Residual Stress Measurement of Fiber Texture Materials Near Single Crystal

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ABSTRACT

In this paper, a sample having <111> fiber texture near single crystal structure made by PVD was evaluated about texture states by the pole figure and about residual stress states by the new expression for X-ray stress analysis. As a result, about 6GPa compressive residual stress existed in the film. However, measurement planes of X-ray line were influence on each stress value.

KEY WORDS: Residual stress; single crystal; texture; X-ray.

INTRODUCTION

X-ray stress measurement methods can measure surface stresses in polycrystalline ceramics and metals without destruction. However this method cannot be applied to anisotropy materials, because it is on the assumption of heterogeneous material in theoretical expression (Noyan and Cohen, 1987). Some researchers have proceeded to develop new procedures applied to fiber texture materials. Zaouali et al. (1991) discussed a measurement technique by using the procedure defined as the ideal orientation. Some groups also discussed the influences on stress determination of the elastic constant (Miki et al., 2000; Ejiri et al., 2000; Tanaka et al., 2000; Scardi and Dong, 2001). In addition, naturally, the new experimental techniques of stress measurement of textured materials were discussed also by some groups (Ma et al., 2001). On the other hand some researchers have studied about X-ray stress measurement of single crystals (Suzuki et al., 2000; 2003; Brückner et al., 2005). About these theories for stress measurements, they assume that materials have ideal orientation. However all materials are not always such extremity condition naturally. Some of the authors studied on the stress measurement of fiber-textured materials (Muratani et al., 2000; Ejiri et al., 2000). The specimens had very strong fiber texture in that study. On the other hand, it is known that the thin films that consisted of the single crystal structure can produce by PVD. The specimen having the intermediate structure between the single crystal and the fiber texture was obtained in this study. In this case, the X-ray stress-strain relation that related to the stress constant should be different between the single crystal and the fiber texture. Therefore, final objective of this research aims at development of stress measurement method for non-ideal orientation system near single crystal.

In this study, the residual stresses of a specimen having fiber texture near single crystal are investigated by procedures for ideal orientation. A sample having <111> fiber texture near single crystal structure was evaluated from the pole figure. Then, the residual stresses were measured by using several stress determinant procedures. One of the procedures is for the single crystal model, and others are for the ideal fiber texture model. At first, in this paper, authors introduce the principal expression of X-ray stress analysis and modify those equations to the procedures. The procedures were applied in the experiments using a strong textured sample. Experimental results obtained by these procedures were compared and discussed.

DETERMINATION OF X-RAY STRESS ANALYSIS

X-ray stress-strain relation of single cubic crystal and isobiaxial stress state

The orthogonal coordinate systems used in the following determination are shown in Figure 1. The axes of the specimen coordinate system P define the surface of the specimen, and P3 axis decides normal direction of specimen surface. The axes of the laboratory coordinate system L are defined as a coordinate system after it is converted by angle $\phi$ and $\psi$ from P system. Then L3 is in the direction normal to the family of planes $(hkl)$ whose spacing is measured by X-ray. The axes of the crystal coordinate system C defined along their primitive axes. Figure 2 shows the relation between three coordinate systems. The laboratory coordinate system L can be transformed from the specimen coordinate system P. The transformation matrix $\omega_\delta$ is given with rotation angle $\phi$ and $\psi$.

$$\omega_\delta = \begin{pmatrix}
\cos \psi \cos \phi & \cos \psi \sin \phi & -\sin \psi \\
-\sin \phi & \cos \phi & 0 \\
\sin \psi \cos \phi & \sin \psi \sin \phi & \cos \psi
\end{pmatrix}.$$ (1)