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Effect of vanadium content on hydrogen storage property in Ti-V-Cr alloys

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Abstract: The effect of vanadium content on the microstructure and hydrogen absorption/desorption properties in Ti-V-Cr alloys was studied. The results show that with the increase of vanadium content from 5at.%, 10at.% to 35at.%, the hydrogen absorption capacity increases gradually from 1.14wt.%, 1.57wt.% to 2.84wt.%, and the hydrogen desorption capacity also increase from 0.43, 0.64, to 1.59. This indicates that the alloy with 35at.% vanadium content has the most optimum hydrogen storage capacity among these alloys. The microstructure observation also indicates that the alloy with 35at.% vanadium turns to be the single-phase alloy of the BCC solid solution. Furthermore, with the increase of vanadium content the pressure plateau becomes more distinguishing and shifts to lower pressure level gradually. The kinetics of hydrogen absorption was also found to be dependent with the vanadium content in these discussed alloys.

Key words: hydrogen storage alloy; vanadium; kinetics

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1. Introduction

With the demand of hydrogen energy in the future, the investigation on the hydrogen storage materials has received more and more attention in recent years[1-3]. As one of the metal based hydrogen storage alloys, the vanadium based solid solution alloys have been regarded as one of the most potential and attractive candidates for practical applications due to their higher hydrogen storage capacity and lower absorption/adsorption temperature [4-6]. But for the poor properties of initial activation and effective absorption capacity these alloys are still unacceptable to the commercial utilization. How to deal with these problems is now under the investigation.

The vanadium content in the vanadium based solid solution alloys is a key factor in affecting the hydrogen storage property. Recently, Kuriiwa T. [7] and Homma H. [8] have reported that the optimum amount of the vanadium in the V-Zr-Ti-Ni alloys turned out to be around 75at.%, with the Laves phase acting as a preferential penetration path for hydrogen. While Yu X.B. *et al.* [9] have found in Ti-xV-10Cr-(50-x)Mn alloys that the vanadium content of 32at.% is appreciated with the maximum and effective hydrogen storage properties to be 3.98wt.% and 2.51wt.% respectively. Also, Okada M. *et al.* [10] have reported that the Ti-Cr-(5% - 7%)V alloys exhibited high hydrogen absorption capacities of nearly 3wt.% after heat treatment. Thus it is very necessary to carry out a detail research in this respect.

In this paper, the role of vanadium content on the microstructure and hydrogen storage property was investigated in Ti-xV-Cr (Ti/Cr = 5/8) alloys. The kinetics of hydrogen absorption in these alloys was also been investigated in order to get a full understanding on the effect of vanadium content.

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2. Experimental

The alloys of the Ti-xV-Cr (Ti/Cr = 5/8, x = 5, 10, 35), which abbreviate to VD1(x = 5), VZ1(x = 10) and VG1(x = 35) in the text and figures, were prepared by arc-melting under purified argon atmosphere from pure metals, with a purity of better than 99wt.%. The alloys were melted into a button form and remelted several times in order to improve the homogeneity of compositions. The pressure-composition isotherms (PCT curves) for the alloys were measured using a self-made Sieverts-type apparatus. After initial activation at 400 ℃ for several times, the specimens were absorbed/desorbed hydrogen under the hydrogen pressure range from 0.001 to 3.0 MPa at the room temperature. The determination of kinetics of hydrogen absorption was performed after the initial activation process and was done under the initial hydrogenation at the pressure of 1.0 or 1.1 MPa at room temperature. The initial hydrogen absorbing pressure in specimen chamber was in vacuum. The specimens before hydrogenation were determined by XRD for phase structure analyses.

3. Results and discussion

3.1. Phase structure

Fig. 1 displays the XRD patterns in the Ti-xV-Cr (x = 5, 10, 35, Ti/Cr = 5/8). It can be seen that the VD1 alloy with 5at.% vanadium has duplex configuration consisting of the tetragonal $Cr_{1.97}Ti_{1.07}$ phase and hexagonal Cr_2Ti phase. As the vanadium content increases to 10%, there appears V-based BCC solid solution phase. As the vanadium content increases to 35at.% in the VG1 alloy, the V-based BCC solid solution phase becomes the main phase in the alloy, with a little second phase coexisting.

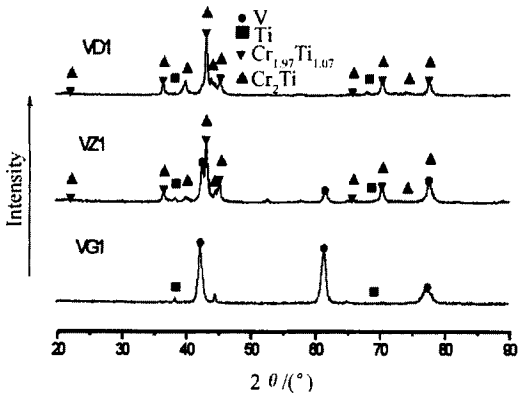

Fig.1. XRD results of Ti-xV-Cr (x = 5, 10, 35, Ti/Cr = 5/8) alloys.

3.2. Hydrogen absorption curves

The hydrogen absorption properties in the VD1, VZ1 and VG1 alloys are shown in Fig.2. It can be seen that with the increase of vanadium content from 5at.%, 10at.% to 35at.%, the maximum hydrogen absorption capacity increases from 1.14wt.%, 1.57wt.% to 2.84wt.% respectively. In these alloys, the plateau pressures are not unchangeable with the hydrogen content and have a slightly slope in the PCT curves. When we define the effective hydrogen absorption plateau as the part with a slightly slope in the PCT curve, indicated by arrows P_1 and P_2 in Fig.2, it can be seen that the alloy with 35at.% vanadium content has the longest pressure plateau region among these alloys and has a maximum effective hydrogen absorption capacity of 2.27wt.%. As the vanadium content decreasing to 10at.% and 5at.%, the pressure plateau rises up to the high pressure level. Due to the restriction of the self-made Sieverts-type apparatus, the high pressure data could not be obtained accurately,

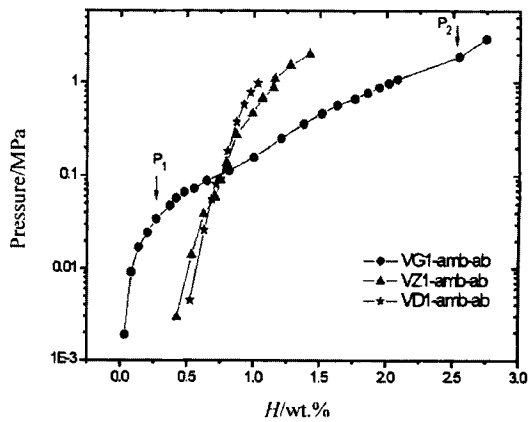

Fig.2. PCT curves of hydrogen absorption in the alloys: VG1, VZ1 and VD1.