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Thermal Stability of the Yttrium Aluminate Film and the Suppression of its structural change and electrical properties degradation

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1. Introduction

Rare earth oxides and their alloys is a promising candidate for the gate insulator in advanced MOS device technology because of their high dielectric constant [1]. The rare earth oxides are transformed easily to silicate structures due to interface reaction through high temperature annealing [2]. These structural changes of rare earth oxides are suppressed by the alumination. However, the addition of the alumina in rare earth oxides degrades their electrical property. The alumination of rare earth oxide was not enough to suppress the Vfb shifts during thermal process [3]. In this paper, we report on the suppression effect of the structure change and degradation of the electrical properties by using thermally grown oxy-nitride as the interface layer.

2. Experimental

The ultra thin yttrium aluminate films were prepared on the thermally grown oxy-nitride with NO (Nitric oxide) annealing and chemical oxide formed on a silicon substrate. The yttrium aluminate films were deposited at 500ºC using DPM (DPM: Dipivaloylmethanate) complex. After deposition, these films were annealed at 800ºC and 900ºC in N_2 ambient for 10 minutes. The MIS (Metal-insulator-semiconductor) diode characteristics were measured after deposition of Pt electrode. The yttrium aluminate films on the some oxidized silicon substrate were characterized using several analytical techniques, such as SIMS (Secondary Ion Mass Spectroscopy), XPS (X-ray Photoelectron Spectroscopy), and FT-IR (Fourier Transformed Infrared Spectroscopy).

3. Results and Discussion

Fig. 1 (a) and (b) shows the CV curves of the yttrium aluminate films on the chemical-oxide and that on the NO annealed oxy-nitride. The flat-band-voltage of yttrium aliminate film on the chemical oxide was shifted after the post-deposition-annealing. On the other hand, that on the NO annealed oxy-nitride was observed only a small shift after annealing. Therefore, we concluded that the shift of the flat-band-voltage was suppressed by using the thermally grown oxy-nitride as the interfacial layer.

Fig.2 (a)-(c) shows SIMS depth profiles of yttrium aluminate film on the NO annealed oxy-nitride with different annealing temperature. Silicon diffuses into the yttrium aluminate flim by the post-deposition-annealing. Fig.3 (a)-(c) shows comparison of the Y3d spectra obtained for the yttrium aluminate film on the both substrates with different annealing temperature. After annealing, the Y3d peak shifted to high binding energy side due to silicate formation. Also, the shift of the films on the chemical oxide was higher than that on the NO annealed oxy-nitride. It is indicated that silicate formation due to silicon diffusion of the yttrium aluminate film can be suppressed by using NO annealed oxy-nitride as the interface layer. Fig.4 (a), (b) shows variation of FT-IR ATR spectra of yttrium aluminate film on the both substrate with different annealing temperature. The absorption of the Si-O stretching located at 1240cm^{-1} was decreased with an increase in annealing temperature. After 800ºC annealing, absorption of Si-O band of the yttrium aluminate film on the NO annealed oxy-nitride was higher than that on the chemical oxide. The suppression effect of the interface reaction was observed by using NO annealed oxy-nitride as the interfacial layer. Thus, it is confirmed that thermally grown oxy-nitride as the interface layer was effective in the suppression of the structural change and the stabilization of the electrical properties.

4. Conclusions

We have characterized the yttrium aluminate film on the several kinds of oxidized silicon substrates with the high temperature annealing process. It is found that the shift of the flat-band-voltage can be suppressed by using thermally grown oxy-nitride. Additionally, using oxy-nitride as the interfacial layer was effective in the suppression of the structural change with the interfacial reaction.

Acknowledgements

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References

[1] International Technologies Roadmap for Semiconductor, 2004 edition.
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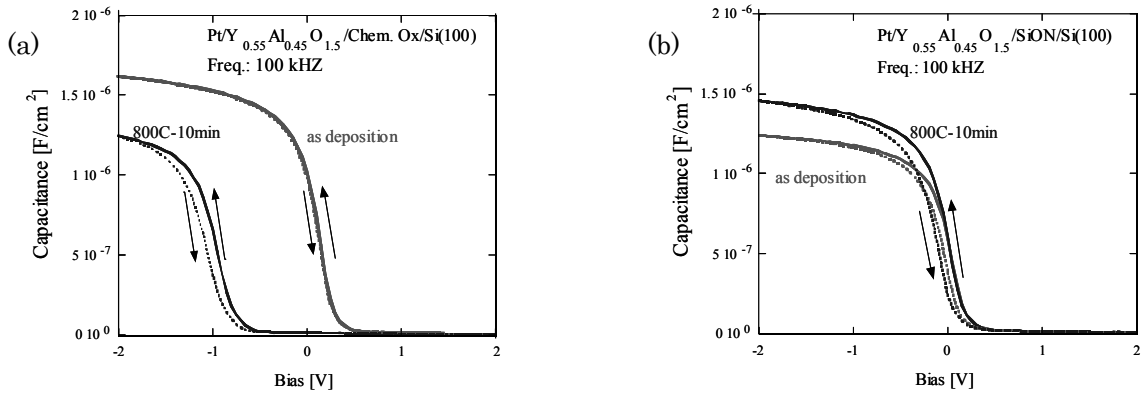

Fig.1 (a), (b) CV characteristic of yttrium aluminate films on differently oxidized silicon substrates. (a) yttrium aluminate films on the chemical oxide. (b) yttrium aluminate films on the NO annealed oxy-nitride

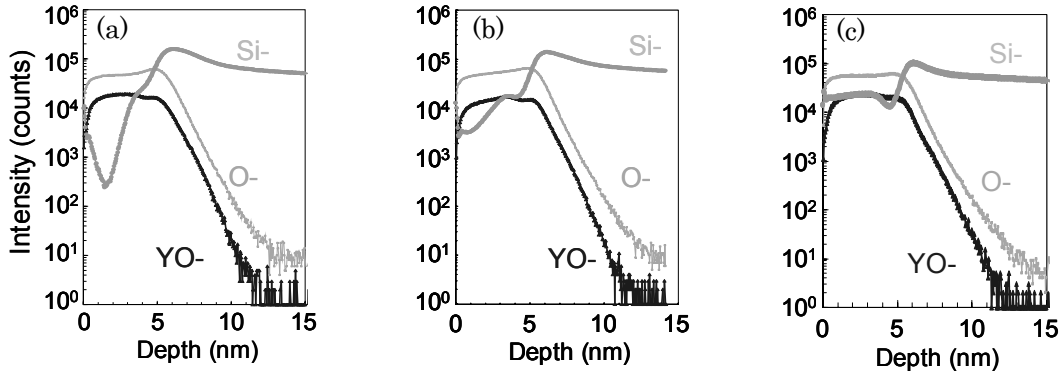

Fig.2 (a)-(c) SIMS depth profiles for yttrium aluminate films on NO annealed oxy-nitride. (a) yttrium aluminate films before annealing. (b) yttrium aluminate films after annealing at 800ºC. (c) yttrium aluminate films after annealing at 900ºC.

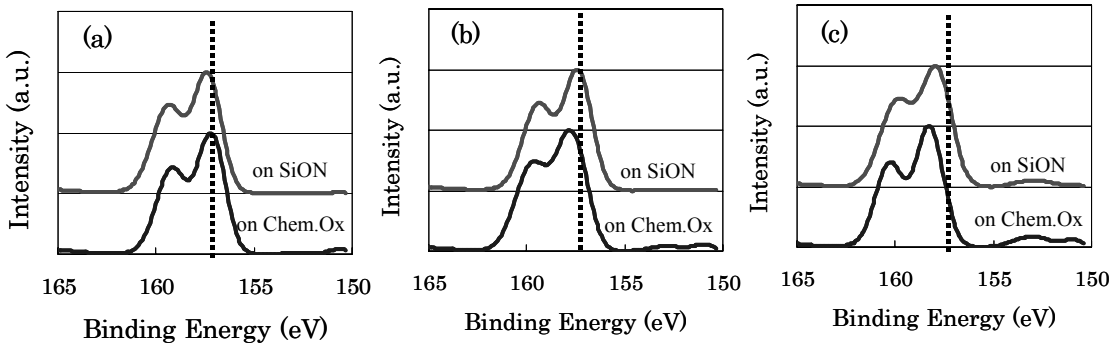

Fig.3 (a)-(c) Comparison of Y3d XPS spectra between yttrium aluminate film on the NO annealed oxy-nitride and that on the chemical oxide. (a) yttrium aluminate films before annealing. (b) yttrium aluminate films after annealing at 800ºC. (c) yttrium aluminate films after annealing at 900ºC.

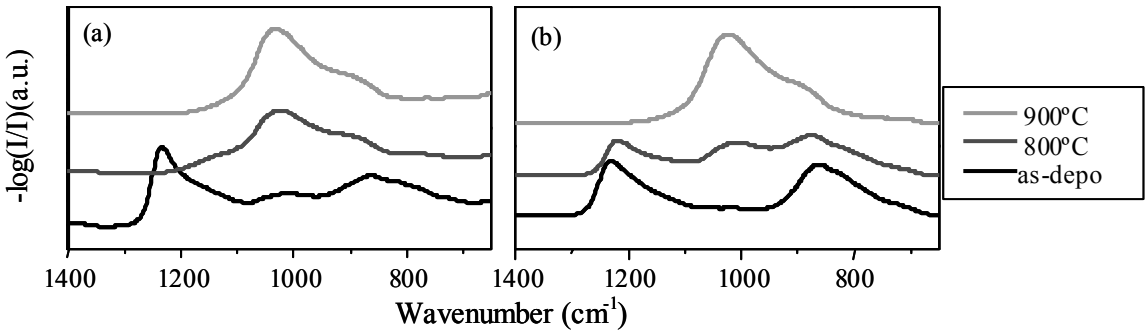

Fig.4 (a), (b) FT-IR ATR spectra of yttrium aluminate films on some oxidized silicon substrates with different annealing temperature. (a) yttrium aluminate films on the chemical oxide. (b) yttrium aluminate films on the NO annealed oxy-nitride