materials. It indicates that deep-level traps are the majority trap in LaNbO because it is hard for electrons trapped in deep-level traps to escape.

IV. CONCLUSION

The charge-trapping properties of niobium-doped La_2O_3 have been investigated based on MONOS capacitors. The memory device with niobium-doped La_2O_3 CTL shows better characteristics than that with pure La_2O_3 CTL in memory window and P/E properties. It also shows good retention characteristics. Therefore, the niobium-doped La_2O_3 is a promising candidate as CTL for nonvolatile memory applications.

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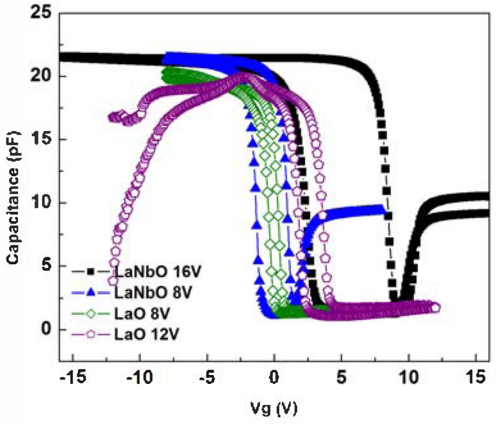
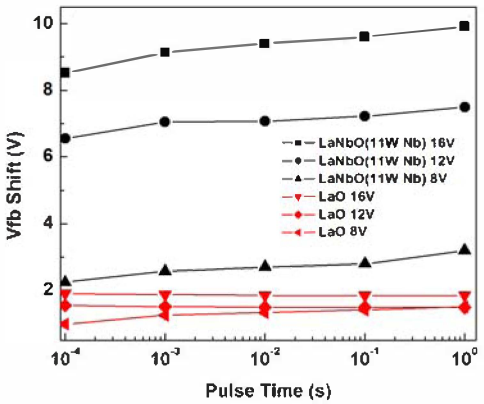
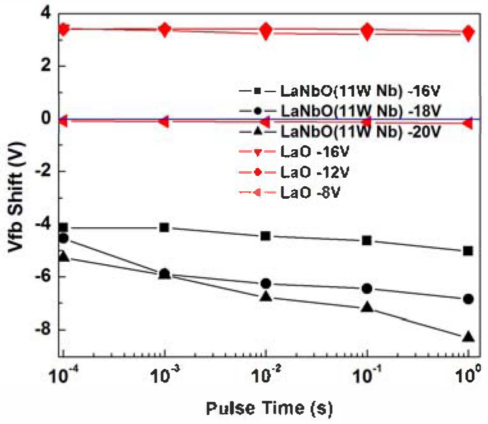


Fig. 1. C-V hysteresis curves of the LaO and LaNbO samples.



(a)



(b)

Fig. 2. (a) Program characteristics of the LaO and LaNbO samples. (b) Erase characteristics of the LaO and LaNbO samples.

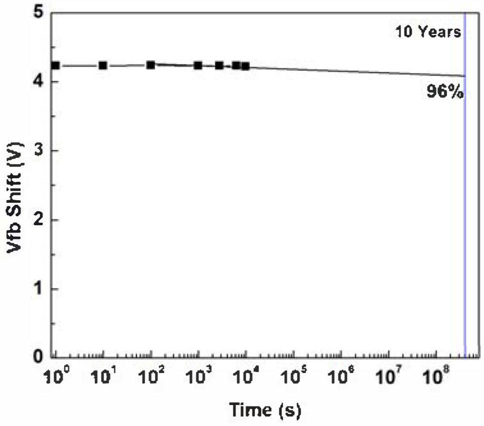


Fig. 3. Retention characteristics of the LaNbO sample.