Oxidation behavior of vanadium carbide powder

炭化バナジウム粉末の酸化挙動

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In this study, the oxidation of vanadium carbide (VC) powder at high temperatures was investigated in order to determine the possibility of its high-temperature use and additional material for improvement of the oxidation resistance of carbon-carbon (C/C) composites. VC powder with an average particle size of about 10 μm was used in this experiment. The sample was oxidized at 300 to 1000 $^{\circ}\text{C}$ for 5 min to 25 h in air. The weight changes were measured to estimate the oxidation resistance. The oxidation of sample for short oxidation times of 5 min started at 300 to 400 $^{\circ}\text{C}$ and weight gain change was measured with increasing oxidation temperature. The sample at the oxidation time of 0.5 to 1 h, exhibited a weight gain change with increasing oxidation temperature. VC is oxidized to V_2O_5 at about 600 $^{\circ}\text{C}$.

Keywords: Vanadium carbide, Oxidation, Vanadium oxide, Weight gain

I. INTRODUCTION

Vanadium carbide (VC), a carbide of a transition metal belonging to the (5A) group, has attracted much attention as a material for structures exposed to high temperatures, for surface protection, and for wear-resistant parts used in a corrosive environment. It has favorable properties, such as high melting point (2684 $^{\circ}\text{C}$), chemical stability and high electrical conductivity.¹

Recently, studies have been carried out to determine the feasibility of refractory materials for space crafts and rocket vehicles.

Although the VC is known to be corrosion resistant up to high temperatures in air, it is rarely used at high temperatures. To date, there have only been few reports regarding the oxidation of VC.

In this study, the oxidation of vanadium carbide (VC) powder at 300 to 1000 $^{\circ}\text{C}$ was investigated in order to determine the possibility of its high-

temperature application and additional material for improvement of the oxidation resistance of carbon-carbon (C/C) composites.

II. EXPERIMENTAL PROCEDURE

VC powder made by Japan New Metals (Osaka, Japan) was used as starting material (purity = 99%, median particle size = 10 μm).

Isothermal oxidation in air was carried out in an electric furnace maintained at the desired temperature (± 1 $^{\circ}\text{C}$). The sample to be evaluated, usually consisting of about 500 mg of the powder, was weighed carefully. A pure α - Al_2O_3 boat containing of the several as-received powder was directly pushed in the hot zone of furnace at operating temperature onto low density stabilized zirconia setter. After the prescribed period, the sample, together with its boat, was removed from

furnace, allowed to cool, reweighed carefully. The mass data were obtained to an accuracy of ± 0.1 mg using an electromagnetic balance.

A few typical samples of partly oxidized powders were subjected to X-ray diffraction (XRD) for phase characterization using an X-ray diffractometer (Cu K α /Ni filter, 40 kV, 30 mA) from Philips Ltd.,. The powder diffraction peaks were identified using the computer program of the X-ray cards of the International Center for Diffraction Data.

III. RESULTS AND DISCUSSION

In general, the evaluation of oxidation resistance of SiC is carried out by investigating the weight gain according to the following reactions²³ :

VC, however, is thought to form the following oxides :

Even if the weight is apparently decreased by the CO gas formed as one of the oxidation products, the

FIG.1. Weight gain as a function of temperature. The oxidation times are ■:5 min, ●:0.5 h, ▲:1 h, ▼:2 h, ◇:5 h, ▽:10 h and ○:25 h.

weight of the sample should increase with the increasing oxidation time. Thus, the weight gain due to the oxidation of the sample was measured in order to determine the relative oxidation resistance.²³

The samples were oxidized at 300 to 1000 °C for 5 min to 25 h in air. The weight gain data of the several sample is the average of three measurements. The weight changes show an initial weight loss of about 5 to 7%. This decrease is followed by the oxidation process. (Fig.1) During the initial heating between 300 °C, water is removed and the weight gain starts at 400 °C. The oxidation of the samples at the short oxidation time of 5 min started at 300 to 400 °C, and the weight gain increases with increasing temperature. The sample annealed at the oxidation times of 0.5 to 1 h show only weight gain with increasing temperature. On the other hand, the sample at the oxidation time of 2 h, and above show a weight decrease with increasing temperature.

Figure 2 shows the results of the powder X-ray diffraction analysis of samples oxidized at 400 to

FIG.2. X-ray diffraction patterns of the samples a)room temperature (as-received), b)400 °C, c)500 °C and d) 600 °C. The oxidation time is 1 h. ○ and ●; the peaks correspond to VC and V₂O₅, respectively.

1000 °C for 1 h in air. The X-ray diffraction data of the starting powder showed only peaks of VC. A similar result was obtained for powders treated in air at 500 °C for 1 h. The weight gain was below 8%. The result of X-ray diffraction showed no crystalline phase other than VC in the sample. The sample heated to 600 °C for 1 h in air showed the presence of an additional phase, vanadium oxide of V₂O₅.

Based on the results of the X-ray diffraction analysis, vanadium oxide (V₂O₅) was present on the surface of the sample oxidized at 600 °C. From the above data, we suggest that the oxidation above 600 °C of VC follows the equation :

IV. CONCLUSIONS

To determine the high-temperature use and additional material for improvement of the oxidation resistance of carbon-carbon (C/C) composites, we investigated the isothermal oxidation condition of VC. The VC powder was oxidized at 300 to 1000 °C for 5 min to 25 h in air.

The results were as follows:

The oxidation of samples at short oxidation time of 5 min started at 300 to 400 °C and weight gain increases with increasing oxidation temperature. The

samples oxidized for 0.5 to 1 h showed also weight gain changes increasing with oxidation temperature. On the other hand, with the samples oxidized 2 h, and above the weight change decreased with increasing temperature. Based on the results of the X-ray diffraction analysis, vanadium oxide (V₂O₅) was present on the surface of the sample oxidized at above 600 °C.

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