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GRAIN REFINEMENT OF THE URANIUM-5 w/o CHROMIUM
ALLOY BY TERNARY ADDITIONS

by

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H. F. Canale
Chief, Declassification Branch

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GRAIN REFINEMENT OF THE URANIUM-5 w/o CHROMIUM ALLOY BY TERNARY ADDITIONS

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Refinement of grain size of the base uranium-chromium eutectic alloy (uranium-5 w/o chromium) by ternary additions is discussed. Thirteen additions to the base alloy were investigated, and three additions were found to exhibit worthwhile grain-refinement tendencies. The three alloys, uranium-5 w/o chromium-0.2 w/o molybdenum, uranium-5 w/o chromium-0.2 w/o germanium, and uranium-5 w/o chromium-0.2 w/o niobium, were heat treated to produce final grain-size structures of between 0.015 and 0.033 mm.

INTRODUCTION

The use of the uranium-5 w/o chromium eutectic alloy as fuel for a power-producing reactor has been intensively investigated. The alloy appears ideally suited to production-type methods of fabrication because of its castability and excellent physical properties. However, its poor behavior under irradiation offsets these desirable qualities. It is believed that the poor stability may be due in part to the large grain size of the as-cast structure. Any treatment which can produce random orientation and grain refinement may improve the alloy's resistance to deformation under irradiation.

Three possible methods of producing small grain structures in metals are (1) chill casting, (2) heat treatment, and (3) alloy additions. Methods of refining grain size of the uranium-5 w/o chromium eutectic alloy by heat treatments are discussed in BMI-999.* The following paragraphs discuss the refinement of grain size of the basic uranium-chromium alloy by means of ternary additions. In addition, results of a heat treatment on selected alloys are given.

*Saller, H. A., Rough, F. A., and Bauer, A. A., "Grain Refinement of the As-Cast Uranium-5 w/o Chromium Alloy by Heat Treatment", BMI-999 (May 13, 1955).

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ALLOY PREPARATION

The alloys were made by the master-alloy technique. This method consists of preparing a 300-g arc-melted button containing chromium, the ternary addition, and Fernald biscuit uranium. This button, together with 700 g of uranium, was inductively melted under a pressure of less than 10^{-3} mm of mercury. The alloys were cast at approximately 2000 F into hot and/or cold graphite molds. After cooling, the resultant 7/8-in. by 6-in.-long ingots were sectioned to produce specimens for heat treatment and for metallographic studies. Because of the screening nature of the program, chemical analyses of the as-cast ingots were not taken, and all compositions listed are nominal.

Discussion and Results

Six ternary alloys were cast into 1100 F graphite molds only. They were not studied in the cold-cast condition, because earlier observations revealed that cold-cast grain refiners were less important than these that refined grain size of the base alloy when cast into hot molds. Of this group, listed in Table 1, alloys containing 0.2 w/o of germanium and molybdenum were finer grained than the eutectic alloy. The uranium-5 w/o chromium-0.2 w/o molybdenum ternary alloy had the smallest grain size of any composition studied.

* Saller, H. A., Dickerson, R. F., and Lind, G. E., "Grain Size of Uranium", BMI-66 (June 1, 1951).

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A diagram showing a grid of dots. A line segment connects two points. The line segment is labeled with a '1' and a '2'.

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TABLE 1. ADDITIONS MADE TO THE URANIUM-5 w/o
CHROMIUM ALLOY FOR GRAIN-REFINING
STUDIES

Element	Amount Added, w/o	Mold Treatment
Aluminum	0.2	Cold mold and 1100 F mold
Silicon	0.2	Cold mold and 1100 F mold
Iron	0.2	Cold mold and 1100 F mold
Iron	1.0	Cold mold and 1100 F mold
Titanium	0.2	Cold mold and 1100 F mold
Boron	0.05	Cold mold and 1100 F mold
Niobium	0.2	Cold mold and 1100 F mold
Zirconium	0.2	Cold mold and 1100 F mold
Thorium	0.2	1100 F mold only
Al ₂ O ₃	0.2	1100 F mold only
Molybdenum	0.2	1100 F mold only
Tin	0.2	1100 F mold only
Copper	0.2	1100 F mold only
Germanium	0.2	1100 F mold only

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Figure 1 shows photomicrographs of the uranium-5 w/o chromium eutectic alloy used as a standard for comparison of alloys cast into cold molds and alloys cast into 1100 F molds, respectively. Figure 2 shows photomicrographs of an uranium-5 w/o chromium-0.2 w/o niobium alloy that showed grain-refinement tendencies when cast into both cold and 1100 F molds. Figures 3 and 4 show photomicrographs of uranium-5 w/o chromium-0.2 w/o molybdenum and uranium-5 w/o chromium-0.2 w/o germanium specimens, the two alloys that showed grain refinement when cast into 1100 F molds.

Heat Treatment

Heat treatment of the ternary alloys was investigated as a means of further reducing grain size in cast specimens. Three ternary alloys having smaller grain size than the base alloy were subjected to one of the heat treatments discovered for refining the grain size in the eutectic composition. This consisted of annealing selected specimens 15 min at 700 C, isothermally transforming them for 2 hr at 475 C, and water quenching them. Results of this treatment on selected specimens are listed in Table 2. Photomicrographs of the three compositions receiving heat treatment are shown in Figures 5, 6, and 7.

As evidenced by results listed in Table 2 and the photomicrographs, heat treatment brought about a reduction of grain size in all compositions.

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b

100X Polarized Light N18525

a. Cast Into Cold Graphite; Grain Size, 0.062 MM

100X Polarized Light N18398

b. Cast Into 100 F Graphite; Grain Size, Above 0.118 MM

FIGURE 1. URANIUM-5 w/o CHROMIUM EUTECTIC ALLOY USED FOR COMPARISON WITH
TERNARY ALLOYS CAST INTO COLD AND 1100 F MOLDS

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100X Polarized Light NI8526

a. Cast in Cold Graphite; Grain Size, 0.049 MM

100X Polarized Light NI8527

b. Cast in Hot Graphite; Grain Size, 0.10 MM

FIGURE 2. URANIUM-5 w/o CHROMIUM-0.2 w/o NIOBIUM ALLOY
CAST IN COLD AND 1100 F MOLDS

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100X

Polarized Light

N18400

FIGURE 3. URANIUM-5 w/o CHROMIUM-0.2 w/o MOLYBDENUM
CAST INTO 1100 F GRAPHITE MOLD

Grain size, 0.060 mm

100X

Polarized Light

N18402

FIGURE 4. URANIUM-5 w/o CHROMIUM-0.2 w/o GERMANIUM
CAST INTO 1100 F MOLD

Grain size, 0.094 mm

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100X Polarized Light N18523

FIGURE 5. URANIUM-5 w/o CHROMIUM-
0.2 w/o GERMANIUM

Heat treatment: 15 min 700 C,
2 hr 475 C, WQ; grain size,
0.033 mm

100X Polarized Light N18524

FIGURE 6. URANIUM-5 w/o CHROMIUM-
0.2 w/o MOLYBDENUM

Heat treatment: 15 min 700 C,
2 hr 475 C, WQ; grain size,
0.015 mm

100X Polarized Light N18522

FIGURE 7. URANIUM-5 w/o CHROMIUM -0.2 w/o NIOBIUM

Heat treatment: 15 min 700 C, 2 hr 475 C, WQ;
grain size, 0.015 mm

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TABLE 2. RESULTS OF HEAT TREATMENT^(a) OF THREE TERNARY ALLOYS

Alloy	Grain Size, mm	
	Before Heat Treatment	After Heat Treatment
Uranium-5 w/o chromium-0.2 w/o niobium	Above 0.118	0.015
Uranium-5 w/o chromium-0.2 w/o germanium	0.094	0.033
Uranium-5 w/o chromium-0.2 w/o molybdenum	0.060	0.015

(a) Heat treatment consisted of annealing specimens 15 min at 700 C, isothermally transforming them for 2 hr at 475 C, and water quenching.

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