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Characteristics of High Density U-Mo Alloy Powder Prepared by Centrifugal Atomization

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Abstract

Characteristics of high density U-Mo alloy powder prepared by centrifugal atomization have been examined. The results indicate that the majority of the atomized U-Mo alloy particles has a smooth surface and frequently near-perfect spheroidal shape with few satellites attached. The size distribution of atomized U-Mo alloy powder shows the mono-modal size distribution seen in ligament disintegration mechanism. All phases of atomized alloy powder below 150㎛ irrespectively to particle size are found to be γ-U (cubic structure) phases with isotropic structure and not to be U_2Mo phase at all. The microstructure of atomized U-Mo alloy particulates has micro-crystalline structure with non-dendritic grain supersaturated with Mo element. Also the grain size of γ-U tends to decrease with the decrease of the powder diameter.

1. Introduction

Uranium-silicide dispersed nuclear fuels have been developed to convert highly enriched fuels for research reactors to reduced enrichment for the purpose of non-profileration since 1978. Up to the present, U_3Si_2 dispersion fuel has been developed to be the most suitable.[1] Nowadays most of research reactors have been converted using U_3Si_2 dispersion fuels. The maximun uranium density of U_3Si_2 dispersion fuel is 4.8 g-U/cm^3.[2] However, this value is not enough for high performance reactors in the world so that higher U density fuels should be developed.

Now there are basically two aspects to the development of high uranium density dispersion fuels for the purpose of reduced enriched research reactors. The first challenge is the achivement of maximum volume fraction of U_3Si_2 fuel particles in the core.[3] The second challenge is the discovery or development of uranium compound or alloy which the highest possible uranium density that can be fabricated in a dispersion, and has acceptable irradiation behavior. To date, the highest density qualified compound is U_3Si_2 used in comminuted powder form, however, recently atomized spherical powder has become available which may possibly alow higher fuel volume loading to be fabricated[4]. Generally high density uranium alloys freezed slowly include anisotropic α-U phase with orthorhombic structure in as-cast ingot. α-U phase uranium alloys have been regarded as the unavailable materials as nuclear fuel for reseach reactor due to the anisotropic growth behavior during irradiation. High density uranium alloys with isotropic γ-phase (cubic structure) become to need discover or develop for the purpose of dispersed nuclear fuels. Centrifugal atomization is applied in preparing U-2wt%Mo and 10wt%Mo alloy powder for U-Mo alloy that is known to form tetragonal or cubic phase in quenching after solution treatment of U-Mo alloy above 5wt%Mo content. And the characteristics of U-Mo alloy powder prepared by centrifugal atomization are examined in this papers.

2. Experimental procedure

Proportioned mixture of depleted uranium lump with purity 99.9% and molybdenium button with purity 99.7% was induction melted in a graphite crucible coated with high temperature resistant ceramics. The molten metal was feeded through the orifice, and atomized by a rotating graphite disk in the ejected argon atmosphere. In order to obtain the suitable size distribution and shape, the atomization parameters, such as feeding rate of melt, revolution speed of disk etc. were adjusted. The atomized powders were trapped in pot at the bottom of the chamber.

Powder size distribution was examined by sieve analysis. The morphology of powders according to atomized particle size was analyzed by scanning electron microsope. The morphologies and the microstructures of powders were investigated by the scanning electron microscope. The alloy phases were analyzed by EDS (: Energy dispersive spectroscope) or XRD (: X-ray diffractometer).

3. Results and discussion

The typical shape of the atomized U-Mo alloy powder as observed by scanning electron microscope is given in figure 1. The majority of the particles has a smooth surface (fig. 1-(a)) and frequently near-perfect spheroidal shape with few satellites attached (fig. 1-(b)). On the other hand the small portion of fine particles below 45㎛ have a lengthened, flake-like morphology. The reason why atomized particles have spherical shape is considered to be resulted from the use of graphite disk with high thermal conductivity[5]. As the heat flow above the disk directs toward the circumference from the center during centrifugal atomization, the thick freezing layer with serrated shape in graphite disk edge is formed. In theses circumstances the droplets that are directly separated from disk edge could be formed in spherical powder due to the spheroidization reaction of surface tension affected to the melt. Few atomized powders of U-Mo alloy have internal pore. The shape of pore is generally spherical. The area fraction and the frequency of internal pores increase with powder size. The results explain that the large droplet has relatively low surface tension and has large chance for cooling gas to be trapped while it is separated from the disk. Fig. 2 shows the typical size distribution of atomized U-Mo alloy powder in terms of weight fraction. The mono-modal size distribution seen in ligament disintegration mechanism is shown[6]. In this mechanism when the feeding rate increases, the dimensions of protuberances around the edge of the disk increase. The larger protuberances strech into ligaments which eventually break down into stings of many particles at some distance from the edge of rotating disk. Each protuberance gives birth to a considerable number of particles.

The typical X-ray diffraction patterns of atomized U-2wt%Mo and U-10wt%Mo alloy powder are shown in figure 3. All phases of atomized alloy powder below 150㎛ irrespectively to particle size are found to be the metastable γ-U (bcc) phase with isotropic structure and not to be the U_2Mo phase at all. It is known that U-2wt%Mo and U-10wt%Mo alloy freezed slowly consists of α-U phase and U_2Mo intermetallic compound with lamellar structure. γ-U (bcc) phase stable above 550℃ exists in room temperature due to rapid solidification effect. Especially, even U-2wt%Mo alloy that is known to include α-U phase with orthorhombic structure has γ-phase with cubic structure. The typical microstructure of atomized U-5wt%Mo and U-10wt%Mo alloy particulates is illustrated in figure 4. It is seen that the microstructure of both atomized particulates has microcrystalline structure with non-dendritic grain supersaturated with about 20at%Mo. The grain size of atomized U-Mo alloy shows 1~5㎛ and tends to decrease with the decrease of the powder diameter. This suggests the rapid cooling effects improves with finer powder owing to the increase of the specific area. As the cooling rate in finer drop is increased, the time available for solidification is decreased and the tendency to form finer microcrystallines is enhanced.

3. Conclusions

In order to develope isotropic uranium alloy with high uranium density, U-Mo alloy powder is prepared by centrifugal atomization. Chracteristics of atomized alloy powder are as follows.

1. The majority of the atomized U-Mo alloy particles has a smooth surface and frequently near-perfect spheroidal shape with few satellites attached. On the other hand the small portion of fine particles below 45㎛ have a lengthened, flake-like morphology. Few atomized powders of U-Mo alloy have internal pore.
2. The size distribution of atomized U-Mo alloy powder shows the mono-modal size distribution seen in ligament disintegration mechanism
3. All phases of atomized alloy powder below 150㎛ irrespectively to particle size are found to be the metastabe γ-U (bcc) phase with isotropic structure and not to be the U_2Mo phase at all.
4. The microstructure of atomized U-Mo alloy particulates has micro-crystalline structure with non-dendritic grain supersaturated with Mo element. The grain size of atomized particulates shows 1~5㎛ and tends to decrease with the decrease of the powder diameter.

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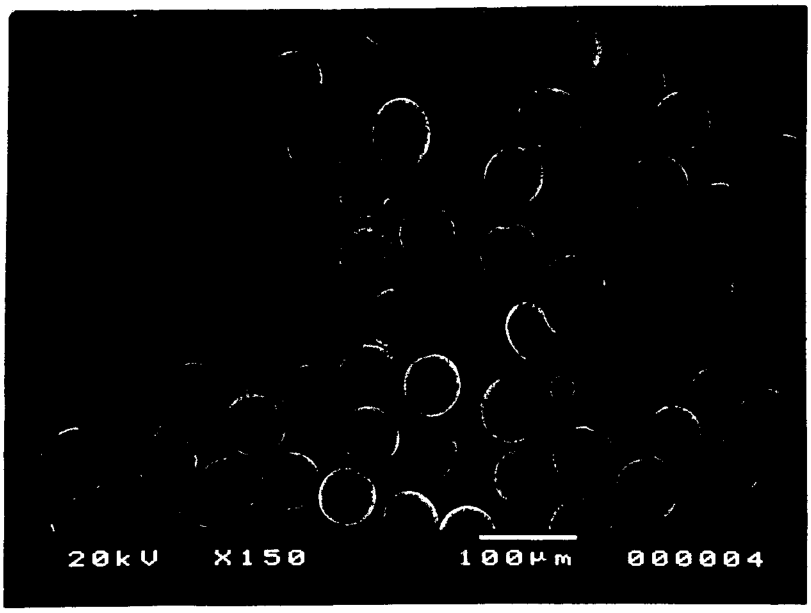


Fig. 1. Photograoh of atomized U-Mo alloy powder.

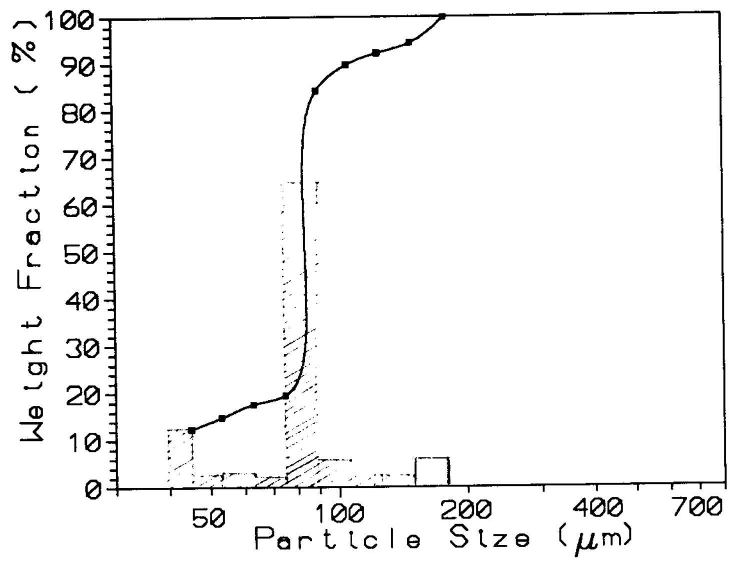


Fig. 2. Typical particle Size Distribution of U-Mo alloy powder in term of weight fraction.

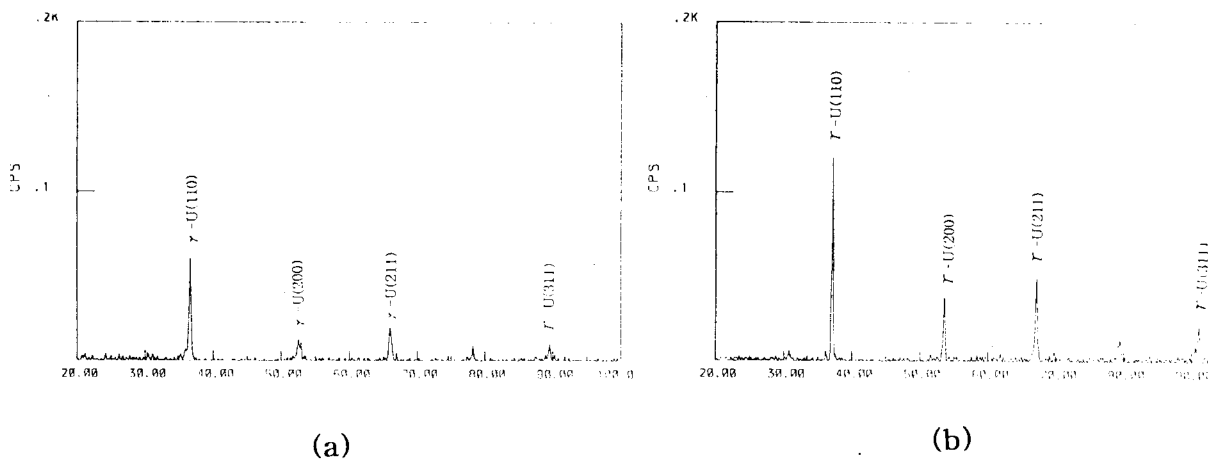
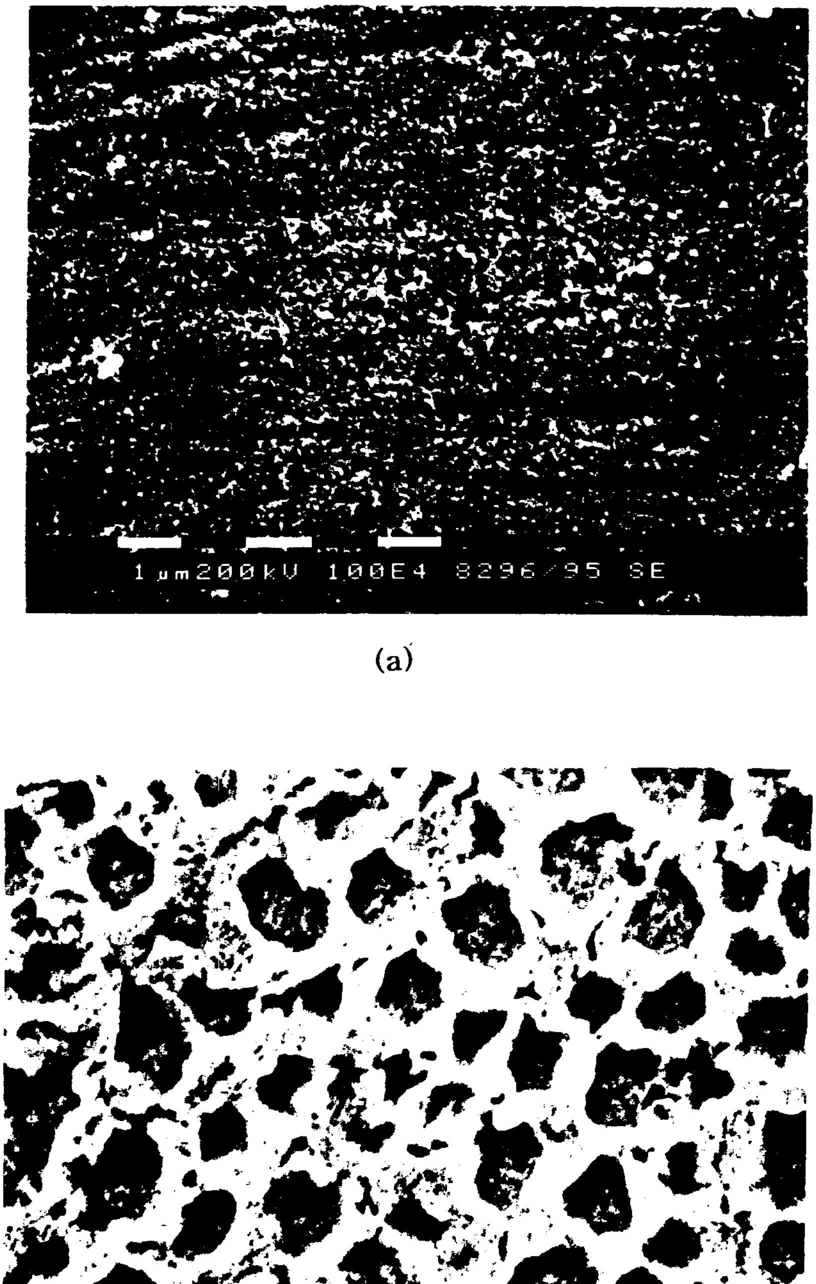


Fig. 3. X-ray diffraction patterns of atomized U-2wt%Mo(a) and U-10wt%Mo(b) alloy powder.



(a)

(b)

Fig. 4. Micrographs of atomized U-2wt%Mo(a) and U-10wt%Mo(b) alloy powder