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Porous structure uniformity investigation of tungsten matrix prepared by jet milled and annealed tungsten powder

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ABSTRACT

The correlation between tungsten powder properties and porosity characteristics of porous tungsten matrix have been investigated in this paper. With the deagglomeration and classification, monodisperse tungsten powders of different particle size with narrow particle size distribution have been obtained. Multi-step annealing operation with continuously increasing temperature was taken to reduce the particle activity, which are conductive to particle size homogenization, shape modification and purification simultaneously. The press-sintered porous tungsten matrix prepared by jet milled and annealed tungsten powder presents homogeneous inter-connected pores with uniform pore size and distribution, indicating that low-activity monodisperse powder with narrow particle size distribution is required for manufacturing homogeneous porous tungsten matrix.

1. Introduction

Owing to its high melting point and boiling point, the lowest vapor pressure and low thermal expansivity, tungsten (W) plays an important role in many technology fields such as atomic energy, military, electro vacuum and other ultra-high temperature applications [1–6]. Typically, porous tungsten matrix is one of the most commonly used materials for dispenser cathode substrate, tungsten-based metal-metal and ceramic-metal composites manufactured by melt-infiltration [7–11]. The porosity characteristics, including open porosity, pore connectivity, pore shape, pore size and distribution, are critical to determine the material properties [10–13].

Due to the mechanical properties of tungsten, powder metallurgy (PM) has been generally used to fabricate tungsten products [14]. The properties of tungsten products formed by PM method are closely related to the raw powders [15]. Melnikova reported that powder particles with low activity are required for manufacturing long lifetime cathodes [16, 17]. Bao employed a reduction of oxide in hydrogen atmosphere above 700 °C which made the pore distribution more uniform [18]. Li fabricated homogeneous porous tungsten matrix with open pore channel by using spherical W powder with average size of 13 μm, and he pointed out that spherical particles could keep initial shape and favor the preservation of inter-connected pores with narrow pore size distribution [19]. The results of these studies indicate that the improvement of the properties of W powder i.e., powder activity, particle size distribution, purity and surface morphology, all lead to the improved performance of porous tungsten matrix. Thus, it is necessary to study the correlation of various properties of tungsten powder and porosity characteristics of porous tungsten matrix in detail.

In this study, jet milling treatment which is successfully applied in dealing with brittle materials in other industries has been taken for our experiments as an innovative method to modulate the particle size distribution [20–24]. First W power was treated with jet milling for deagglomeration and classification. This was then followed by multi-step annealing to reduce the activity of W powder. Three kinds of W powders were consolidated by pressing and sintering. The microstructural analysis and pressure mercury method are used to provide insight into the microstructure and porosity characteristics of the sintered samples.

2. Experimental

2.1. Powder

Commercially available as-received W powder with particle size of 5 μm FSSS, was purchased from Xiamen Golden Egret Special Alloy Co. Ltd.

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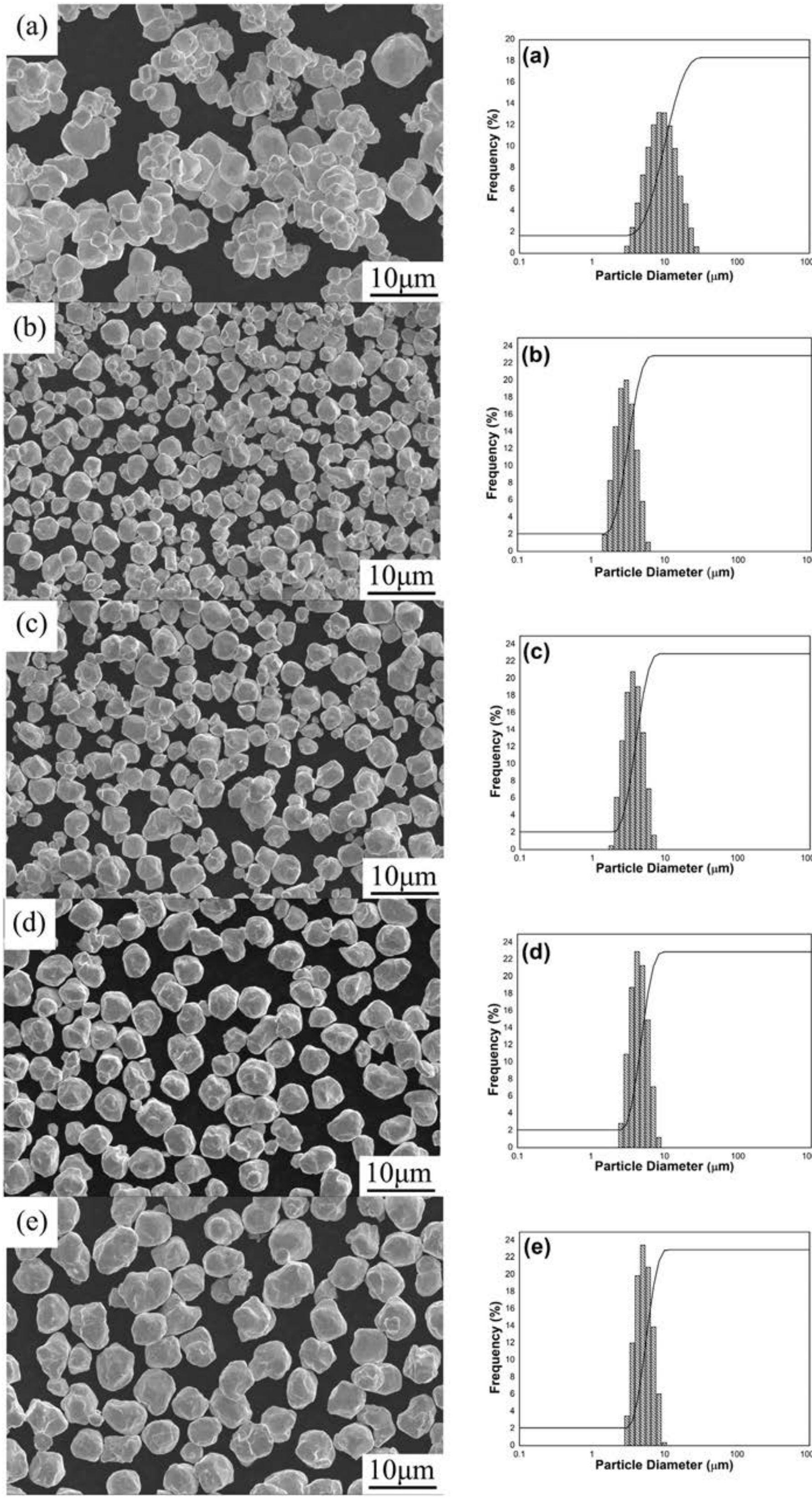

Fig. 1. SEM photographs of surface morphology and particle size distribution of W powders at different rotating speed: (a) as-received powder; (b) 4200 rpm; (c) 3500 rpm; (d) 3150 rpm; (e) 2800 rpm.

2.2. Experimental procedures

W powder was comminuted in high-purity nitrogen by QLMR-150T fluidized bed jet mill. The process was determined by the operational parameters including the feed quantity, grinding gas pressure and rotating speed. The feed mass was kept constant at 5 kg, the grinding gas pressure was 0.70 MPa, and the rotating speed was set at the range of 0–4200 rpm. The further annealing of W powder was performed in