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Effects of Annealing Temperature on Microstructure and Mechanical Properties of High Purity Vanadium Alloys

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1. Introduction

Low-activation vanadium (V) alloy is regarded as a candidate structural material for fusion reactors. V-4Cr-4Ti composition was selected as a reference composition, which contained ~ 1000 wppm interstitial impurities (i.e., carbon, nitrogen, oxygen). In order to shorten the recycling periods of vanadium alloy after fusion reactor shutdown, high-activation impurities, like cobalt, niobium, nickel molybdenum, etc., were reduced by refinement melting. Further improving the low-activation characteristic of V-Cr-Ti alloy is to reduce Ti concentration, which produces long-lived isotopes under neutron irradiation. On the other hand, Ti reduction degrades the strength of the alloy. Increasing Cr concentration is expected to compensate for the strength loss. High purity vanadium alloys containing lower than 300 wppm interstitial impurities with various levels of Ti and Cr concentration were developed at NIFS. In this study, aiming at revealing the precipitation and recrystallization behavior of the high purity V-Cr-Ti alloys, the effects of annealing temperature on microstructure and mechanical property of cold-rolled vanadium alloys were investigated.

2. Experimental

High purity V alloys with nominal chemical composition of V-4Cr-xTi (x=0, 0.1, 1, 2, 3, 4, in wt%) and V-yCr-1Ti (y=4, 8, 12, in wt%) were fabricated by arc-melting process. Button ingots were sealed, and hot forged in the temperature range of 1000 – 1200 ℃. Then, they were machined and cold rolled to plate sheets with final thickness of ~0.25 mm. Discs and SSJ tensile specimens were punched out from the sheets. The specimens were annealed conducted at 600 – 1000 ℃ for 1 h in a vacuum. Microstructure was characterized by scanning electron microscopy and transmission electron microscopy. Vickers hardness and tensile tests were performed at room temperature.

3. Conclusion

Hardness decreased with increasing annealing temperature to the minimum at 900 ℃ mainly due to recovery of dislocations and recrystallization, and increased slightly at 1000 ℃. Precipitation of Ti-CON was observed at 700 ℃ for 1%Ti and above. Based on the microstructural characterization and Orowan’s mechanisms, precipitation hardening increased up to 2%Ti, leveled off at 3%Ti, and decreased for 4%Ti after 900 and 1000 ℃ annealing, indicating that 2~3%Ti addition results in more precipitation hardening than 1% and 4%. Additionally, the effects of Ti and Cr concentration on tensile properties will be discussed. Comparing with the tensile properties of the reference V-4Cr-4Ti alloy, the alternative composition with higher Cr and lower Ti levels will be presented.