Extended Abstracts of the 2010 International Conference on Solid State Devices and Materials, Tokyo, 2010, pp217-218

A Novel Hot DI Water Rinse on SOD Filled Self-Aligned Shallow Trench Isolation for Highly Reliable NAND Flash Memory

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Abstract

Hot deionized (DI) water rinse effect on spin on dielectrics (SOD) filled STI has been demonstrated for the first time on 42nm node NAND flash memory. Significant improvements in cell performance and reliability are obtained : (1) Better endurance : total 0.37V less cell Vth shift after 10k E/W endurance test. (2) Good data retention : 36.7% less cell Vt shift after baking 125°C , 2 hours. Moreover, (3) Stress induced leakage current (SILC) life time is extended 54%. Aforementioned improvements are due to better SOD transformation and considerable impurity reduction by hot DI water treatment.

1. Introduction

As the dimension of NAND Flash memory scales down, SOD is well known for with excellent gap filling properties, but the worse thermal stability, high wet etch rate and non-transformed impurity are crucial concern[1]. Although high curing temperature by steam vapor after SOD coating can improve the above issue, the serious oxidized active area and gate oxide bird's beak will deteriorate device reliability [2]. In this work, we have successfully demonstrated the use of hot DI water rinse method to improve SOD transformation without scarifying cell tunnel oxide bird's beak encroachment. Moreover, much better cell performance reliabilities can be achieved.

2. Experiments

The devices were fabricated by 42nm node NAND Flash process on p-type Si substrate with self-aligned STI process. The cell STI trench is filled by SOD coating and cured in steam ambient for SOD converted to pure SiO_2. The conventional SOD curing process and novel hot DI water rinse method between two steps SOD curing are shown in Fig.1. The cell STI recess, ONO, WSix gate, inter-layer dielectric contact and back end of processes were fabricated by conventional fabrication process.

3. Results and Discussion

The impurities of SOD film after curing were detected by FTIR (Fourier Transform Infrared) Spectroscopy and SIMS. The IR results in Fig. 2 show higher Si-O and lower Si-H bonding intensity in those with hot DI water treatment. According to the SIMS data in table.1 and Figs.3 and 4, the nitrogen atom (N) intensities are apparently reduced more than 50% by hot DI water treatment. Moreover, higher temperature (T1+10°C) DI water treatment shows the highest oxygen atom (O) intensity (nearly 16.7% increment, almost twice as large as the sample with T1°C DI water treatment).

For SOD process, the solution with perhydrosilazane polymer ((SiH_2NH)n) is coated. After 1st and 2nd SOD cure, film is converted to SiO_2 with Si-N, Si-H and N-H bond as shown in Fig2.

$$SiH_2NH + 2O \rightarrow SiO_2 + NH_3 \qquad [3]$$

This reaction is in progress when SOD is immersed in hot DI water and converts SOD into SiO_2 with less Si-N, Si-H and NH. Raising the temperature of DI water indicates more kinetic energy supplied to H_2O molecular, which makes it diffuse into SOD film more easily and further accelerate SOD transformation. Therefore, SOD oxide CMP polish rate increases by better oxide transformation as shown in Fig. 5. The cell TEM cross-sections of conventional and hot DI water rinse samples are shown in Fig. 6. There is no difference from tunnel oxide thickness and bird's beak encroachment.

Most good block ratio (MGM) are shown in Fig.7, Hot DI water rinse can obviously improve the yield of MGM>99%, moreover, the cell function fail rate is also reduced. The 10K endurance is shown in Fig. 8. The cell Vth shift of program/erase state after 10k cycling of Hot DI water rinse samples are 0.21/0.16V less than conventional sample. Data retention results after baking 125°C , 2 hours are shown in Fig.9. Hot DI water rinse also improves cell retention performance. Particularly, the higher temperature (T1+10°C) DI water treatment perform best retention characteristic, with 36.7% less Vth shift than the conventional sample. The SILC results are shown in Fig.10. The higher temperature (T1+10°C) DI water treatment sample can extend SILC lifetime by 54% compared to the conventional sample. According to previous literature [4], the impurity like nitrogen or hydrogen are piled up on the side wall of STI to create space charges and traps, those defects located at active area edge will distort device Vt distribution control, which have been much reduced by hot DI water treatment, so the MGM and reliabilities are much improved.

4. Conclusion

The hot DI water rinse process on SOD filled SA-STI of NAND flash memory has been successfully developed. Better SOD conversion to pure oxide and less N, H impurity in STI can be attained without suffering cell tunnel oxide bird's beak encroachment by hot DI water rinse method, especially in higher temperature water rinse. Therefore, the manifest improvement of most good block ratio and cell reliability had been achieved.

Reference

[1] W. Z. Wong, J. J. Fan, et al *VLSI-TSA,* pp9-10 (2009).
[2] J. S. Choi, J. H. Lee, et al., *ISSM,* pp419-422 (2003).
[3]A.Kawasaki et al. *US patent* 7538047 (2009).
[4]O.Arisumi et al. *US patent* 7416955 (2008)

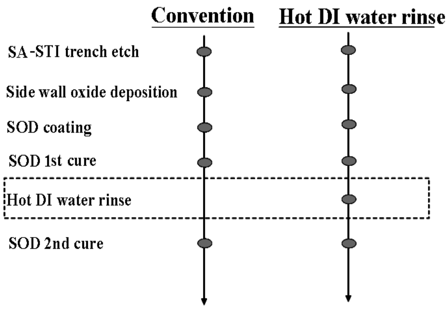

Figure 1: The process steps and sequences of SOD filled STI by the conventional process and hot DI water rinse treatment of 42nm node NAND Flash memory.

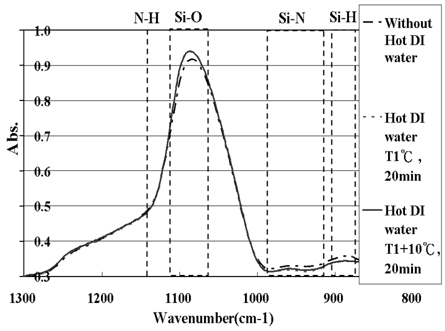

Figure 2: FTIR analysis results of N-H, Si-O, Si-N, Si-H bonding intensity of SOD film with/without hot DI water treatment after SOD curing.

Table 1: SIMS Analysis results of Nitrogen (N) and Oxygen (O) in SOD filled STI after SOD curing.

SIMS Analysis after SOD curing				
Intensity avg. (c/s)	Elements	Without Hot DI water	HOT DI water T1℃ 20mins	HOT DI water T1+10℃ 20mins
	N	33.04	13.8 (- 58.2%)	15.86 (- 52.0%)
	O	91441.1	99755.7 (+ 9.0%)	106763.6 (+16.7%)

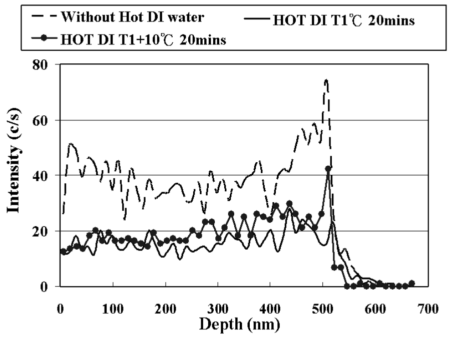

Figure 3: SIMS analysis results of nitrogen (N) of SOD film with/without hot DI water treatment after SOD curing. The hot DI water treatment can reduce nitrogen content in SOD film.

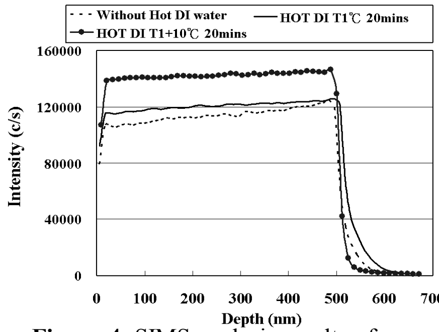

Figure 4: SIMS analysis results of oxygen (O) of SOD film with/without hot DI water treatment after SOD curing. The hot DI water treatment can enhance SOD transformation to pure oxide.

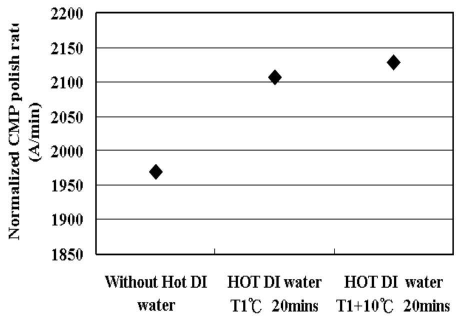

Figure 5: The SOD oxide CMP polish rate versus SOD film with/without hot DI water treatment.

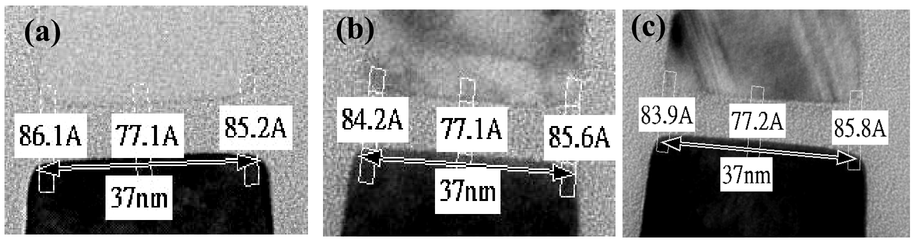

Figure 6: The cell TEM cross-sectional photograph along BL direction for (a) without (b) with hot DI water rinse T1°C and (c) T1+10°C. No apparent difference from tunnel oxide thickness and bird beak's offset in each case.

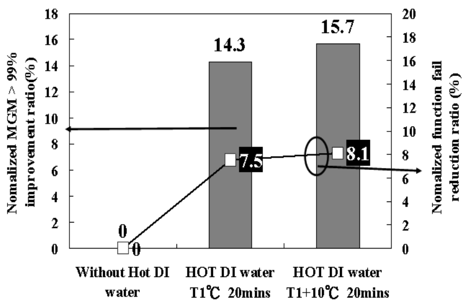

Figure 7: Most good block ratio (MGM) of samples with/without hot DI water treatment. Higher MGM yield and lower function fail rate by hot DI water treatment.

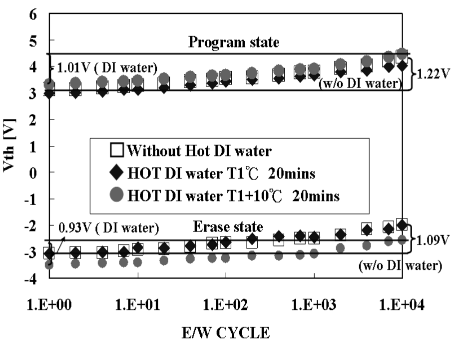

Figure 8: The 10k Endurance of cell array with/without hot DI water treatment, the program /erase state Vth shift of hot DI water treatment (1.01V/0.93V) are better than conventional sample (1.22V/1.09V).

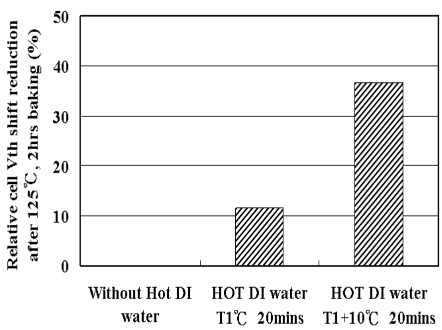

Figure 9: The relative cell Vth shift reduction after 125°C, 2 hours baking. The higher temperature of hot DI water treatment performs the best retention characteristic.

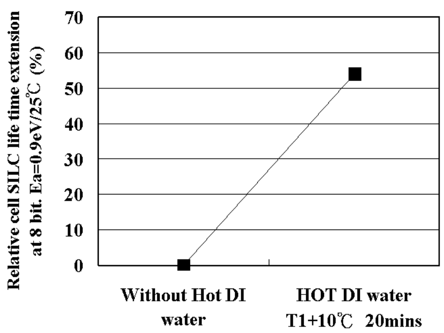

Figure 10: SILC life time of samples with/without hot DI water treatment. The life time can be extended 54% by hot DI water treatment.