A Novel Gas Switching Method to Improve the Reliability of Rapid Thermal Oxide

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INTRODUCTION

The precise control of the thickness and the quality of the oxide layer is a crucial factor for the performance of the MOS devices since the gate oxide thickness is less than 2 nm for the 0.13 μm technology node and beyond [1]. Since the interface state density increases with the decreasing oxidation temperature [2], the growth of low temperature oxide near the Si/SiO_2 interface during the ramp-down time may be responsible for the increase of interface state density. To avoid oxidation in the slow ramp-down cycle, we investigate the novel process to switch off the oxidation precursor (oxygen) during the ramp-down time and the reliability of the resulting oxide is enhanced.

EXPERIMENT

The ultrathin gate oxide of the NMOS diode was grown by RTO with the spike ramp oxidation process at various peak temperatures from 800 °C to 1000 °C. Fig.1 is the temperature and oxygen flow rate profiles of overall oxidation and ramp-up oxidation processes. The oxygen is switched off instantaneous at the beginning of the ramp-down cycle for the ramp-up oxidation. NMOS diodes have Al gate electrodes with circular area of $3x10^{-4}cm^2$ defined by photolithography. The constant current stress (CVS) measurements were carried out using an HP 4156A semiconductor parameter analyzer.

RESULTS AND DISCUSSIONS

Fig. 2 shows the gate current variation as a function of stress time of NMOS diodes with oxide grown at peak temperature of 900 ℃ for both overall oxidation and ramp-up oxidation. Both device are designed to have similar oxide thickness (T_{ox} ~ 1 nm) and are stressed under CVS. There is no gate current fluctuation for ramp-up oxidation device but obvious gate current fluctuation for overall oxidation device under CVS. The similar results are also obtained on the samples grown at peak temperature of 1000℃. Besides, the gas switching effect was also studied for the thick oxide devices, which are grown by convention RTO at the temperature of 1000 ℃ with 70 seconds plateaus oxidation. Both devices with similar oxide thickness (Tox ~ 5.2 nm) are stressed under 200 sec CVS at V_g= -7.5V as shown in Fig. 3. The hard breakdown of oxide occurs under CVS and the injection influence (Q_{inj}) maintains similar (about 10^{-1} coul/cm^2) for both devices.

CONCLUSIONS

We have demonstrated the reliability improvement by gas switching, which controls oxidation time in spike ramp oxidation process. The oxygen is switched off instantaneously at the beginning of the ramp-down cycle to avoid inferior oxide formation. The gas switching can enhance the oxide reliability at the spike ramp oxidation temperature of 900 ℃ and 1000 ℃, and its effect is not apparent at 800℃ since the low temperature oxidation(800 ℃) forms inferior oxide and higher interface state density. The gas switching can also improve the oxide leakage current for thick oxide, which the hard breakdown does not show improvement. This simple technique can be easily used in VLSI fabrication to improve the oxide quality.

REFERENCES

[1] International Technology Roadmap for Semiconductors, 1999.

[2] H. Fukuda, T. Arakawa, and S. Ohno, “Thin-Gate SiO_2 Films Formed by *in situ* Multiple Rapid Thermal Processing,” *IEEE Trans. Electron Devices*, vol. 39, no. 1, pp. 127-133, Jan. 1992.

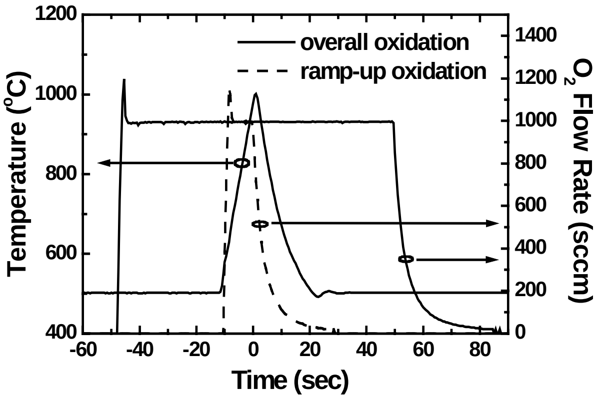

Fig. 1 The temperature and oxygen flow rate profiles of overall oxidation and ramp-up oxidation processes.

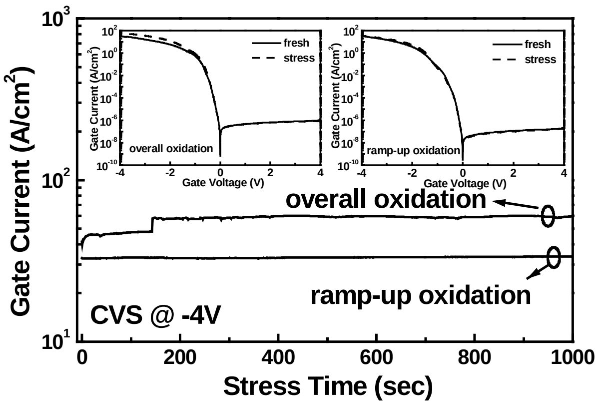

Fig. 2 The gate current vs stress time plot of the both NMOS diodes for overall oxidation and ramp-up oxidation at the peak temperature of 900 °C, with the oxide thickness of ~ 1 nm under CVS at V_g= –4V for 1000 sec.

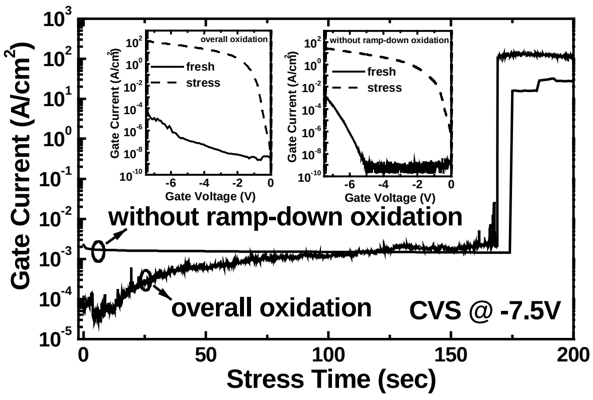

Fig. 7 The CVS measurement under V_g= –7.5V for overall oxidation and without ramp-down oxidation processes at temperature 1000°C grown oxide.