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Nitrogen Depth Profiles in Ultrathin Oxynitride Films

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Abstract

For quantitative N depth profiling, N profiles were measured in a ~ 3 nm Si oxynitride by low energy O_2^+ sputtering and the result was calibrated with MEIS analysis of the N thickness and areal density. The quantitative depth profile of nitrogen showed the pileup of nitrogen atoms at the interface of ultrathin oxynitride films.

1. Introduction

Ultrathin oxynitride film on Si is a promising candidate for gate dielectrics owing to their properties such as very large charge-to-breakdown ratio, less charge trapping, less interface-state generation, less B penetration, and a lower threshold-voltage shift under constant current [1,2]. The improved dielectric properties are attributed to the fact that the nitrogen atoms at the interface of SiO_2/Si act as a barrier to boron penetration and reduce interfacial strain [3-5]. Depth distribution of nitrogen in the oxyinitrde thin films plays a very important role in determining electrical properties of gate dielectrics. Many studies [1-4] have been carried out to obtain depth profile of nitrogen in the oxynitride films but quantitative nitrogen profiling procedure has not been established. In this work, the depth profile of nitrogen in ultrathin oxynitride film was obtained quantitatively with complementary use of low energy second-ion-mass spectroscopy(SIMS) and medium energy ion scattering spectroscopy(MEIS).

2. Experiment

The silicon oxynitride film on Si(100) supplied by Hynix, Korea was made by annealing at 900℃ for 20 min after wet oxidation at 700℃ and then annealing for 20 min under 300 torr NO ambient. The nominal thickness of oxynitride film was 2.7, 3.4, and 3.7 nm, respectively, as determined by ellipsometry. To obtain low energy primary ion beam, CAMECA 4f SIMS instrumentwas modified by attaching an acceleration and deceleration lens system in primary ion beam column. In SIMS measurements, 650 eV O_2^+ ions were used with as a primary beam. For MEIS analysis, 100 keV H+ ions incident along the [011] were used and the back scattered ions along the $[01\bar{1}]$ were measured in a double alignment condition to eliminate the crystalline Si substrate signal [6].

3. Results

Figure 1 shows SIMS depth profiles of the silicon oxynitride thin films taken with 650 eV O_2^+.

The Si^+ peak intesity generated in oxynitride is stronger than that in silicon substrate. The thickness of nm gate oxynitrides was determined with the 50% intensity of the plateau Si^+ intensity by SIMS with 650 eV O_2^+.

The SiN^+ peaks are located just above the interface.

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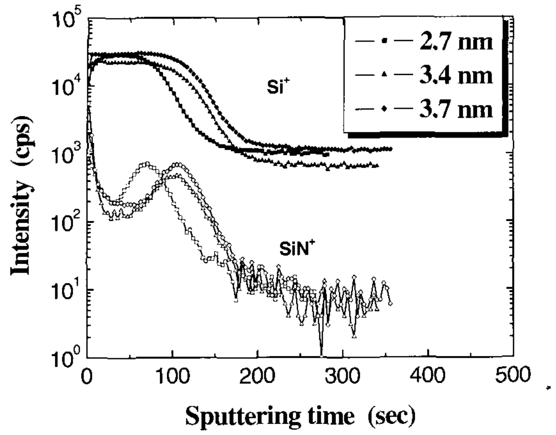

Fig. 1. SIMS spectra taken with 650 eV O_2^+

It suggests the pileup of the nitrogen atoms at the interface in oxynitride films. To calibrate the sputtering time and SiN^+ secondary ion intensity shown in Fig. 1. as depth scale and concentration, MEIS analysis of nitrogen was done and the result is shown in Fig. 2. The MEIS spectra in Fig. 2(a) gives the quantitative nitrogen distribution and the thickness of the Si oxynitrides as shown in Fig. 2(b), (c), and (d). The thickness values from MEIS were used to calibrate the SIMS depth scale. The nitrogen areal densities in Si oxynitrides 2.7, 3.4, and 3.7 nm are calculated to be 1.1×10^{15}, 4.9×10^{14}, and 4.5×10^{14}/cm^2, respectively, from MEIS results. RSFs calculated from nitrogen areal density for each specimen are 3.82×10^{23}, 1.67×10^{23}, and 1.48×10^{23}/cm^3, respectively.

Figure 2 shows the nitrogen depth profile obtained by MEIS spectrum fitted with computer simulations

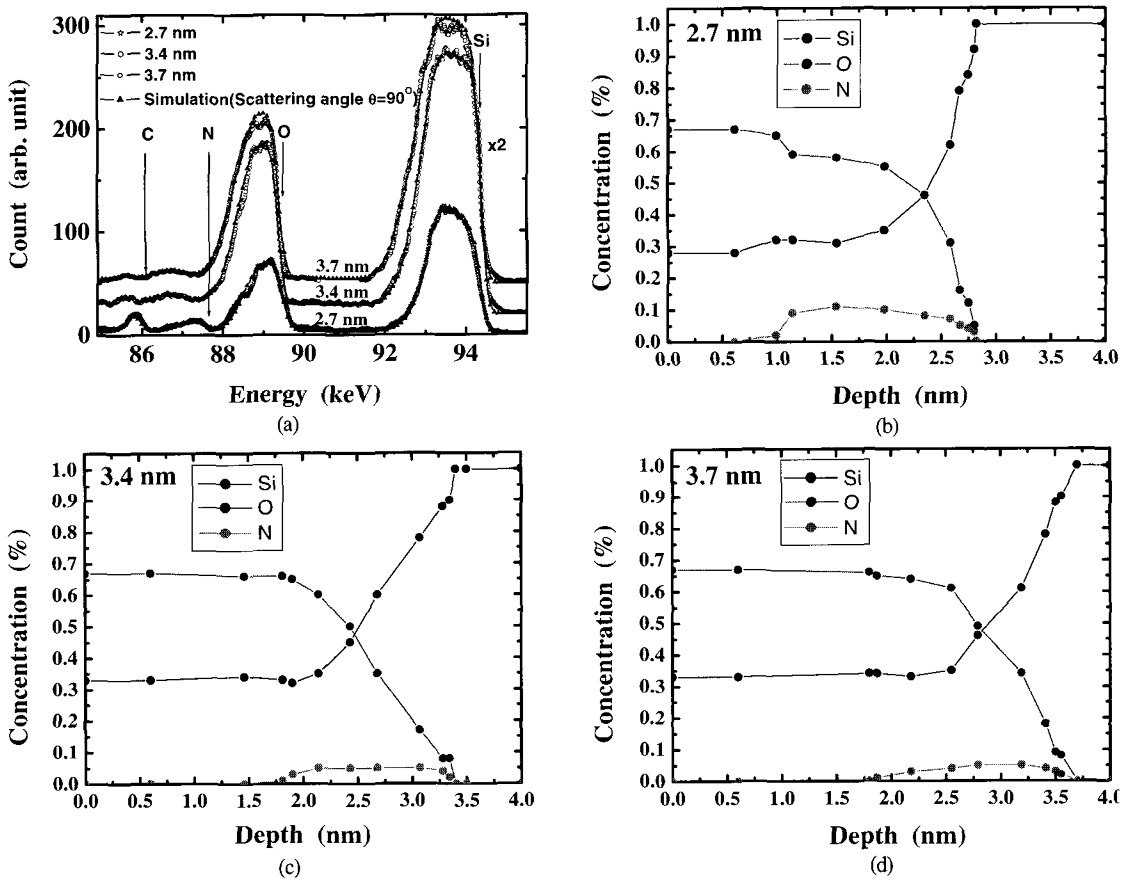

Fig. 2. MEIS spectra (a) for silicon oxynitrides and its composition profiles (b), (c), and (d) simulations

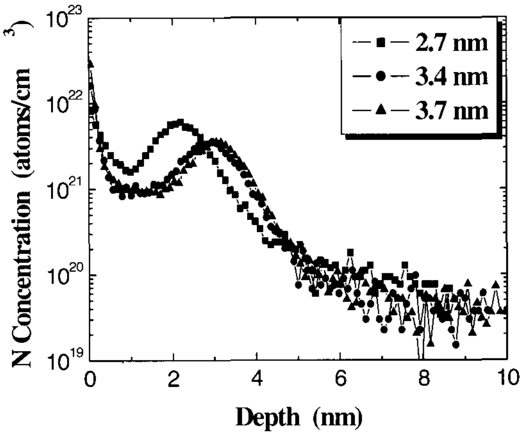

Fig. 3. Quantitative SIMS N profiles for O_2^+ SIMS

[6]. MEIS results show that nitrogen distributes in the SiO2 layers near the interface. The peak nitrogen concentration is ~10% for the 2.7 nm specimen and ~5% for the 3.4 nm and 3.7 m specimens. To convert sputtering time in Fig. 1. into the depth, we suppose that thin film thickness measured by MEIS in Fig. 2 is linearly proprotional to the sputtering time corresponding to the 50% decrease of Si^+ intensity from the plateau in Fig. 1. The final SIMS nitrogen profiles calibrated with the MEIS results are given in Fig. 3 for O_2^+. It showed quntitative depth profiles of nitrogen in ultrathin oxynitride films with low energy SIMS. The profile of SiN+ signal clearly shows the pileup of nitrogen atoms at the just above interface.

4. Conclusion

Quantitative nitrogen profiling in ultrathin oxynitride film was studied with the complementary use of low energy SIMS and MEIS. Thickness calibration and nitrogen area density determined with MEIS can be useful for quantitative nitrogen profiling with low energy SIMS.

Acknowledgement

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References

[1] H. Hwang, W. Ting, B. Maiti, D-L. Kwong, and J. Lee, Appl . Phys . Lett. **57**, 1010 (1990).

[2] H.C. Lu, E.P Gusev, T. Gustafsson, E. Garfunkel, M. Lgreen, D. Brasen, and L.C Fedman, Appl. Phys. Lett. **69**, 2713 (1996).

[3] K-S. Chang- Liao and N-K. Yi, Appl. Phys. Lett . **76**, 2770 (2000).

[4] Y. Tamura, M. Shigeno, S. Ohkubo, K. Iriino, T. Nakanishi and K. Takasaki, Jpn. J. Appl. Phys. **39**, 2158 (2000).

[5] K. Watanabe and T. Tataumi, Appl. Phys. Lett. **76**, 2940 (2000).

[6] J.C. Lee, C.S. Chung, H.J. Kang, Y.P. Kim, H.K. Kim and D.W. Moon, J. Vac. Sci. Technol. A **13**, 1325 (1995).