The Effect of Yttrium Oxide on the Sintered Density of Tungsten

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1. Introduction

Tungsten possesses a unique combination of extremely high density, strength and erosion resistance at ultra-high temperature so that it is useful for various military and nuclear application fields. In general, tungsten without binder phases has been produced by solid state sintering under hydrogen atmosphere or by arc melting processes. However, it is difficult to obtain the tungsten with full density by conventional processes because of the extremely high melting point (3,410 ℃). On the other hand, the addition of yttrium oxide, which has excellent thermal stability, high creep strength and anti-toxicity, appears to increase the sintered density of the tungsten. Thus, in the present work, we investigated the effects of yttrium oxide on the sintered density and microstructure of tungsten. The processing variables were the content of yttrium oxides and sintering temperature.

2. Experimental Procedure

Average grain sizes of tungsten and yttrium oxide powders used were 2.4 ㎛ and 0.05 ㎛, respectively. The powders were prepared to be the compositions of 99.5W-0.5Y_2O_3, 99.0W-1.0Y_2O_3, 98.5W-1.5Y_2O_3 and 98.0W-2.0Y_2O_3 by weight percent. The blending was performed in a tubular mixer for 8 hours without processing controlling agents. The blended powder was compacted under the pressure of 100 MPa. Solid state sintering was conducted at ultra-high temperatures under flowing hydrogen gas atmosphere. The sintering cycle consisted of heating up to reduction temperature at 800 ℃, holding for 1 hour, and sintering in the temperature ranging from 1,500 ℃ to 2,500 ℃. The effects of sintering temperature and yttrium oxide on the density of tungstens have been studied through density measurements and microstructural observations.

3. Results and Discussions

When sintered below 2,000 ℃, the density of tungsten with yttrium oxide (W-Y_2O_3) was lower than that of without it, irrespective of the amount of yttrium oxide added. In contrast, in the case of sintering temperature higher than 2,000 ℃, the density of W-Y_2O_3 was higher than that of unalloyed tungsten. Therefore, it was founded that the addition of yttrium oxide retards or promotes the densification of tungsten, dependent on sintering temperature. As the amount of oxide added was increased from 0 to 1.5 wt%, the density

of W-Y_2O_3 was gradually increased, and then unchanged with increasing oxide content.

Since tungsten and yttrium oxide are expected to be mutually insoluble below 2,000 ℃, the observed low sintered density of W-Y_2O_3 is due to the restricted diffusion of tungsten atoms by yttrium oxide particles. On the other hand, as the increased sintered density of tungsten with the addition of yttrium oxide above 2,000 ℃, is closely associated with melting of yttrium oxide. The melting of yttrium oxide leads to the enhanced mobility of tungsten atoms. The variation of sintered density of tungsten with yttrium oxide content is discussed with the changes of solubility of tungsten atoms in melted yttrium oxide and diffusion paths of them through it.

4. Summary

This study shows that the sintered density of tungsten is greatly influenced on the addition of yttrium oxide. The addition of yttrium oxide results in the retardation of sintering of tungsten below 2,000℃, while it enhances above 2,000 ℃. As the amount of yttrium oxide is increased from 0 to 1.5wt%, the density of W-Y_2O_3 is increased and then it remains unchanged with increasing oxide content.