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Local Stress Assessment in Patterned Interlayer Dielectric Films using Cathodoluminescence Spectroscopy

S.Kakinuma*, M.Kodera**, K.Nishikata*, J.Aoyama*, Y.Saijo*, and G.Pezzotti***

* R&D Center, HORIBA, Ltd. 2 Miyanohigashi, Kisshoin, Minami-ku, Kyoto 601-8510, Japan
** Process & Manufacturing Engineering Center, Toshiba Co. 8 Shinsugita-cho, Yokohama 235-8522, Japan
*** Ceramic Physics Laboratory & Research Institute for Nanoscience, Kyoto Institute of Tech., Matsugasaki, Sakyo-ku, Kyoto 606-8585, Japan

Current progress in stress measurement and instrumentation for cathodoluminescence (CL) spectroscopy is described. CL, the light stimulated by electron beam, is known to yield information about point-defects, dislocations, impurity, and stress [1]. Engineering of residual stress in the field of LSI devices is essential to improve the quality of the materials. However, analytical methods for residual stress are limited by problems of spatial resolution [2]. In this paper, we measured local stresses stored in the patterned interlayer dielectric (ILD) films by CL with less than 50 nm spatial resolution.
Our CL system is shown in Fig. 1. The stress dependence of the luminescence peak shift (Fig. 2) is calculated by the linear tensorial equation, $\Delta\nu = \Pi_{ij}\sigma_{ij}$, where $\Delta\nu$ is the spectral peak shift, Π_{ij} is the matrix of piezo-spectropic (PS) coefficients, σ_{ij} is the stress tensor [3]. In homogeneous and isotropic materials, $\Delta\nu = \Pi\sigma$, where Π is independent of crystallographic axes, σ is the trace of the stress tensor. For calibrating the Π value, we used the equi-biaxial stress state stored at the tip of an indentation crack. It was indeed found that stress gave a linear contribution to the peak shift of a selected luminescence band. In the calibration, the SiO_2 film used was a typical ILD film. Figure 3 shows a crack on a SiO_2 film and its CL spectrum. A clear spectral shift was observed at the tip of the crack and the Π value was calculated as 23.1 meV/GPa, from the knowledge of the local stress field obtained by a fracture mechanics assessment of crack opening displacement [4].
Line analysis results at the cross section of Cu/SiO_2 (0.25 μm/0.25 μm) pattern are shown in Fig. 5. Compressive stress caused by coefficient of thermal expansion (CTE) appeared, and the stress was released in the neighborhood of the surface. Figure 5 shows the mapping results at the edge of 100 μm Cu interconnects. A higher chemical mechanical polishing (CMP) downward pressure led to a shift toward the tensile side of the residual stress field stored in the SiO_2 film. These tensile stresses can be explained by invoking the presence of surface microcracks in the SiO_2 film.

We have designed a prototype of a CL system (Fig.6), which is more sophisticated and compact desktop system compared with a conventional one. Key features are that CL-focusing mirror is fixed on the objective lens in the SEM and the actuator of the XY stage is brought into the chamber.
We have also been developing the software for optimization of stress analysis.

References

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[4] Y. Yamashita, et al., *J. Appl. Phys. 98,* (2005) 034110

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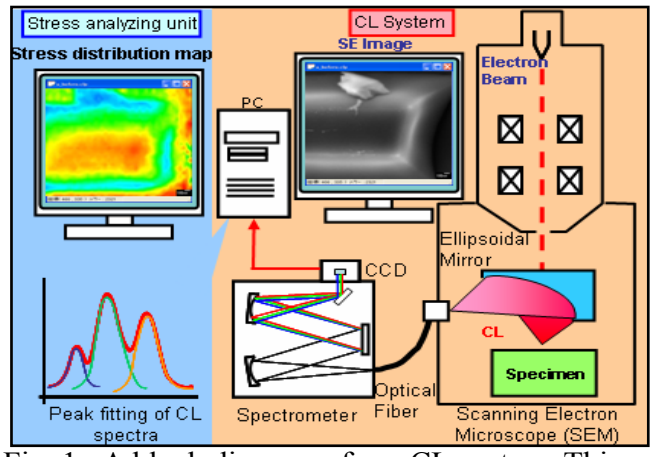

Fig. 1. A block diagram of our CL system. This consists of a scanning electron microscope (SEM) and a CL detecting unit. Each CL spectrum is analyzed to construct the stress distribution map.

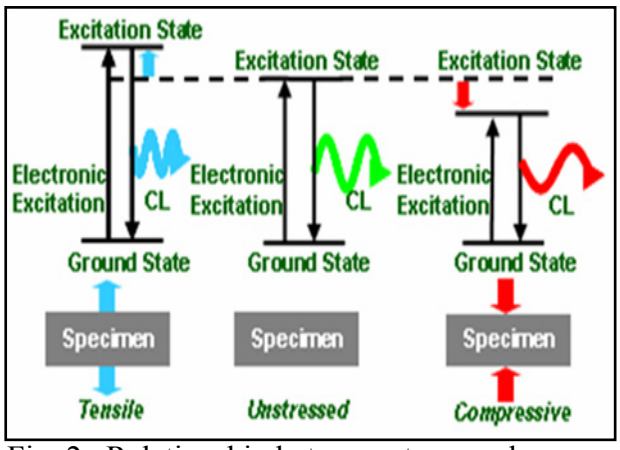

Fig. 2. Relationship between stress and luminescence energy. The stress applied to the specimen can be estimated by measuring a CL spectral peak shift.

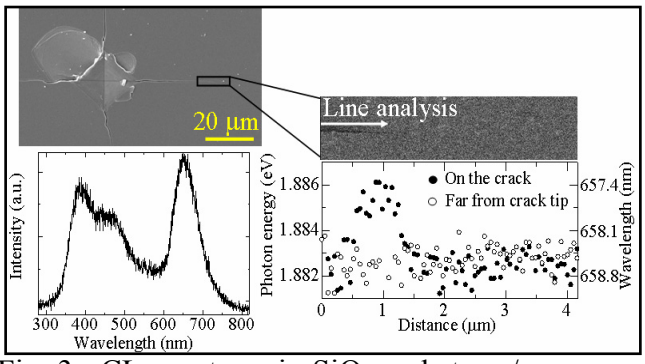

Fig. 3. CL spectrum in SiO_2 and stress/energy-shift calibration method at an indentation crack tip.

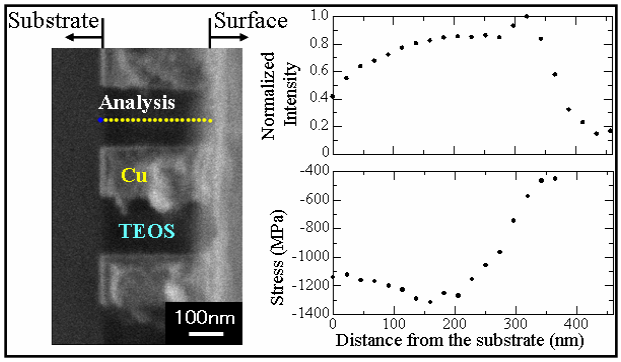

Fig. 4. Cross section analysis of the 0.25/0.25 µm pattern. The dotted line in the SE image represents the measurement location.

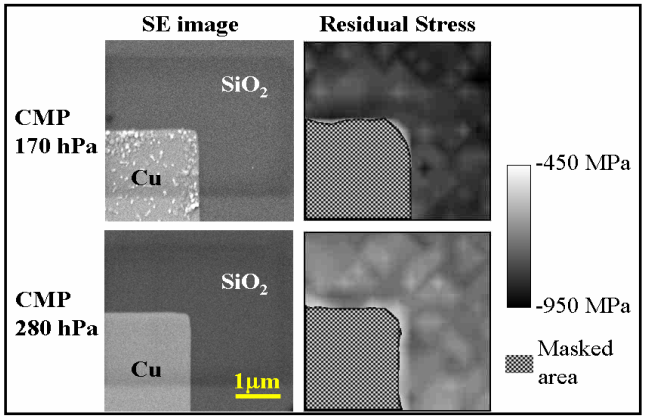

Fig. 5. Mapping analysis of residual stress in SiO_2 films at the corner of 100 µm width Cu lines.

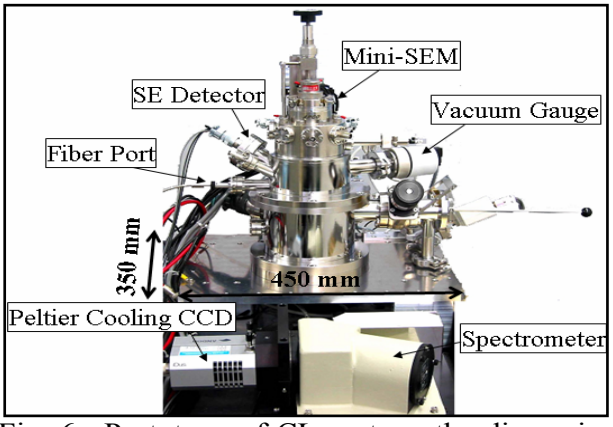

Fig. 6. Prototype of CL system, the dimension of this chamber is 450 mm (W) x 350 mm (D)

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