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TRANSMISSION ELECTRON MICROSCOPY OF RAPIDLY SOLIDIFIED DU-5% W ALLOY

Ravi Batra

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Rapidly solidified depleted uranium alloys containing 5% tungsten have been characterized. Transmission electron microscopy work on depleted uranium-tungsten alloys reveals that tungsten is precipitated out in the form of fine dispersion and that these dispersoids are thermally stable.

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INTRODUCTION

Rapid solidification technology (RST) has been exploited to enhance mechanical properties of metallic materials. Industry has used RST to improve properties of metallic systems based on aluminum, iron, magnesium, titanium, etc.

The purpose and scope of this investigation was to characterize rapidly solidified depleted uranium (DU) with 5% tungsten (W) alloy ribbon in both the as-cast and heat-treated conditions, using transmission electron microscopy (TEM).

A ribbon about 0.003-inch thick was produced by the molten jet ribbon casting technique. Details of the equipment and procedure are available in another publication.*

HEAT TREATMENT

Since DU is very reactive and pyrophoric, ribbon samples of DU-5% W were encapsulated in a 1/2-inch-diameter quartz tube under vacuum. The samples were heat treated in the Lindberg furnace at 600°C for 8 hours and at 800°F for 1 and 10 hours, respectively. After the required heat treatment, samples were water quenched to room temperature.

SPECIMEN PREPARATION

Specimens, about 3-mm in diameter, were punched from the as-cast and heat-treated ribbons. These samples were mounted with hot wax on the specimen holders and were then polished on 600 grid paper to make them flat and even on both sides. Final polishing was accomplished in a 5% perchloric-methanol bath cooled down to -50°C, using the Struers electropolishing apparatus. The electropolisher was operated at 30 volts and at maximum sensitivity.

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* Batra, Ravi, "Casting and Characterization of Rapidly Solidified Depleted Uranium Alloys Containing Tungsten," Technical Report ARAED-TR-90031, ARDEC, Picatinny Arsenal, NJ.

RESULTS AND DISCUSSION

Transmission electron microscopy was done on both as-cast and heat-treated samples. The heat treated samples were annealed at 600°C for 8 hours and at 800°C for 1 and 10 hours, respectively. These heat treatment temperatures were chosen to coincide with DU-3/4 Ti alloy processing. Differential thermal analysis was also conducted on a DU-5% W alloy and showed that the precipitation is occurring at about 600°C.

A TEM view of RS DU-5% W alloy ribbon in the as-cast condition is shown in figure 1. It is apparent that the material has fine grains (1 to 5 μ) and has a highly strained structure. Also, it is evident that W, which has a very low solubility in DU, has been retained in the supersaturated condition. A TEM view of the sample heat-treated at 600°C for 8 hours is shown in figure 2. The grain size is still about 1 μ and there is an appearance of fine W dispersion throughout the matrix. In fact, W has precipitated at triple grain boundary points, thereby indicating that W is effectively pinning the grain boundaries. The presence of W precipitates was confirmed by EDAX analysis.

In order to determine dispersoid coarsening characteristics of W, samples heat-treated at 800°C for 1 and 10 hours, respectively, were examined. Very fine dispersion (less that 1/2 μ) of W in both samples is shown in figures 3 and 4, but the number of W dispersoids increased when heat-treated at 800°C for 10 hours. The figures indicate that these dispersoids, when exposed to elevated temperatures for an extended time, do not coarsen.

Principles of rapid solidification dictate that grain size refinement is responsible for an increase in yield strength. Fine dispersoids having low solubility and diffusivity at high temperatures are required to effectively pin the grain boundaries and prevent grains from growing. Also, dispersoids may contribute to higher ultimate tensile strength. In the case of DU-5% W, it is apparent that W dispersoids precipitate from supersaturated matrix are effective in pinning grain boundaries. Additionally, when dispersoids are exposed to higher temperatures, they do not coarsen and become ineffective as grain boundary pinners.

It is contended that rapidly solidified DU with W alloys, when consolidated, will have superior mechanical properties because W seems to pin the grain boundary and prevents grain growth.

CONCLUSIONS

1. Fine grained structure is observed in rapidly solidified DU-5% W alloy.

2. Grain structure is stable after long exposure at high temperatures.

3. Tungsten in DU-5% W alloy is in a supersaturated condition and dispersoids precipitate out on heat treatment.

4. Tungsten dispersoids are very fine and seem to pin prior gamma grain boundaries.

Figure 1. TEM of as-cast RS DU-5% W alloy ribbon

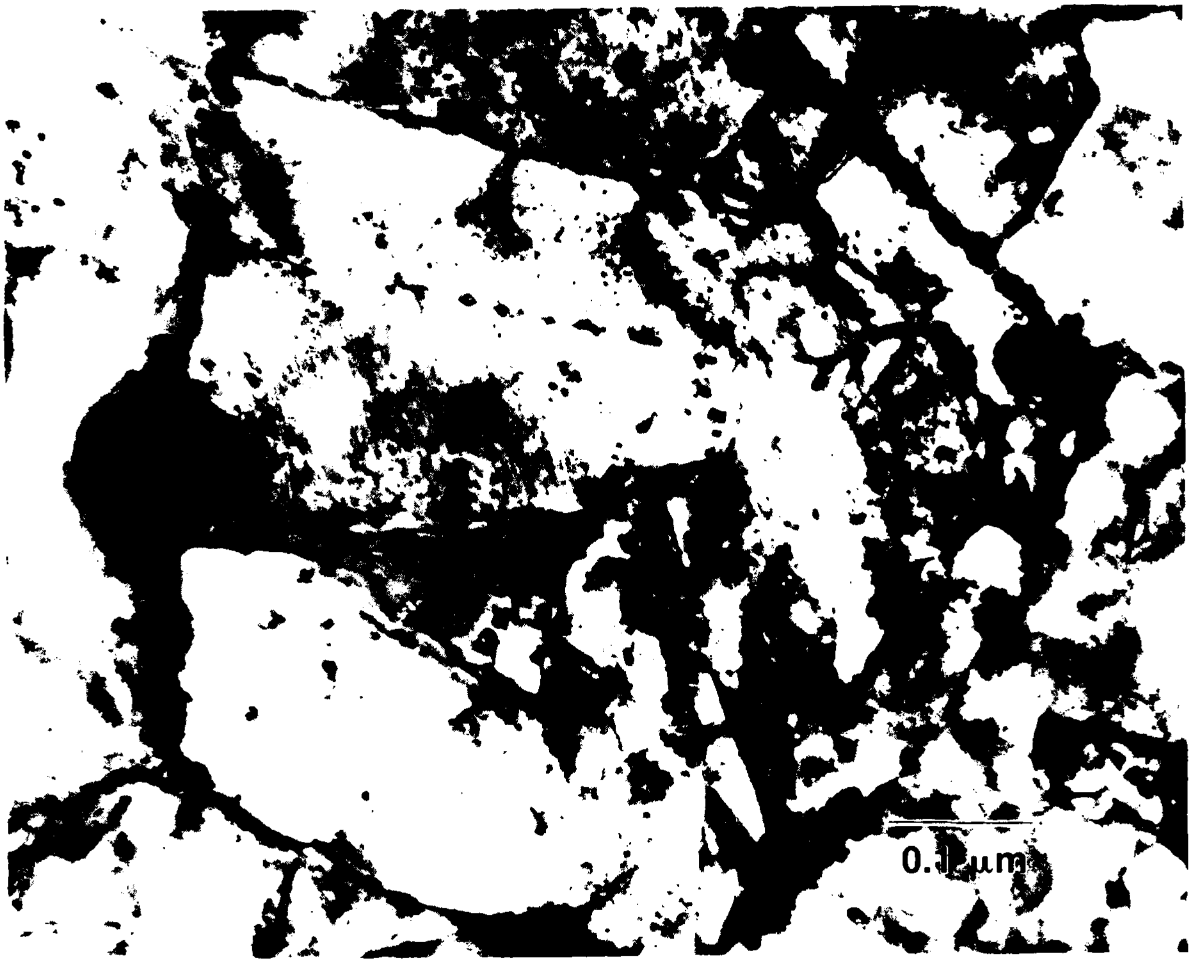

Figure 2. TEM of RS DU-5% W alloy ribbon
heat-treated at 600°C for 8 hours

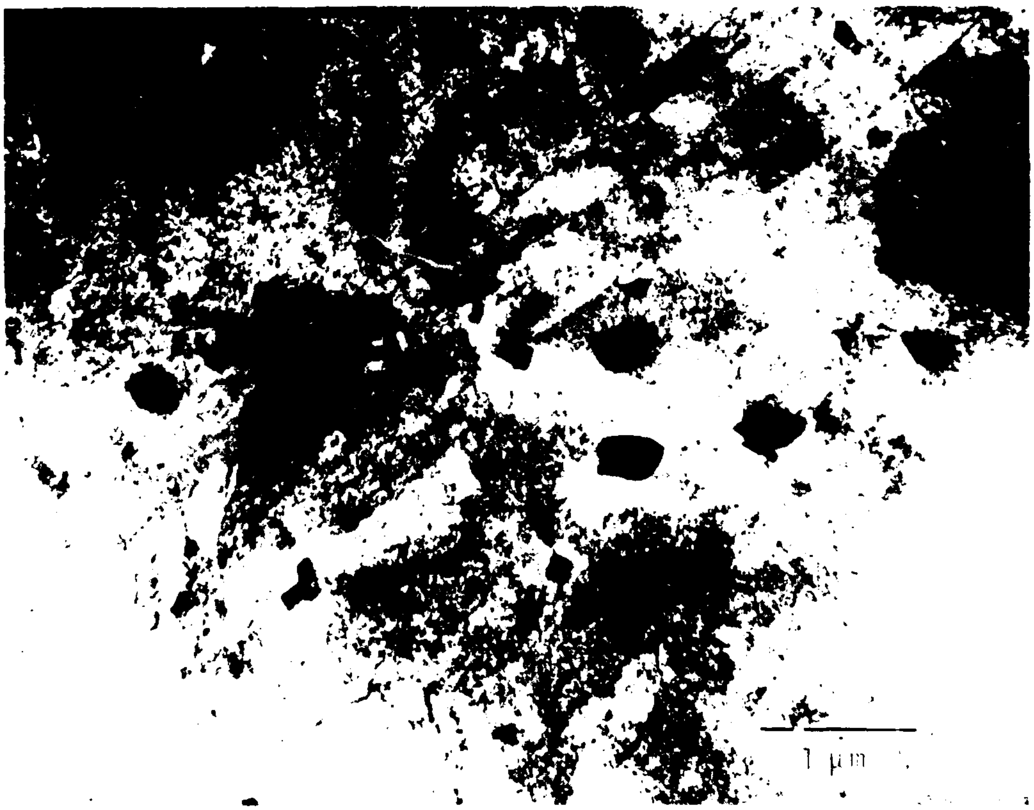

Figure 3. TEM of RS DU-5% W alloy ribbon heat-treated at 800°C for 1 hour

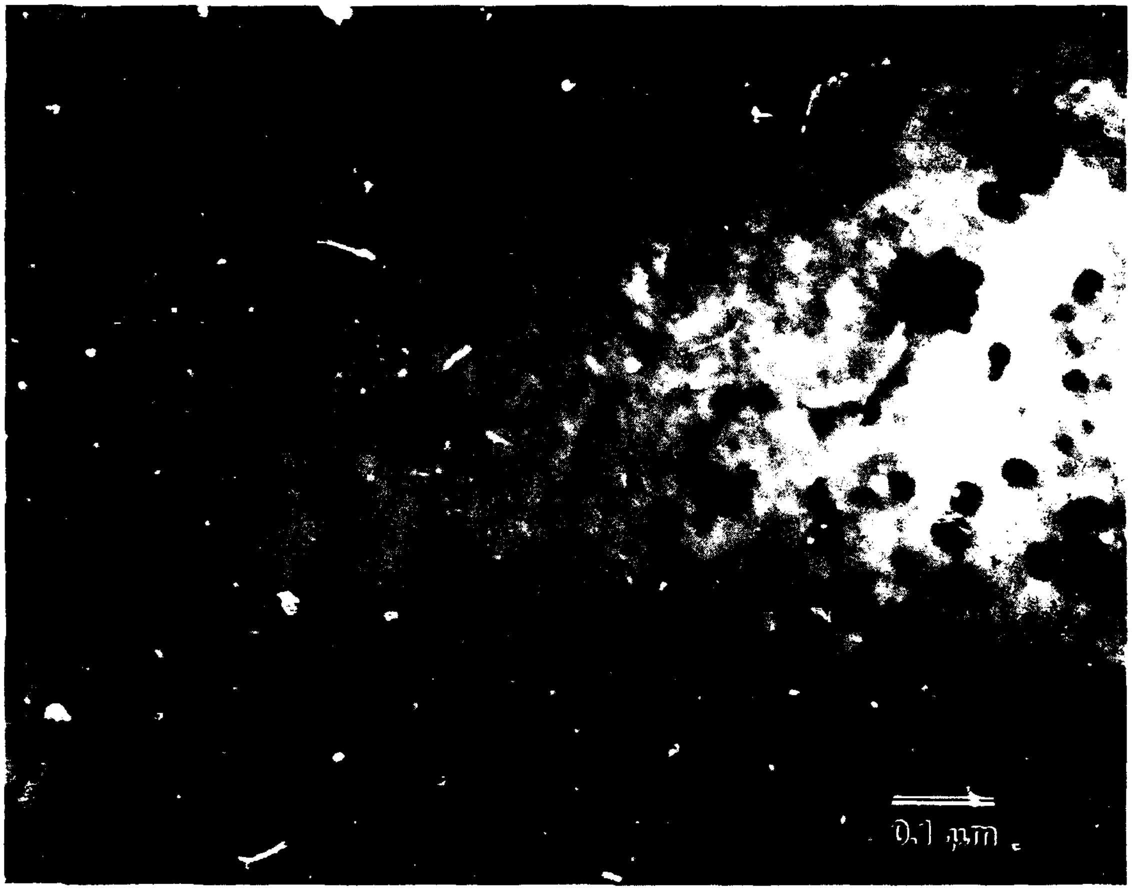

Figure 4. TEM of RS DU-5% W alloy ribbon heat-treated at 800°C for 10 hours

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Jerry LaSalle, Ph.D.
Allied-Signal Corporation
Morristown, NJ 07960