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Characterization of Crystalline Defects and Stress in Shallow Trench Isolation by Cathodoluminescence and Raman Spectroscopies

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1. Introduction

The performance of LSI devices has been improved by new processes, designs, and materials, such as strained Si, low-k inter-connection dielectric layer, and high-k gate dielectrics, etc. However, the reliability tends to decrease and the risk of failure increases because of the complexity of new technologies. Strained Si technology is considered one of the "Technology Boosters" in LSI. However, it is well known that the strain sometimes generates crystalline defects in LSI, and then increases the leakage current. Therefore, the precise control of strain and crystalline defects is important to improve the device performance.

Spectroscopic methods such as luminescence and Raman spectroscopies are powerful techniques to investigate crystalline defects and stress. Though the application of Cathodoluminescence (CL) to Si devices is restricted because of the low luminescence efficiency, it is reported that the plastically deformed Si shows characteristic dislocation-related luminescence labeled D1 (0.81eV), D2 (0.87eV), D3 (0.95eV), and D4 (1.0eV) [1,2].

In this paper, we have characterized the crystalline defects and stress in Shallow Trench Isolation (STI) process in LSI by CL and Raman spectroscopies. We discuss the generation mechanism of dislocations with comparing the CL results and the stresses derived by Raman microprobe measurements.

2. Experiment

Figure 1 shows the STI process flow. All samples used in this work were fabricated under the same process except for the thickness of silicon nitride (SiN) films. After the thermal oxidation, the SiN films with the thickness of 190nm, 210nm, 230nm, and 250nm were deposited by low-pressure chemical vapor deposition (LP-CVD) methods. Then the typical STI processes including the trench patterning, the liner oxidation, and the deposition of high-density plasma chemical vapor deposition (HDP-CVD) film were used. CL and Raman microprobe measurements were performed by extracting the wafers after specific processes.

We carried out CL measurements to evaluate the crystalline defects. The emitted light was collected by an ellipsoidal mirror and optical fiber, and then analyzed with a single monochromator equipped with an InGaAs multichannnel detector. All CL measurements were performed at 30K. We recorded the average CL spectra in the areas 20μm x 20μm at raster scan mode. Raman microprobe measurements were performed to evaluate the residual stress. A 457.9nm line of an Ar^+ laser was used as an exciting light. The backscattered light was dispersed with a Jobin Yvon U1000 double monochromator, and then detected by a charge coupled device (CCD) detector.

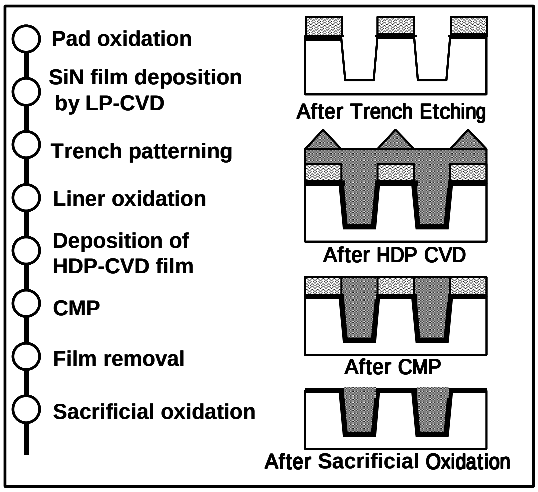

Fig. 1 STI process flow.

3. Results and Discussion

Figures 2 and 3 show the CL spectra of the samples with different SiN thickness during STI process. The sample with the thickness of 190nm showed no dislocation-related lines during STI process at any region, while the samples with the thickness of 230nm and 250nm clearly showed the dislocation-related lines at the specific regions. These D lines are observed in the same areas during the STI process, showing that the dislocations do not disappear and new crystalline defects are not introduced during the STI process. However, the relative intensities of D lines change after the sacrificial oxidation. It is reported that the intensity of D1 line becomes large at high dislocation densities [4]. Therefore, these spectral changes indicate that the dislocations grow and the dislocation densities become high after the sacrificial oxidation. The origin of broad bands at 1.0eV in Fig. 3 (a) is not clear. We consider these broad bands originate from the point defects generated by the trench patterning.

The stand-by leakage current increased as the SiN film thickness increased [3]. The sample with high stand-by leakage current has shown the crystalline defects near the STI boundary by the cross-sectional TEM images, suggesting that the main cause of the leakage is the crystalline defects.

Figure 4 shows the stress distribution of the sample with the thickness of 250nm after the trench patterning obtained by Raman microprobe measurements. This region contains the several size of STI pattern. In Fig.4, the active regions have large compressive stress and the field regions have large tensile stress. It is noted that the stresses after the pad oxidation and SiN film deposition before trench patterning are about 3MPa and under 1MPa, respectively. Therefore, the trench patterning generates large inhomogeneous stress distribution. Figure 5 shows the stress distribution after the liner oxidation. Though the stress distribution is not changed so much, both the maximum stress and the minimum stress are increased. We consider that this inhomogeneous stress distribution and succeeding thermal processes including liner oxidation are the main cause of dislocations. CL measurements also show the D lines after the liner oxidation as shown in Fig. 3 (b).

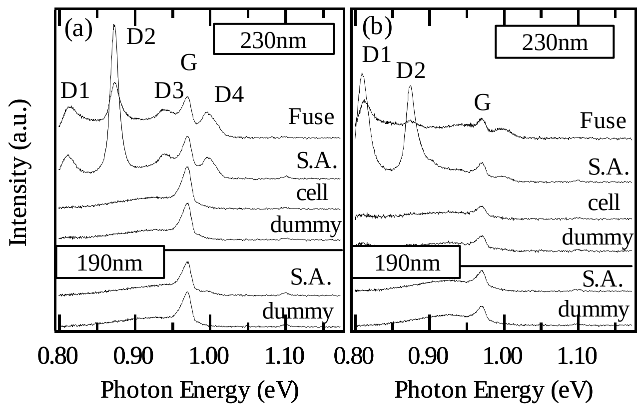

Fig. 2 CL spectra of the samples with different SiN film thickness (a) after the CMP and (b) after the sacrificial oxidation.

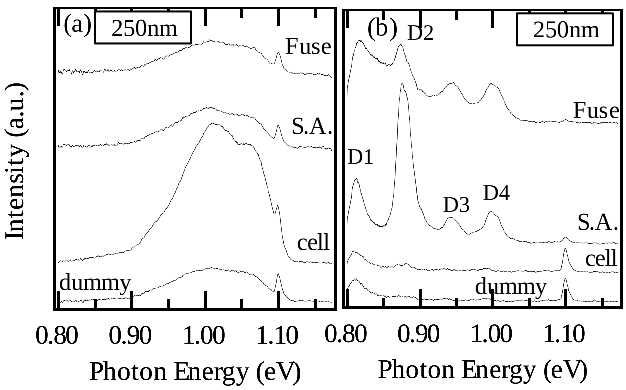

Fig. 3 CL spectra of the samples with the SiN thickness of 250nm (a) after the trench patterning and (b) after the liner oxidation.

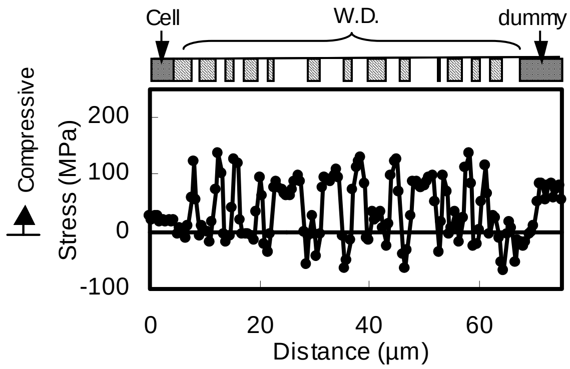

Fig. 4 Stress distribution of the sample with the SiN thickness of 250nm after the trench patterning.

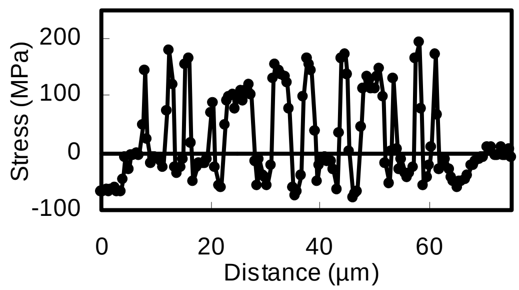

Fig. 5 Stress distribution of the sample with the SiN thickness of 250nm after the liner oxidation.

4. Conclusion

In conclusion, we have characterized the crystalline defects and stress in Shallow Trench Isolation (STI) process in LSI by CL and Raman spectroscopies. The sample with high stand-by leakage current showed clearly dislocation-related luminescence at the specific area and specific process, while the normal sample showed no dislocation-related luminescence. The large inhomogeneous stress is introduced by the trench patterning. It is considered that the inhomogeneous stress distribution by the trench patterning and succeeding thermal process are the main cause of dislocations. The comparison between CL spectra and the stress obtained by Raman measurements is effective to clarify the generation mechanism of dislocations. These methods is also useful to optimize the STI and other LSI processes.

References

[1] B. G. Yacobi and D. B. Holt, "*Cathodoluminescence Microscopy of Inorganic Solids*", 1990 Plenim Press, New York.

[2] R. Sauer, J. Weber, J. Stolz, E. R. Weber, K. H. Kusters, and H. Alexander, Appl. Phys. A36, 1 (1985).

[3] T. Mizukoshi, S. Yo, K. Shibusawa, R. Sugie, and T. Ajioka, Proc. Int. Sym. Semiconductor Manufacturing Tokyo, PO05, (2004).

[4] V. V. Kveder, E. A. Steinman, S. A. Shevchenko, and H. G. Grimmeiss, Phys. Rev. B51, 10520 (1995).