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Improvement of Reliability of MOSFET's with N_2O Nitrided Gate Oxide and N_2O Polysilicon Gate Reoxidation

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1. Introduction

The hot electron reliability is correlated to the gate oxide integrity near the polysilicon gate edge [1]. A damage phenomenon, edge damage, occurred near the drain and source junctions during gate polysilicon plasma etching [2]. It was reported that N_2O oxynitride poly-gate reoxidation process is effective in suppressing the reverse short channel effect (RSCE) without degradation the short channel behavior of the MOSFETs [3]. Therefore, polysilicon gate sidewall reoxidation is important for improving gate oxides. Recently, it is found that N_2O nitrided gate oxide is more robust than O_2 gate oxide in resisting the process-induced degradation. Also, to grow a thin oxide on the polysilicon-gate in N_2O ambient lessens the degradation on the underlying gate oxide than to grow it in O_2 ambient[4].

In this work, firstly, the electrical characteristics of MOSFETs with N_2O nitrided gate oxide and processed by N_2O poly-gate reoxidation have been investigated, including hot electron immunity, RSCE, interface generation and antenna effect.

Table I The preparation sequences for this work.

Devices	Gate Dielectrics: Wet Oxidation	Gate Dielectrics: N_2O annealing	Poly-Si gate	poly-Si gate(WSix) re-oxidation
$ON_{00}PO$	√	—	√	— (O_2)
$ON_{00}PN$	√	—	√	√ (N_2O)
$ON_{20}PO$	√	√(20 min)	√	— (O_2)
$ON_{20}PN$	√	√(20 min)	√	√ (N_2O)
$ON_{40}PO$	√	√(40 min)	√	— (O_2)
$ON_{40}PN$	√	√(40 min)	√	√ (N_2O)
$ON_{60}PO$	√	√(60 min)	√	— (O_2)
$ON_{60}PN$	√	√(60 min)	√	√ (N_2O)

2. Experiments

N^+ polysilicon-gate n-MOSFET's with different gate oxides were fabricated using a 0.35 μm CMOS process. The O_2 gate oxide was grown in wet-oxidation at 800 ℃ and then annealed in N_2 at 900℃. For comparison, the N_2O nitrided oxide was firstly grown in wet-oxidation at 800 ℃ followed by N_2O annealing at 850℃ for 20 to 60 min to control the final thickness of 8.5 nm. For the poly-Si gate reoxidation process, there are two groups, one is reoxidized in O_2 ambient (O_2 poly-reoxidation) and the other in N_2O ambient (N_2O poly-reoxidation) at 850 ℃ for 20 min.

The preparation sequences for these samples were summarized in Table I. For example, the O_2 oxide sample with O_2 poly-reoxidation is denoted as $ON_{00}PO$. For the 40 min N_2O nitrided oxide with N_2O poly-reoxidation is denoted as $ON_{40}PN$.

3. Results and Discussion

Hot carrier immunity was investigated which devices were biased at peak value of substrate current under constant drain voltage (V_d=5V). Fig 1 (a) and (b) show the hot carrier induced transconductance (g_m) degradation for O_2 and N_2O poly-reoxidation, respectively.

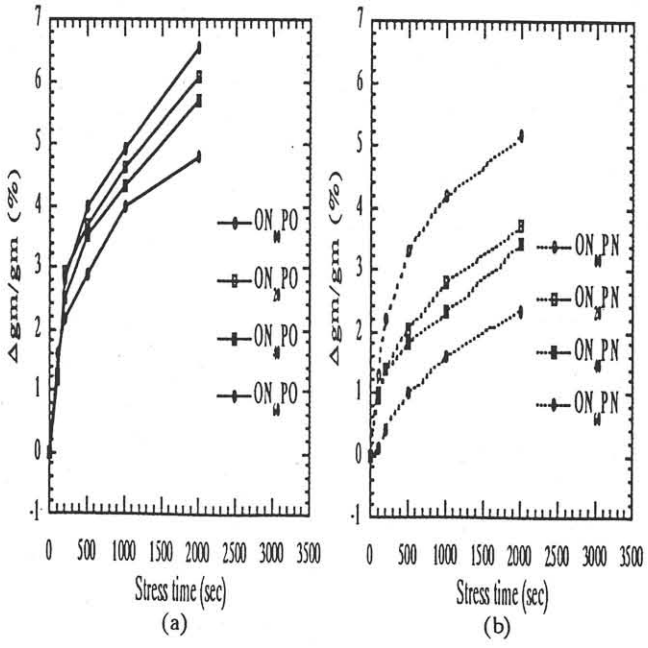

Fig. 1 The hot carrier stress induced g_m degradation for (a) O_2 and (b) N_2O poly-reoxidation, respectively.

We can find that degradation is decreased as increasing N_2O nitrided time. This reduction in g_m degradation was mainly due to a reduction in interface generation under stress. Comparing to O_2 poly-reoxidation samples (solid line), N_2O poly-reoxidation sample (dotted line) had much improved hot carrier immunity.

Measurement of the charge pumping current , I_{cp}, was carried out as shown in Fig. 2 which the repetition frequency and width of the gate pulse were 100 kHz and 5 μ s, respectively.

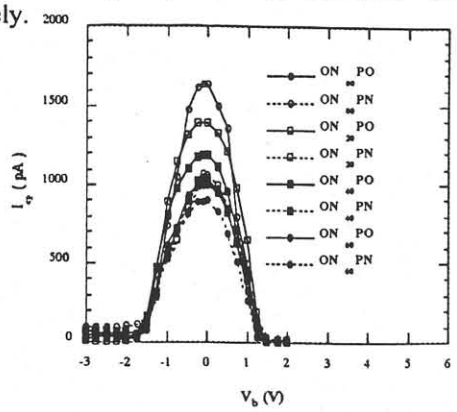

Fig. 2 Charge pumping current, I_{cp}, for all samples.

It showed that $ON_{60}PN$ had the smallest I_{cp} after hot carrier stress. This meant that $ON_{60}PN$ has the smallest generation of interface state density. This was consistent with the result of g_m degradation as shown in Fig. 1.

The RSCE was studied as shown in Fig. 3 (a) and (b) for O_2 and N_2O poly-reoxidation, respectively.

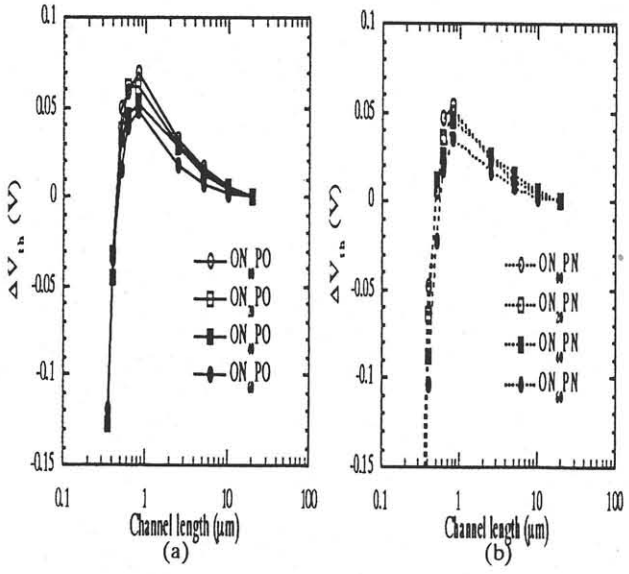

Fig. 3 The treshold voltage virsus channel length (a) O_2 and (b) N_2O poly-reoxidation, respectively.

It can be seen that the RSCE was suppressed, not only for N_2O nitrided oxides but also N_2O poly-reoxidation process. As increasing N_2O annealing time, the RSCE was decreased. Due to the incorporated nitrogen at the oxide/Si-substrate interface which retarded the poly-reoxidation enhanced channel boron diffusion, resulted in uniform channel boron distribution.

We use F-N tunneling leakage current and charge-to-breakdown (Q_{bd}) of gate oxides to monitor the plasma charging induced degradation on all samples. Antenna effects on gate leakage current were shown in Fig. 4.

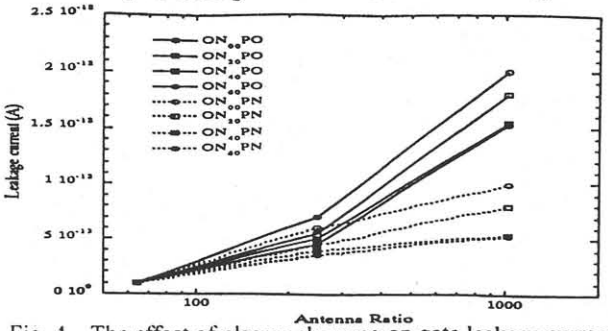

Fig. 4 The effect of plasma charging on gate leakage current with various atenna ratio for all samples.

It shows that leakage current is increased by increasing antenna ratio. However, as increasing N_2O nitrided time, the leakage current due to antenna effects was decreased. The leakage current is slightly increased as increasing antenna ratio for all samples with N_2O poly-reoxidation.

The Q_{bd} under 100 mA/cm^2 F-N stressing with different antenna ratio was shown in Fig.5 (a) and (b) for O_2 and N_2O poly-reoxidation, respectively. When the antenna ratio was increased, the Q_{bd} was decreased for all samples with poly-O_2 reoxidation. Fortunately, the Q_{bd} is slightly decreased as increasing antenna ratio for all samples with N_2O poly-reoxidation.

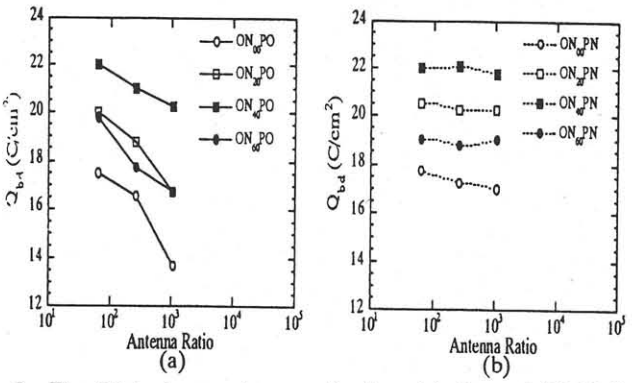

Fig. 5 The Qbd virsus antenna ratio for (a) O_2 and (b) N_2O poly-reoxidation, respectively.

4. Conclusion

A systematic study of the reliability of MOSFET's with N_2O nitrided gate oxides and processed by N_2O poly-gate reoxidation was presented. Combination of N_2O nitrided gate oxides and N_2O poly-gate reoxidation, hot electron immunity was improved and RSCE, interface generation, antenna effect on leakage current and Q_{bd} was suppressed.

References

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