

Intrinsic Martensite Formation in Neutron Irradiated V-1.6%Y Alloys with Fine-grained Structure of Highly Pure Matrix

It is known that in vanadium gaseous interstitials (H, N, O) cause transformation from the bcc to bct structure by elongating one axis relative to the other two to accommodate the induced strain. This paper describes the first finding of intrinsic martensite formation that is not associated with the interstitials for neutron irradiated V-1.6Y (in wt%) with a fine-grained structure of a highly pure matrix [1]

Development of refractory transition metals with improved resistance against mechanical property degradation by high energy particle irradiation is required for their use under irradiation environments. It has been shown that the most effective microstructure to improve the radiation resistance consists of fine grains and finely dispersed particles, the finer the better because grain boundaries and particles can serve as effective sinks for irradiation induced point defects. For vanadium such a microstructural refinement requires a processing method that enables to make the vanadium matrix free from gaseous interstitials, particularly nitrogen and oxygen. This is because vanadium is chemically very reactive with the interstitials and their dissolution into the matrix leads to significant embrittlement. We have proposed an advanced powder metallurgical (P/M) method utilizing mechanical alloying and hot isostatic pressing and successfully developed ductile V-Y and V-Y-Cr alloys with fine grains of a highly pure matrix free from gaseous interstitials and very fine dispersoids of Y_2O_3 and YN [2-4]. The Y_2O_3 and YN dispersoids are formed as a result of consuming solute oxygen and nitrogen impurities.

V-1.6Y alloys were irradiated at 290 and 600°C to 0.25 and 0.6 displacement per atom (dpa), respectively, in the Japan Materials Testing Reactor to examine the effect of neutron irradiation. It has been demonstrated that the alloys exhibit much improved radiation resistance [5] Another noticeable finding is that the irradiated V-1.6Y exhibits the intrinsic martensite formation of a vanadium bct structure that is not caused by gaseous interstitials. The emergence of intrinsic martensite is the first to be observed in vanadium or its alloys not only in neutron irradiated states but also in unirradiated states. The main results and conclusions are as follows [1]:

1. The martensite emerges heterogeneously in some of the bcc grains of V-1.6Y and has a high density of $\{101\}_{bct}$ microtwins as the lattice invariant shear strain. The bct structure exhibits a tetragonality (a/c) of 1.06 as measured with Kikuchi line analyses.

2. The habit planes between the bct martensite and the surrounding bcc matrix are $\{101\}_{bct} // \{110\}_{bcc}$, which can be regarded as the close-packed plane with coherency even for the bct structure because of the slight changes in the lattice constants of both the phases.

3. The features of the P/M V-1.6Y alloys, an interstitial-scavenged matrix and extremely fine grains, are considered to be responsible for the martensite formation caused by irradiation.

4. The transformed vanadium bct lattice provides

preferential sites as the host phase for hydrogen atoms to occupy with an ordered arrangement (Fig. 1). The ordered arrangement of hydrogen atoms occurs in a very thin specimen area that is susceptible to hydrogen pickup associated with TEM specimen preparation after irradiation, but does not occur in a thicker specimen area.

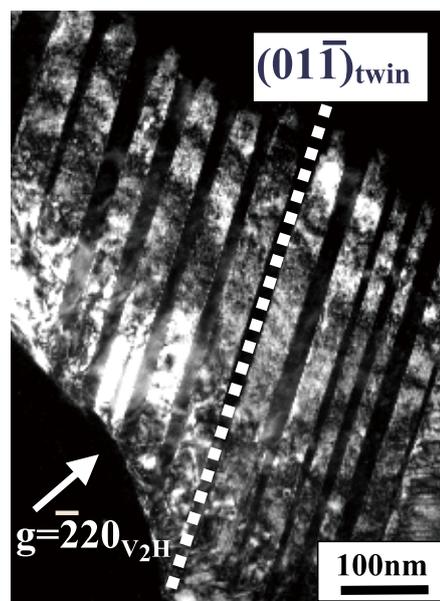


Fig. 1 TEM micrograph of dark field image from a very thin specimen area with a transformed region that provides preferential sites for hydrogen atoms to occupy with an ordered arrangements in V-1.6Y irradiated at 290°C to 0.25dpa.

5. The hydrogen content (H/V) in the ordered bct structure is estimated to be approximately $H/V = 0.24$. This content is much lower than $H/V \sim 0.41$, the lowest content of the β_1 hydride phase that can exist in the thermoequilibrium state, supporting the absence of hydride formation in the bct phase.

References

- [1] H. Kurishita, S. Kobayashi, K. Nakai, T. Kuwabara and M. Hasegawa, J. Nucl. Mater. **358**, 217 (2006).
- [2] T. Kuwabara, H. Kurishita and M. Hasegawa, J. Nucl. Mater. **283-287**, 611 (2000).
- [3] T. Kuwabara, H. Kurishita and M. Hasegawa, Mater. Sci. & Eng. A **417**, 16 (2006).
- [4] H. Kurishita, T. Kuwabara and M. Hasegawa, Mater. Sci. & Eng. A. **433**, 32 (2006).
- [5] H. Kurishita, T. Kuwabara, M. Hasegawa, S. Kobayashi and K. Nakai, J. Nucl. Mater. **343**, 318 (2005).

Contact to

Hiroaki Kurishita (International Research Center for Nuclear Materials Science)

e-mail: kurishi@imr.tohoku.ac.jp