Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 934-935

C-10-2

Nano-Scale Stress Field Evaluation with Shallow Trench Isolation Structure Assessed by Cathodoluminescence, Raman Spectroscopy, and Finite Element Method Analyses

Masako Kodera [1*], Tadashi Iguchi [1], Norihiko Tsuchiya [1], Mizuki Tamura [2],
Shigeru Kakinuma [3], Nobuyuki Naka [3] and Shinsuke Kashiwagi [3]

1 Process and Manufacturing Engineering Center, Toshiba Semiconductor Company, 8 Shinsugita-cho, Isogo-ku, Yokohama, 235-8522 Japan

2 Toshiba I. S. Corp., 8 Shinsugita-cho, Isogo-ku, Yokohama, 235-8522 Japan ,

3 Horiba, Ltd., 2 Miyanohigashi, Kisshoin, Minami-ku, Kyoto, 601-8510 Japan

* Phone; +81-45-770-3518, Fax; +81-45-770-3568, e-mail; masako.kodera@toshiba.co.jp

1. Introduction

Stress engineering related to the frontend process as well as the backend process of LSI is required [1-7]. As for shallow trench isolation (STI) structures, it was reported that a high stress field in the structure causes a variation in electrical characteristics [8]. Although stress fields or strains in a Si-substrate are able to be detected by Raman spectroscopy or Nano Beam Diffraction (NBD), no effective technique was known for a measurement of nano-scale stress field in a dielectric material. Recently, it has reported that the cathodoluminescence (CL) system enabled us to detect nanometer-scale stress fields in SiO_2 materials [9-14]. In this study, we performed overall estimation of stress fields with a STI structure filled with a SiO_2 film, applying CL and Raman spectroscopy for the stress measurement in the SiO_2 film and the Si-substrate, respectively. Moreover, we calculated stress fields by finite element method (FEM) with the same STI structure. Thus, this study is the first trial to understand a whole image of stress fields in the STI structure, combining CL, Raman spectroscopy, and FEM analyses.

2. Experiments

STI structures were fabricated on a 300 mm diameter Si substrate, where a SiO_2 films was deposited on the surface. Stress measurements were performed after SiO_2 deposition by Raman spectrometer (HORIBA, Ltd., FR-3000) for the Si-substrate, and by CL system (HORIBA, Ltd., MP32-FE) for the SiO_2 film. An excitation laser of the Raman spectrometer was water cooled Ar with 363.8 nm excitation line. The outline or principle of CL system is shown in Figs. 1 or 2 [12], respectively. An electron irradiation on a material causes an excitation of optically active parts, and their photon energy (CL wavelength) is altered by the amount of residual stress (Fig. 2). FEM analyses were performed with a non-linear finite element analysis program.

3. Results and Discussions

Figure 3 shows the images of measurement area. The stress mapping of the SiO_2 film on active areas (AA) or the Si-substrate is shown in Figs. 4 or 5, respectively. In Fig.4, the distribution of SiO_2 stresses within the trench was eliminated, because the CL wavelengths in the trench were different from those on the AA due to a luminescent light interference that was caused by a variation in SiO_2 thicknesses between the trench and the AA. Figure 6 shows the FEM result of the Si-substrate with the same structure.

We observed that a tensile stress field appears in the center area of the AA both in the results of CL (SiO_2 film) and Raman (Si-sub.) spectroscopy. In addition, we also found stress shifted region more on tensile side that locally appear within the SiO_2 film near the edge of the AA, corresponding to the FEM stress distribution in the SiO_2. On the other hand, at the edge of the AA, high compressive stresses occur within the Si-sub. Moreover, CL result also shows a compressive side stress shift along the AA/STI boundary. These phenomena can be attributed to the intrinsic tensile stress of the SiO_2 film, which causes the large stress variation along the AA/STI boundary.

Thus, the stress values as well as the distribution tendencies show an excellent agreement with the results of CL and Raman spectroscopy. This agreement also suggests that CL spectroscopy is a reliable method to evaluate nano-scale stress fields. Stress values of CL spectroscopy are now being determined.

4. Conclusions

We performed overall estimation of stress fields with a STI structure filled with a SiO_2 film by CL and Raman spectroscopy, as well as FEM. These results showed an excellent agreement one another, revealing that large variation in stresses at edges of an AA induced by the intrinsic tensile stress of the SiO_2.

Acknowledgement

The authors would thank to Prof. Pezzotti of Kyoto Institute of Tech. for his support of CL spectroscopy (Nano Stress Microscope). Special thank to Hideaki Masuda and Masahiro Kiyotoshi both of Toshiba Corp. for their technical support and Yutaka Saijo of Horiba, Ltd. for his kind support throughout the study.

References

[1] H. Shibata, Proc. Jpn. Soc. Precision Engineering Autumn Conf., (2004) 477-478 [In Japanese].

[2] M. Kodera et al., Jpn. J. Appl. Phys. Soc. **44**(12), 8401-8408 (2005).

[3] T. Ghani et al., IEDM Tech. Dig., 978-980 (2003)

[4] A. Shimizu et al., IEDM Tech. Dig., 433-436 (2001)

[5] S.E. Thompson et al., IEDM Tech. Dig., 221-224 (2004)

[6] G. Scott et al., IEDM Tech. Dig., 827-830 (1999)

[7] T.Okagaki et al., VLSI Tech. Dig., 120-121 (2004)
[8] K. Horita et al., Ext. Abstr. 2006 Int'l Conf. Solid State Devices and Materials, Yokohama, 174-175 (2006)
[9] G. Pezzotti, International Pat. WO 03/076888 A1
[10] G. Pezzotti, JEOL News 38E, 13 (2003)
[11] G. Pezzotti et al., Horiba Tech. Reports (28), 28-33 (2004)
[12] M. Kodera et al., Proc. International Interconnect Tech. Conf., San Francisco, 212-214 (2005)
[13] M. Kodera et al., Abstract of Advanced Metallization Conf. 2005: Asian Session, Tokyo, Japan, 58-59 (2005).
[14] M. Kodera et al., Conf. Proc. AMC XXI, 2006 Material Research Society, 655-660 (2006).

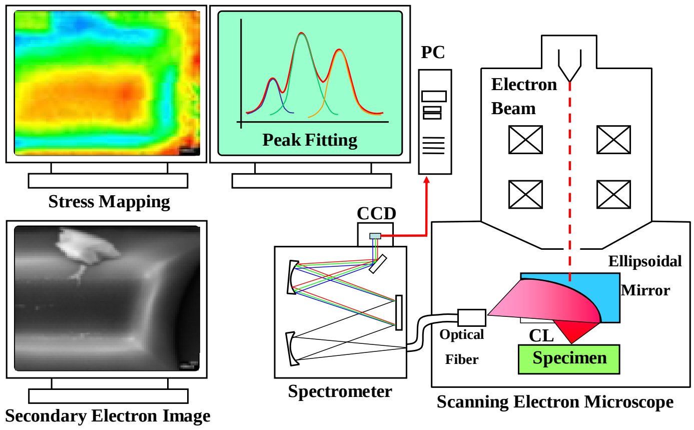


Fig.1 Nano-stress microscope using CL spectroscopy

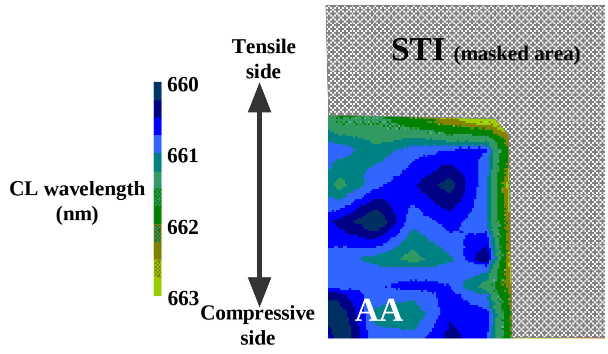


Fig.4 Stress distribution in SiO_2 film upon AA area obtained by CL spectroscopy

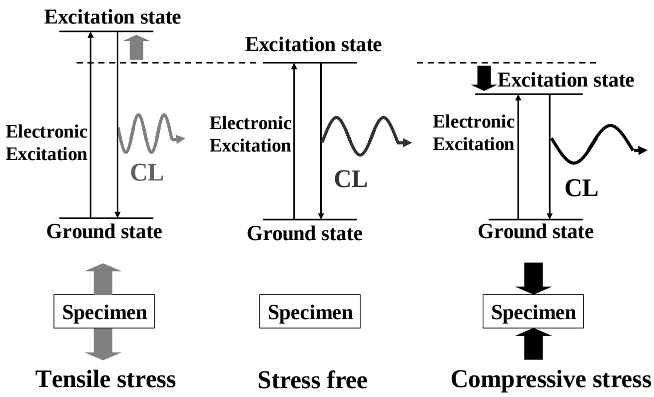


Fig.2 Relation between stress and CL energy

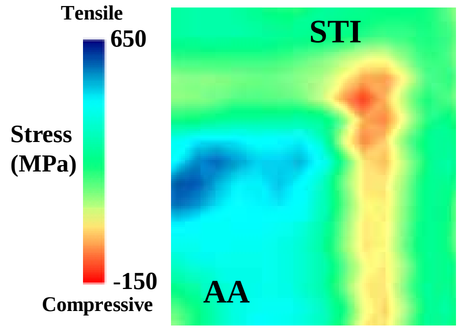
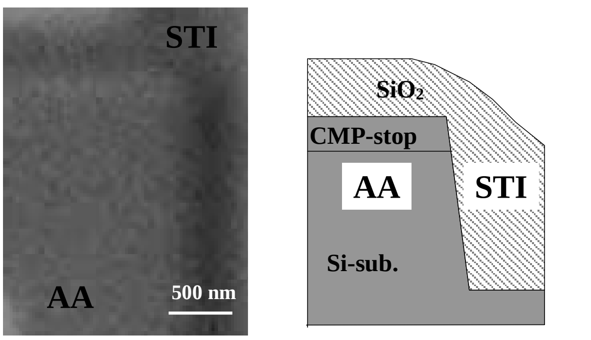


Fig.5 Stress distribution in Si-sub. obtained by Raman spectroscopy



(a) SEM top image **(b) Cross sectional model**

Fig.3 Images of observed area

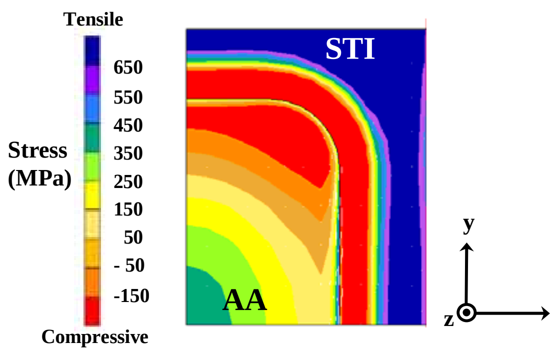


Fig.6 Stress contour map calculated by FEM