3C2, 15C /2002G070

A Novel High-Resolution Mapping of d-Spacing and Lattice Plane Orientation in boron high-doped silicon single crystal wafers

Yasumasa OKADA*, ZHANG xiaowei, Hiroshi SUGIYAMA, Masami ANDO
KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

Introduction

A novel, fast and stable crystal lattice-spacing comparator have been developed at BL3C2 of the Photon Factory, which can complete one measurement process within a few tens of seconds with resolution of 10^{-8}.[1)] Because local variations in a crystal are not only in d-spacing, but also in orientation of the lattice plane[2)], it is necessary to add a function in the comparator system to measure local orientations of a crystal.

Since using a pair of quasi-simultaneous Bragg diffractions of two equivalent indexes in a sample is the principle of our lattice-spacing comparator, only utilizing a combination of the comparator with an autocollimator as shown in FIGURE 1, both d-spacing and lattice plane orientation (Δα) in the same location of the crystal can be measured without any additional sample movements. In case of 117 and -1-17 as a pair of quasi-simultaneous Bragg diffractions indexes, a particular wavelength for these two diffractions was chosen as 0.149088nm by a monolithic double-crystal monochormator (MDCM) that is framed by two channel-cuts of 117 and -1-17 with (+, -, -, +) arrangement on a monolithic silicon crystal.

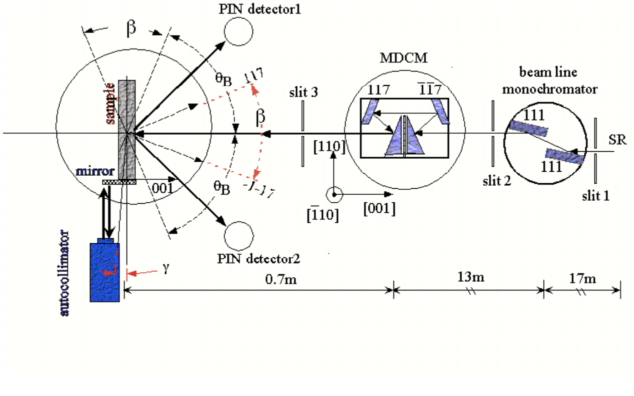

FIGURE 1. Schematic side view of the experimental arrangement.

Experiment and data analysis

The sample is a quarter 8” boron high-doped CZ silicon wafer where -1-10 surface is bottom and 001 surface is almost perpendicular to the incident x-ray beam. The incident beam size is 1(V) x 2(H) mm^2. Details of tuning of the comparator and measuring process has been described in reference 1 and 3. Because one measurement process can be finished within a few ten seconds, local lattice variations of 1,600 positions were measured in about 20 hours. The relative changes of d-spacing Δd/d can be obtained from next formula, where θ_B is 78.5782°.

$$\Delta d / d = 1/\tan\theta_B \times \Delta\theta = 1/\tan\theta_B \times (P_1 - P_2)/2 = 1/\tan\theta_B \times \gamma/2$$

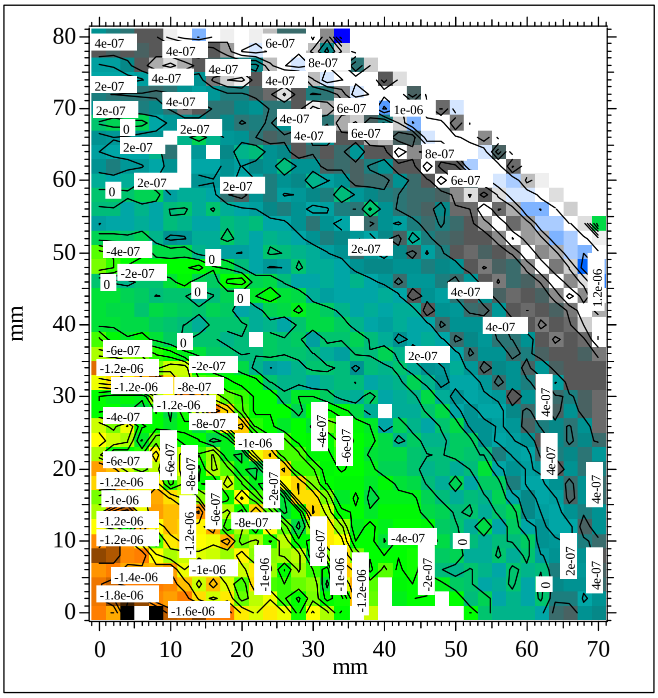

FIGURE 2. 2D imaging plots with contour of deviation from Δd/d on the sample, B conc.:2.8e19 cm^{-3}. Δd/d is –1.594e-4.

The variations in orientation of the lattice can be obtained from next formula, where α_0 is an initial attitude of the sample monitored by the autocollimator.

$$\Delta\alpha = (P_1 + P_2)/2 - \alpha_0$$

Finally, the serial data of d-spacing were converted to 2D matrix, and plotted in FIGURE 2 with units of Δd/d, and where d is standard value of silicon, 0.543107 nm (at 25.0 C). We are able to recognize a variation of 2e-7 (Δd/d), and it seems that this is due to variation of boron concentration (2e16 cm^{-3}). It was found that a center of wafer is higher concentration of 5e17 cm^{-3} of boron than average.

Furthermore, orientation of the lattice plane of 10 arc-sec across a wafer was discovered by above method of BL3C2 and a plain topograph of BL15C.

References

[11. X. W.,Zhang, H. Sugiyama, M. Ando, Y.Imai, Y.Yoda, J. Appl.Cryst. 36, 188-192(2003)

[2] U. Bonse, Z. Phys. B. 153, 278-296 (1958).).

[3]. X. W. Zhang, Y. Okada, H. Sugiyama, M. Ando, 8th SRI (2003).

*yaokada@post.kek.jp