3A/1999G037

Local Stress Measurements of Single Crystal Using Synchrotron Radiation

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Introduction

The strains from several diffractions are required for the stress measurements of single crystal. An hkl diffraction with higher Bragg angle should be selected to measure the stress with high accuracy, however, it is not always to get suitable combination of characteristic X-rays and the diffraction plane as far as the conventional X-ray source was used. Whereas, a pure monochromatic X-rays with optional wavelength can be obtained by using synchrotron radiation source (SR). In addition, it is possible to reduce the beam size to micrometers order because of the high brightness and good parallelism of synchrotron beam. Therefore, the stress measurements in local area can be expected with high accuracy.

In this study, a system with a position-sensitive proportional counter (PSPC) was developed to measure the local stresses in the silicon specimens of single crystal by using SR.

Experimental Procedure

A single crystal silicon specimen with a small hole was prepared for the measurement of stress distribution near the hole. The specimen has a dimension of a length of 40 mm, a width of 4 mm and a thickness of 3 mm and the direction of applied stress is [110] and plane orientation is (001). The circular hole of 400 μm in diameter and a depth of 400 μm is produced at the center on the surface of this specimen using a plasma etching. A stress of 29 MPa was applied by the four-point bending device, and the stresses were measured at 5 positions with intervals of approximately 50 μm from the edge of the circular hole. A ϕ30 μm pinhole slit was used, and the distance between the PSPC and the specimen was set at 500 mm. The diffraction planes measured and the condition of stress measurement are listed in Table 1.

Table 1: Experimental conditions of the measurement of stress distribution near the edge of the circular hole.

Diffraction plane	$3\bar{1}5$	315	$\bar{1}35$
Wavelength, nm	0.1789		
Relative applied stress, MPa	29		
Diameter of pinhole, μm	30		

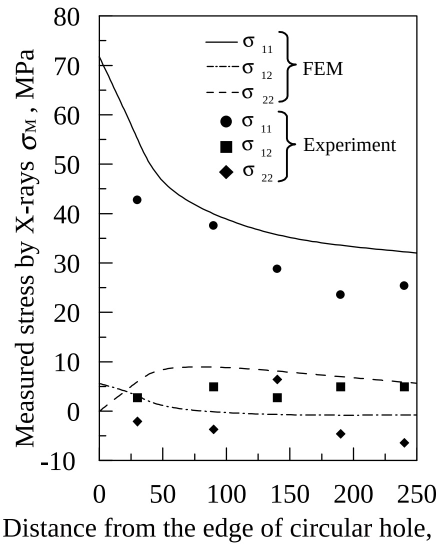

Fig. 1: Result of the measurement of stress distribution near the edge of the circular hole of ϕ400 μm.

Results and Discussions

It was already verified that the stresses in a single crystal were measurable by using the system developed in this study and SR [1].

Figure 1 shows the result of the measurement of stress distribution near circular hole. Lines in this figure show the stress distributions determined by the finite element method (FEM). Experimental results on σ_{11} are less than the analytical ones, in particular, stress at the position of 30 μm apart from the edge is lower because of steep stress gradient. However, the trend of distribution agrees to the analytical one. Therefore, the behavior of the stress concentration could be observed.

The FEM analytical results of σ_{22} and σ_{12} were close to 0 MPa, and measured values of them were also close to 0 MPa, because the steep stress gradient does not exist in these stresses.

Conclusion

Stresses in a local area such as 30 μm in diameter are measurable by using synchrotron radiation source.

Reference

[1] K. Akita et al., Photon Factory Activity Report #17 142 (1999).

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