Diffraction-Enhanced X-ray Imaging of Hydride in Alpha-Titanium and Titanium Alloy

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Although titanium and its alloys are promising materials for preserving hydrogen, until now it has been impossible to visualize hydrides in titanium using non-destructive methods,, that is, conventional radiography that utilizes absorption of X-rays. Therefore, the present work was planned and performed with the aim of confirming the visualization of titanium hydride in alpha-titanium by using the diffraction-enhanced X-ray imaging method.

Titanium crystals (99.99 at. %, 1 x 5 x 20 mm) were annealed at 560 ℃ in hydrogen gas at 1 atm for 66 min. resulting in the formation of titanium hydride in the specimen. To observe the specimen cross-section, another specimen was prepared with hydride deposited on the surface using electrolytic charging.

The present observations were performed at a vertical-wiggler beamline, BL-14B (precision X-ray optical station), at the Photon Factory in the High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan. The collimator and the analyzer were adjusted at the asymmetric and symmetric 220-diffraction condition, respectively. Absorption images of the specimen were also recorded without an analyzer crystal. The exposure time for all refraction images was 2 - 3 min for 30 keV X-ray.

Diffraction-enhanced image of hydrogen annealed titanium show weak contrast images as white weathers. The images were not observed in the absorption contrast condition and in the specimen before annealing in hydrogen gas. We founded that the white contrast image originated by refraction of hydride. To confirm that the image does indeed show hydrides in titanium, we also examined a cross-section of the specimen covered with surface hydride. The cross-sectional image of the electrolytic charged titanium specimen shows white and black contrast images at the circumference of the specimen. And the contrast of the image is reversed between low-angle and high-angle side image of the rocking curve. In contrast with titanium, refraction-contrast images of hydride were not observed in titanium-aluminum alloy. Aluminum atoms prevent the hydride formation.

We were able to obtain a high-contrast projection image of a hydride in titanium using refraction-contrast radiography. The study shows that this is a promising new technique for non-destructive inspection of bulk material systems with only small differences between refraction indexes of the components.