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Synchrotron X-ray topography of lattice undulation of bonded silicon-on-insulator wafers

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Introduction

Recently, low-power and high-speed large-scale integrated circuits (LSIs) using silicon-on-insulator (SOI) technology are now in practical use. This is based on the significant progress in wafer manufacturing processes such as Smart Cut and SOI-Epi Wafer. The crystalline quality requirements for the SOI layer are increasing with the improvement of the device manufacturing process. Lattice undulation of the SOI layer of bonded SOI wafers, which has been observed as a wrinkled pattern in X-ray topographs for SOI layers thicker than a few micrometers, is one of the problems. Recently, we have shown the existence of the lattice undulation of the 100-nm-thick SOI layer of state-of-the-art commercial bonded SOI wafers by observing a granular pattern in X-ray topographs taken in the Bragg case instead of the wrinkled pattern [1].

In this study we show, using synchrotron X-ray topography, the dependence of patterns of the lattice undulation on the camera distance between a specimen and an X-ray film and on the diffraction geometry of the Laue and Bragg cases.

Experimental

The SOI wafer used in this study was prepared by bonding of two [001]-oriented Czochralski Si(001) wafers. In the bonding process, the bond wafer with a thermal oxide layer of 50 nm was rotated 5 deg around the [001] axis of the base wafer, so that Bragg reflections of the SOI layer could be observed separately from that of the substrate. The excessive silicon of the bond wafer was removed by lapping and polishing, until the thickness of the SOI layer became 2.0 mm. The specimens were cut out of the wafer into 20×15mm^2 rectangles.

Synchrotron X-ray topography measurements were carried out at the beam line 15C of the Photon Factory, KEK, Tsukuba, Japan. The energy of incident X-ray was set to 17.4 keV using a Si(111) double-crystal monochromator, and the sectional size of that was set to 2×2mm^2 using a four-quadrant slit. The 220 reflection in the Laue case and the asymmetric 115 reflection in the Bragg case at a glancing angle of 4.1 deg were used. X-rays were irradiated on to the SOI layer of the wafer set on a sample holder of a horizontal-axis precision goniometer. The diffracted X-rays were recorded on the X-ray films of Fuji IX-100. The obtained images were converted to digital data by an optical microscope with a charge-coupled device (CCD) camera.

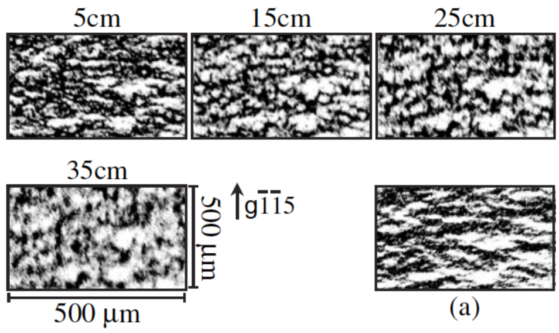

Fig.1 A series of X-ray topographs of the SOI layer of 2 µm thickness taken with the asymmetric 115 reflection, in which the camera distance was changed. The numerical value on each topograph indicates the camera distance. In (a) the topograph with the camera distance of 5 cm taken in Laue case is shrunken to 58% in the direction parallel to the g vector and is shown upside down.

Results

Figure 1 shows a series of topographs as a function of the camera distance, where the asymmetric 115 reflection was used. In order to compare these topographs with those taken in the Laue case, the topograph with the camera distance of 5 cm taken in Laue case is shrunken to 58% in the direction parallel to the g vector and is shown upside down in Fig. 1(a). We can see that the topograph with the camera distance of 5 cm taken in the 115 Bragg case has a wrinkled pattern and is similar to the image taken in the Laue case. However, the wrinkled pattern gradually changes to a granular pattern with increasing camera distance.

References

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