Evaluation of Hydrogen Diffusion in Alpha-Titanium by Diffraction-Enhanced X-ray Imaging Technique

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There have been a number of investigations of the hydrogen diffusion in titanium in order to develop hydrogen-storage materials and so on. However, the majority of investigations deal with isotope experiments or indirect detection techniques such as internal frictions of hydrogen atoms. Therefore, we applied the diffraction-enhanced X-ray imaging technique to visualize hydride, TiH_2, in alpha-titanium polycrystals and evaluated the hydrogen diffusion.

The alpha-titanium specimens (1 x 5 x 15 mm) were prepared with hydride deposited on the surface using electrolytic charging at room temperature and cut into a 1 mm thick slice for cross-sectional observation. Electrolytic charging time and current density were 18 or 48 hours and 5 mA/mm^2, respectively. The observation was carried out in BL-14B at the Photon Factory in KEK, Japan. The collimator and the analyzer were adjusted at the asymmetric and symmetric 220-diffraction condition, respectively. Low-angle and high-angle diffraction images were recorded on X-ray films with nearly half maximum of the rocking curve from the analyzer. The X-ray energy was 30 keV and the exposure time was about 3 min.

Hydride layer was visualized by thick black or white line parallel to the surface. Intensity profile of the refraction image of hydride was obtained from the low-angle and high-angle images by subtraction. In the titanium-hydrogen system, heat of solution and formation are negative. So, the hydride formation was subject to diffusion process of hydrogen atoms. Hydrogen diffusion from the surface was calculated using a solution of one-dimensional diffusion equation. Deviation angle of X-ray by refraction was calculated from hydride density distribution using the Snell's low. Finally, X-ray intensity profile obtained from the deviation angle using the rocking curve was compared with the intensity profile of refraction images of the hydride. The obtained diffusion coefficient of hydrogen in alpha-titanium, $D = 3 \times 10^{-15}$ m/s^2, is slightly larger than the widely accepted value at room temperature. The result is explained by the assumption that the specimen temperature rose during the electrolytic charging by reactions and Joule heating.