Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 14-15

A-2-1

Highly Reliable SiO_2 Films Formed by UV-O_2 Oxidation

Akinobu Teramoto, Kiyoteru Kobayashi, Yoshikazu Ohno, and Makoto Hirayama
Mitsubishi Electric Corporation, ULSI Laboratory
4-1, Mizuhara, Itami, Hyogo 664, Japan
Tel: +81-727-84-7355, Fax: +81-727-80-2675, E-Mail: teramoto@lsi.melco.co.jp

1. Introduction

According to the further integration of ULSI devices, the gate oxide becomes thinner and thinner. Thus the gate oxide, which determines device reliability, is used on hostile conditions. Furthermore, for the shrinking of the ULSI devices, the channel profile control of MOSFETs requires the low temperature process even on the gate oxidation. Some new oxidation methods have been given a lot of attention as candidates for thin gate dielectrics. In this work, we studied the UV-O_2 oxidation method.

2. Sample Preparation

MOS capacitors were fabricated on p-type (100) substrate with resistivity of 8.5 - 11.5 Ωcm and n-type (100) substrate with resistivity of 10 - 20 Ωcm. Gate oxides were grown in dry O_2 ambient at 600 - 900 °C under ultraviolet irradiation (UV-O_2 Oxidation) and were grown in dry O_2 ambient at 900 °C (dry oxidation). The wave lengths of ultraviolet were 185 and 254 nm. The electrodes were formed from in-situ phosphorous-doped polycrystalline silicon.

3. Results and Discussions

Figure 1 shows the weibull plots in constant current TDDB measurement for the 63 Å oxides formed by UV-O_2 and dry oxidation at 900 °C. The charges to breakdown (Q_{BD}) in the UV-O_2 oxides and the dry oxide are 2.3 and 0.9 C/cm^2, respectively. Figure 2 shows the Q_{BD} value at 50% cumulative failure (50%Q_{BD}) as a function of oxide thickness. 50%Q_{BD} in the oxide formed by UV-O_2 at 900 °C (shown as ●) is larger than that in the dry oxide (shown as ○) in the thicknesses ranging form 50 to 90 Å.

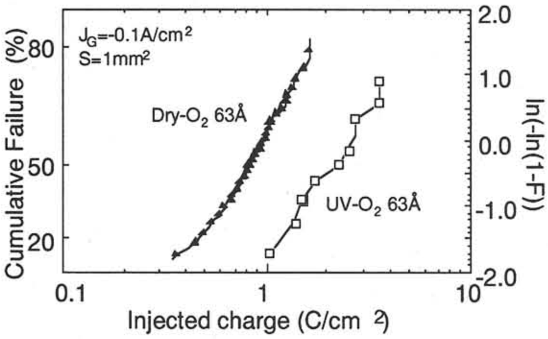

Fig. 1 Weibull plots in constant current TDDB measurement for oxides formed by UV-O_2 and dry oxidation.

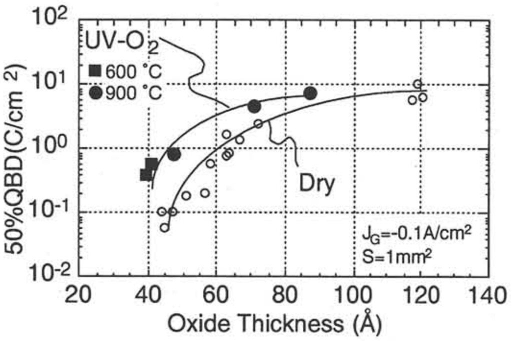

Fig. 2 Q_{BD} at 50% cumulative failure in constant current TDDB measurement as a function of oxide thickness.

Figure 3 shows the gate current density as a function of the oxide field for positive and negative polarities of samples with 64 Å oxides before and after F-N stress. The stress induced leakage current (SILC) in UV-O_2 oxide is less than that in dry oxide for both polarities. These results indicate that UV-O_2 oxides are stable against the electrical stresses as compared with the dry oxides.

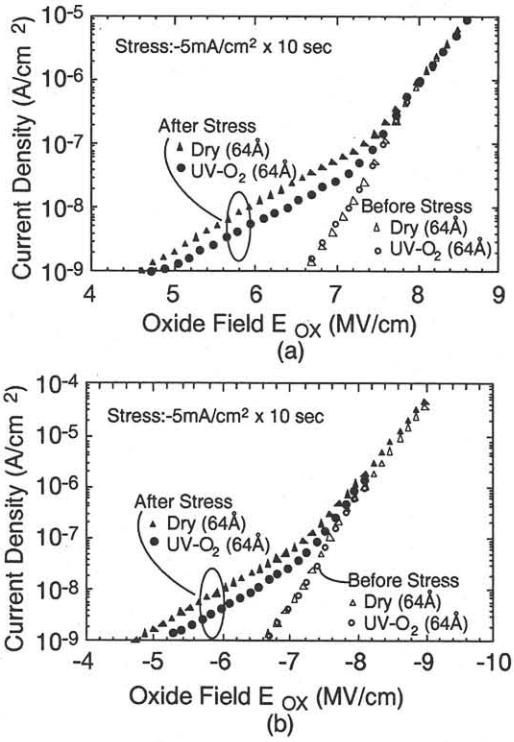

Fig. 3 J_G-E_{OX} characteristics for (a) positive and (b) negative polarities of samples with 64 Å oxides formed by UV-O_2 and dry oxidation.

Figure 4 shows the gate voltage shift in the UV-O_2 oxide and the dry oxide during constant current stressing of -0.1 μA/cm^2. The gate voltage shift in UV-O_2 oxide is less than that in the dry oxide. The shift of gate voltage in the negative gate voltage direction indicates that hole trapping occur in the oxides. These facts indicate hole trap density of UV-O_2 oxides smaller than that of dry oxide. Figure 5 shows the proposed defects in SiO_2 films. The Si-Si bond or oxygen vacancy (A), the Si dangling bond (B), the Si-H bond, and the Si-OH bond exist as defects in SiO_2 films. It has been reported that the oxygen vacancy acts as the hole trap [1], and the hole trap causes the SILC and the dielectric breakdown in SiO_2 [2]-[5]. The binding energies of those bonds, O=O bond, and UV-rays are shown in Table. 1. The binding energies of all bonds in SiO_2 and O=O bonds in O_2 gas are lower than the energy of UV-rays. It indicates that these bonds are cleaved by the UV-rays and the Si- bonds generated from these bonds react with activated oxidant to form SiO_2. These suggest that the amount of Si-Si bonds in the UV-O_2 oxide is less than that in the dry oxide.

Figure 6 shows the weibull plots in constant current TDDB measurement for the positive gate voltage stressing. The lifetimes in the UV-O_2 oxides is larger than that in the dry oxide. These indicate that the high reliable oxide can be formed by UV-O_2 oxidation even at 600 °C. This indicates that the UV-O_2 oxidation technology is very useful for the formation of the future devices which require low-temperature processing.

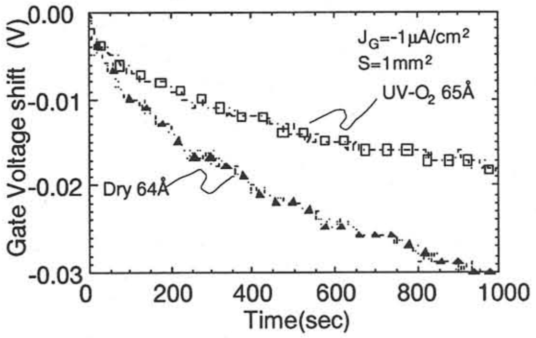

Fig. 4 Gate voltage shift of MOS capacitors during constant current stressing of -0.1A/cm^2.

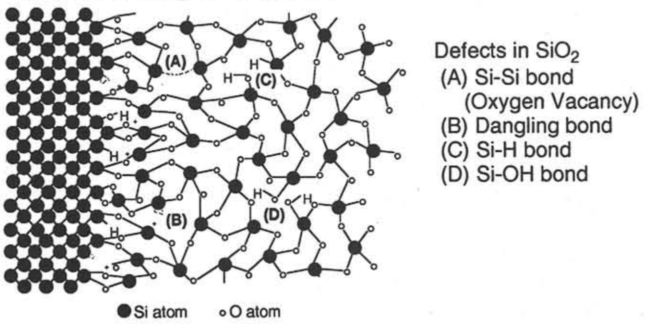

Fig. 5 The proposed defects near the Si-SiO_2 interface.

Table 1 Binding energies for bonds in SiO_2 films and O_2 gas and the energy of UV-rays.

	Binding Eenrgy
Si-Si	2.0 eV
Si-H	3.3 eV
Si-O	4.8 eV
O=O	5.2 eV
UV rays (185 / 254 nm)	6.7 / 4.9 eV

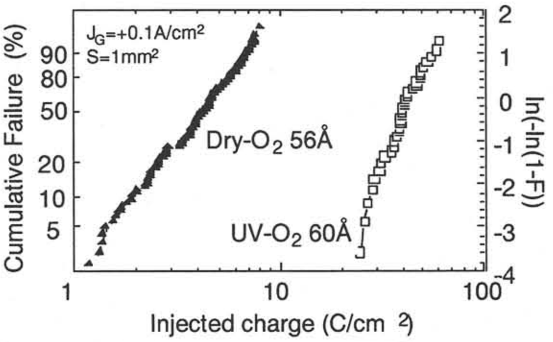

Fig. 6 Weibull plots in constant current TDDB measurement for oxides formed by UV-O_2 at 600 °C and dry oxidation.

4. Conclusions

We have developed and evaluated SiO_2 films formed by UV-O_2 oxidation. It has been found that TDDB, SILC and hole-trapping characteristics in SiO_2 formed by the UV-O_2 oxidation are superior to those formed by conventional oxidation. The UV-O_2 oxidation is very useful for the formation of the future devices.

Acknowledgment

We thank Dr. M. Fujisawa for the useful discussion and Mr. S. Shikama for the his help in the electrical measurements.

References

1) H. Miki, M. Noguchi, K. Yokogawa, B. W. Kim, K. Asada, and T. Sugano. IEEE Trans. Electron Devices, 35, 2245 (1988).

2) K. Kobayashi, A. Teramoto, and M. Hirayama, Proc. Int. Reliability Phys. Symp., 1995, pp.168.

3) A. Teramoto, K. Kobayashi, Y. Matsui, M. Hirayama, and A. Yasuoka, Proc. Int. Reliability Phys. Symp., 1996, pp. 113.

4) K. Kobayashi, A. Teramoto, Y. Matsui, M. Hirayama, and A. Yasuoka, J. Electrochem. Soc., Vol. 143, No. 10, 3377 (1996).

5) A. Teramoto, K. Kobayashi, Y. Matsui, and M. Hirayama, To be published in Appl. Surf. Sci..