Crystallographic Orientation Dependent Electrical Characteristics of La_2O_3 MOS Capacitors

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Abstract

Effect of substrate surface orientation on the properties of La_2O_3 MOS capacitors was investigated. The dielectric-thickness dependence on V_{FB} indicated that the (110) sample contains smaller amount of fixed charge than the other samples of (100) and (111). The EOT also varied with the orientation: larger value for (111) compare to the others. The XPS revealed that the growth of SiO_2-rich silicate phase of low permittivity depends on the orientation and can change EOT. The results suggest that the (110) is preferable for small EOT and adequate V_{FB} value when the interface-state density is significantly reduced.

Introduction

Aggressive scaling of MOSFET devices requires a Metal gate/High-k gate stack [1-2]. Using a different surface orientation is regarded as one of the performance booster techniques. Thus it is important to combine this booster technique with the high-k technology. The chemical and physical interfacial properties of the Si-SiO_2 system have been extensively studied, including the effect of crystallographic orientation: (100), (110) or (111). However, the properties of high-k dielectrics with different surface orientations of Si, have not investigated yet. In this study, our main interest is to understand the differences of interfacial structures of the Si-La_2O_3 system with different orientations.

Experiment details

La_2O_3 MOS-capacitors were fabricated on n-type Si substrates of (100), (110) or (111) surface orientation. Thin film of La_2O_3 was deposited by the e-beam after SPM cleaning and HF cleaning. Tungsten (W) layer was deposited *in situ* on the La_2O_3 film by RF sputtering. The tungsten film was patterned by the reactive ion etching (RIE) with SF_6 gas to form gate electrodes. Post-metallization annealing (PMA) was carried out for 30 min in a forming gas at 400, 450 and 500^{o}C. EOT, flat-band voltage (V_{FB}), chemical states were investigated by the *C-V* data and XPS.

Results and discussion

Fig 1(a) shows *C-V* characteristics of La_2O_3 MOS capacitors on different wafer orientations of the same EOT (1.1nm) but different physical thickness. The V_{FB} value of (110) and (111) sift positively and negatively from the one for (100), respectively. Here, the V_{FB} values are plotted as a function of EOT in Fig 1(b). The V_{FB} of the (110) sample was less dependent on EOT than other orientations and its values were around 0.3 V. Considering the ideal V_{FB} of 0.3 V for obtained on the W/La_2O_3/Si system, (110) seems to be optimal orientations. That is, the

amount of the fixed charges with (110) orientation is smaller than the other orientations. Fig 2(a) shows EOT as a function of PMA temperature for W/La_2O_3/Si capacitors with different orientations of the same physical thickness but different EOT. We investigated the chemical state of the silicate layer formed after annealing at 500 ^oC by XPS[3], the results are shown in Fig 2(b). S. J. Jo et al reported that the peak at higher energy position of O *1s* spectra is from silicate with low La concentration and the peak at lower energy position is from silicate with higher La concentration, the peak at higher energy position should be SiO_2 rather than La-silicate[4]. It is not anomalous with our results and it is indicated that higher amount of (111) should mean the silicate of (111) has resemblance to SiO_2. This identification is in good agreement with the results of EOT increment as shown in Fig 2(a).

References

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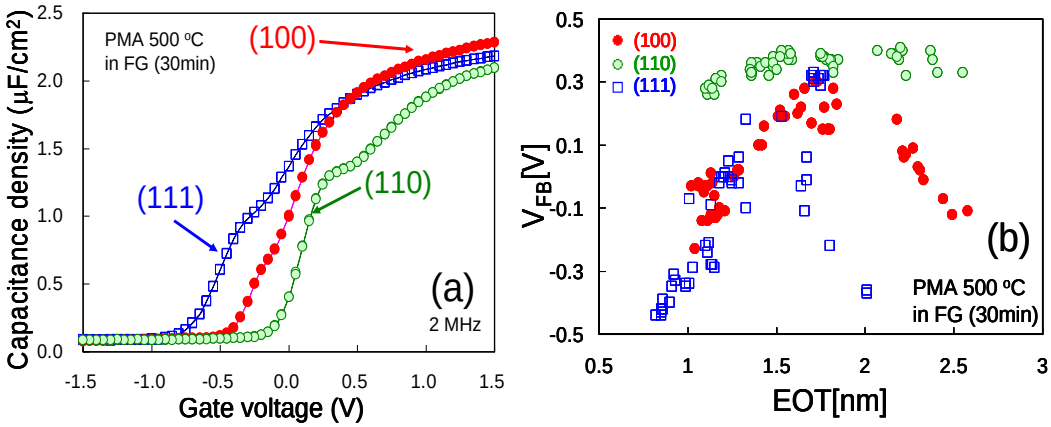

Fig 1 (a) *C-V* characteristics of La_2O_3 MOS capacitors

(b) V_{FB} as a function of EOT for La_2O_3 MOS capacitors.

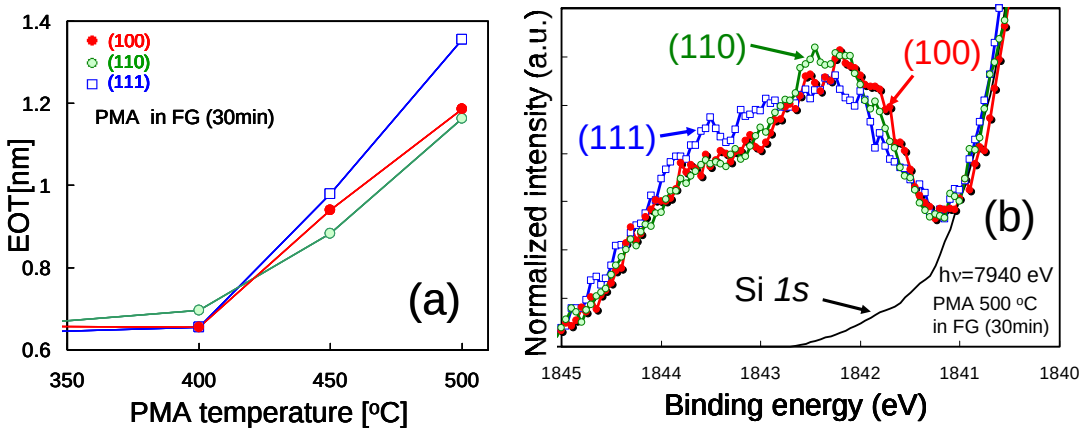

Fig2 (a) EOT as a function of PMA temperature in forming gas.

(b) Si 1s spectra arising from La-silicate normalized by the intensity arising from Si substrate.