§2. Recovery and Recrystallization Behavior of Vanadium at Controlled Various Nitrogen and Oxygen Levels

Nagasaka, T., Muroga, T., Takahashi, H. (Graduate School of Eng., Nagoya Univ.), Tanabe, T. (Center for Integrated Research in Sci. and Eng., Nagoya Univ.), Matsui, H. (Inst. for Mater. Research, Tohoku Univ.)

It is known that interstitial impurities such as nitrogen and oxygen strongly affect various properties of vanadium and vanadium alloys for structural materials of fusion reactors. Especially nitrogen effects remain to be studied further in spite of the fact that contamination with nitrogen to some extent is unavoidable during manufacturing of metal vanadium and alloying on a large scale.

Recently, a NIFS (National Institute for Fusion Science) program for a large scale heat of a candidate vanadium alloy has been started. In the program, high-purity large vanadium ingots were fabricated. The NIFS-grade vanadium contains only several tens weight ppm (wppm) oxygen. The NIFS-grade vanadium made it possible to investigate systematically nitrogen effects at low oxygen levels.

The purpose of this study is to investigate the effects of nitrogen and oxygen on recovery and recrystallization of vanadium after work hardening using high-purity metal vanadium singly doped with nitrogen or oxygen. The data from this study will be applied to explain the effects of nitrogen and oxygen in candidate vanadium alloys, since intrinsic effects of the interstitial impurities can be more clearly extracted from the behavior of pure vanadium.

Table I shows the contents of interstitial impurities in the vanadium specimens used in this study. V-LI (Vanadium Large Ingot) is the NIFS-grade vanadium produced by industrial scale (25 kg) EB-melting. Nitrogen and oxygen contents of these specimens are systematically distributed from about 10 to 500 wppm and 50 to 1000 wppm, respectively. The specimens were cold-rolled 90 % or more. They were annealed at 200 to 1100 °C for 1 hour in a vacuum. Vickers hardness tests and microstructural observations were carried out.

Figure 1 shows typical hardness recovery curves. For the other vanadium specimens, the curves ranged between those of V-EB-1 and V-O-3.

Hardness of vanadium as-melted, as-rolled and annealed at 1100 °C linearly increased with increasing nitrogen and oxygen contents. The hardening coefficient of nitrogen was almost twice that of oxygen.

Anneal hardening at 200 to 400 °C was observed in most of the recovery curves. In the series of V-EB and V-LI, however, the anneal hardening was much smaller than that in the other specimens. The anneal hardening was attributed to the decoration of dislocations with interstitial impurities because the dislocation structure was not changed by annealing at 300 °C. The anneal hardening is very small when the nitrogen content is below 100 wppm. The effect of oxygen on the anneal hardening was weak relative to that of nitrogen.

The present study showed that recrystallization of un-alloyed vanadium was not strongly affected by nitrogen and oxygen.

Table I. Interstitial impurity content in the vanadium specimens used in the present study (wppm).

Code	N	O	C
V-EB-1	12	290	33
V-EB-2	75	52	46
V-EB-3	100	50	60
V-LI	91	43	93
V-LI-R	94	55	70
V-N-1	170	51	79
V-N-2	400	52	72
V-N-3	540	56	74
V-O-1	120	260	68
V-O-2	130	570	77
V-O-3	140	920	64

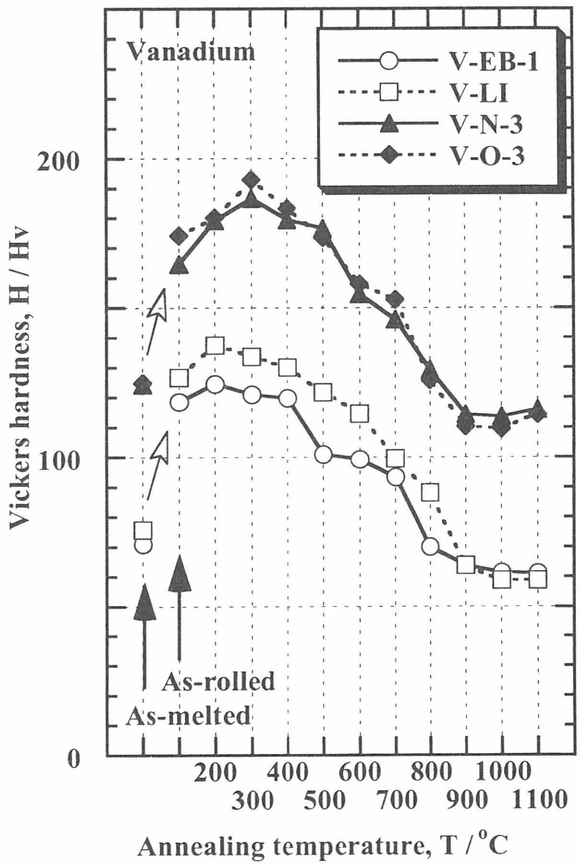

Fig. 1. Recovery behavior of hardness of the EB-melted, nitrogen-doped or oxygen-doped vanadium.