Fine-grained Tungsten Heavy Alloy by Mechanical Alloying and Yttrium Oxide Addition

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Abstract

In this study, the trace amount of Y_2O_3 (0.04 wt%) was added during MA process of 90W-7Ni-3Fe powder mixture to enhance the tensile performance and control microstructure during liquid phase sintering, the effect of rare earth oxide on microstructure and mechanical properties of tungsten based alloys were studied.

The raw materials in this experiment include the hydrogen-reduced polygonal tungsten powder, spherical carbonyl nickel powder, spherical carbonyl iron powder and Y_2O_3 powder; their average particle sizes were 2.91 μm, 2.66 μm, 3.97 μm and 5.0μm, respectively. The powder were mixed at a weight composition ratio of 90wt%W-7wt%Ni-3wt%Fe-0.04wt%Y_2O_3, and then mechanically alloyed in a high energy mill for 40 h at a rotation speed of 200 rpm, ball-to-powder ratio of 10:1 using tungsten balls of 6 mm in diameter, ball-filling ratio of 6% in volume fraction, liquid-to-ball-and-powder ratio of 1.4:1, and ethanol as the liquid milling media. N,N-Dimethylformampe was used as the process control agent and Ar as a protecting atmosphere. The mechanically alloyed composite powder was pressed and then sintered at temperature of 1480℃ for 30min in H_2 atmosphere.

The elemental powders form a new multi-layer composite powder after MA. The mechanically alloyed powder has a much higher specific surface area and a much finer particle size than the initial powder mixture. The large specific surface area increases surface energy and the activity of powder, hence producing the bridge-juncture effect, which leads to powder conglomeration.

It is clearly seen from morphologies that morphology appears threadlike and flocculencelike, the single particle size of powder is smaller than 0.1μm, the agglomerates cannot be effectively separated due to the gravity effects and the high surface activity of the powder.

Trace Y_2O_3 plays an important role in inhibiting bubbles produced during liquid phase sintering and in enhancing density. The reason for the phenomenon may be related to the double rearrangement , dissolution precipitation of the MA powder during liquid phase sintering owing of the very higher surface activity of the nano-structured particles, which result in a lot of gases escaping from the liquid and the forming bubbles. The relative density of alloy increases to above 99.3%, with addition of Y_2O_3, the dissolution-precipitation process can be controlled to some extent by decreasing W dissolve in liquid phase, which is responsible for the inhibition of the gas bubble formation, with addition of trace Y_2O_3 change the existence form and distribution state of the impurity element oxygen. So the sintered alloy possesses very high strength and excellent ductility, which is much higher than that without adding Y_2O_3 addition, especially for the elongation which is above 30%.

It is seen from SEM micrograph of tensile fracture for the specimen that the intergranular rupture of W-W and ductile rupture of matrix are the dominant fracture modes of the alloy without adding Y_2O_3. With adding 0.04wt% of Y_2O_3 in the alloy, the number of tungsten grain transgranular fracture increases, and the matrix shows obvious ductile rupture characteristics, which appears to be a nest-like shape. At this time, the alloy has high meachanical properties, where the maximum tensile strength and elongation reach about 1050 MPa and 30.8%, respectively.

The optical micrographs of the alloys show the tungsten grain size and its distribution. It is seen that the average tungsten grain size of alloy is between 8~12μm, which is much finer (about 5 times) than that of conventional tungsten heavy alloys (40~60μm). The results indicate that refining the crystalline size or particle size of the initial powder by MA process is very useful for obtaining fine-grained tungsten heavy alloy. The influence of trace amount of Y_2O_3 on refining the microstructure of tungsten heavy alloy is not very obvious, because the content of Y_2O_3 addition in our study is much less such that it cannot effectively prevent the mass flow and transfer of the liquid phase. When Y_2O_3 was added, smaller particle tungsten grain that reprecipitated from liquid phase were found, causing the contiguity of W-W to decrease. When yttrium oxide was not added, the optical micrograph showed a tight arrangement of near spherical tungsten particles. Thus, by adding 0.04wt% Y_2O_3, the alloy show good microstructure characteristics such as high elongation and strength.

Fine-grain 90W-7Ni-3Fe tungsten heavy alloy was obtained by MA process and liquid phase sintering at 1480℃ for 30min,in which tungsten grain size is 8-12μm, and the alloy has good mechanical properties.Y_2O_3 effectively prevents from bubbling of the samples during liquid phase sintering, and thus enhances the density of the alloy and has great influences on mechanical properties, microstructure and tensile fracture modes of alloy.

