FORMATION AND APPLICATION OF A PARALLEL X-RAY MICROBEAM

Electron devices such as large-scale integrated circuits (LSI) decrease in size and increase in structural sophistication, as their functions grow more numerous. In these devices, the distribution of local stresses, which may affect device performance and life-span, is very complicated. Therefore, analysis of this local strain under operating conditions is essential.

An X-ray microbeam with small angular divergence has been produced at beamline **BL24XU** for analysis of local strain in electron devices. The X-ray beam was compressed and collimated by asymmetric reflections using silicon single crystals as shown in Fig. 1. X-rays with the energy of 15 keV were monochromatized by the beamline monochromator. An X-ray beam with size of about 7×5 μm^2 was obtained at the sample position by adopting 115 (+ , –) successive asymmetric reflections from Si (001)-surface crystals in both horizontal and vertical directions. The asymmetry factor and beam divergence were about 0.2 and 1.8 arcsec, respectively. The beam size obtained was consistent with the calculations considering the compressed beam divergence.

By the rocking curve measurements [1] and the reciprocal lattice mapping method using this beam, we evaluated the strain induced by field oxidation in silicon wafers. The results of the rocking curve measurements for 004 reflections are shown in Fig. 2. The vertical axis gives the position of the silicon wafer (Si-appearing area is represented in the negative region and SiO_2/Si area is in the positive region). The extended tails of the rocking curves in the boundary regions indicate degradation in the crystalline perfectness in these areas. In addition, peak positions of rocking curves in the Si area near the boundary are shifted to the higher angle side and those in the SiO_2/Si area are shifted to the lower angle side. This indicates that the Si area near the boundary has a decreased lattice constant, while the SiO_2/Si area has an increased constant. This difference in the lattice constant, however, may be as small as $\Delta d/d \sim 5 \times 10^{-6}$.

Figure 3(a) shows a 004 reflection reciprocal

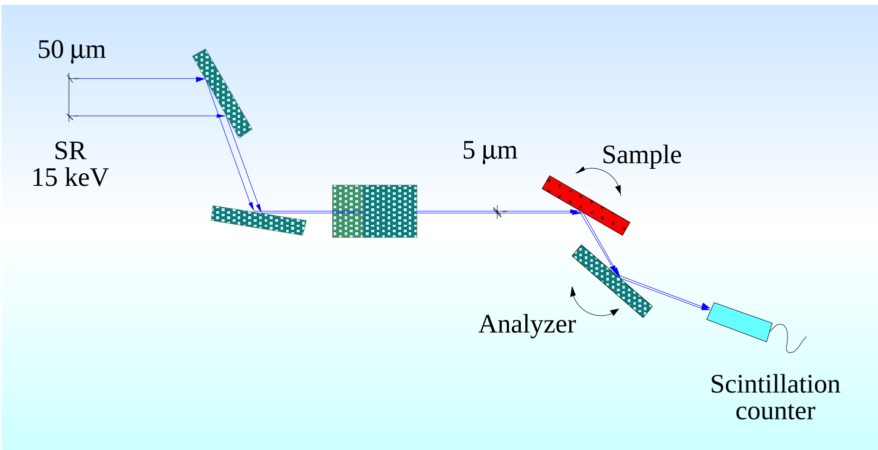

Fig. 1. Optical system for parallel X-ray microbeam experiments. The X-ray beam was compressed and collimated by adopting 115 (+, –) successive asymmetric reflections from Si (001)-surface crystals in both horizontal and vertical directions. The analyzer crystal is removed from the X-ray path in the rocking curve measurements.

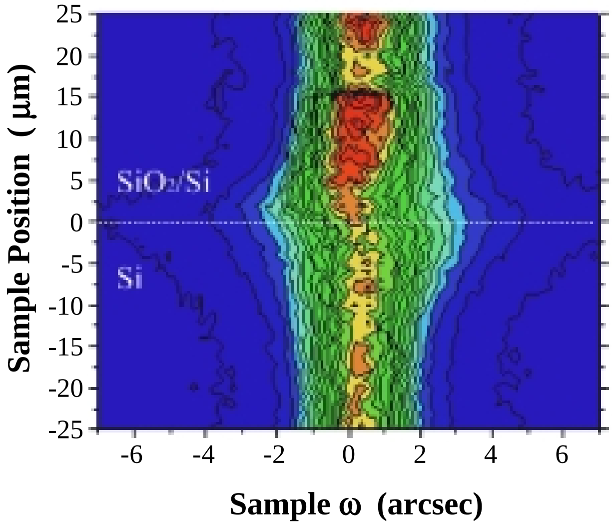

Fig. 2. The results of the rocking curve measurements. The contour map represents the diffraction intensity. The vertical axis gives the sample position. The Si area is in the negative position and the SiO_2/Si area is in the positive position.

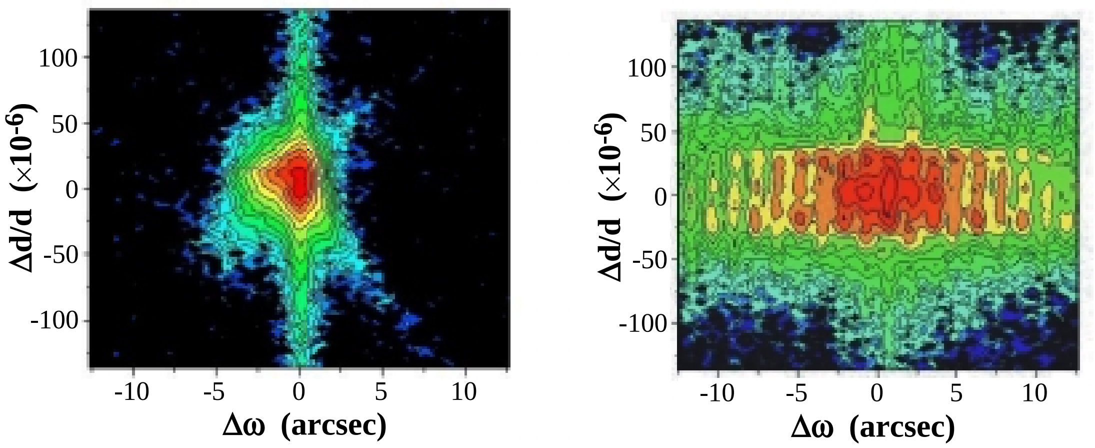

*Fig. 3. 004 reflection reciprocal lattice maps. **(a)** the Si area and **(b)** the minute oxidation pattern region.*

lattice map generated from the silicon area and Fig. 3(b) shows that from the SiO_2/Si area. Some streaky intensity distributions elongated in the radial direction from the reflection point are clearly seen in Fig. 3(a). These distributions are due to a dynamic effect of the X-ray diffraction. This indicates that the crystal perfectness in the silicon area is very superior. Many peaks, however, are clearly seen in Fig. 3(b) in such a way that they are angularly separated from each other by about 1.4 arcsec. These peaks are currently understood to arise from discrete distributions of lattice surface inclination or from an interference effect of diffracted X-rays from the strain region by a minute oxidation pattern.

Yoshiyuki Tsusaka, Yasushi Kagoshima and Junji Matsui

Himeji Institute of Technology

E-mail : tsusaka@sci.himeji-tech.ac.jp

References

[1] Y. Tsusaka, K. Yokoyama, S. Takeda, M. Urakawa, Y. Kagoshima, J. Matsui, S. Kimura, H. Kimura, K. Kobayashi and K. Izumi, submitted to Jpn. J. Appl. Phys.