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URANIUM ALLOYS CONTAINING SMALL AMOUNTS OF ALLOYING ELEMENTS

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The present invention is concerned with uranium alloys which contain small amounts of alloying elements and which can be employed in particular as fuel materials in nuclear reactors.

It is known that, for reasons of neutron economy, natural uranium can only be employed as fuel material in nuclear reactors either in the pure state or containing low percentages of alloying elements which have a low neutron-capture cross-section.

It is also known that the deformations induced in uranium metal in the alpha phase at the time of in-pile irradiation are of minimum extent when the grain of the metal is fine and without preferential orientation.

A standard method of refining of the grain structure of pure uranium consists in carrying out after casting an annealing treatment in the beta phase followed by quenching. However, a treatment of this kind is effective only in the case of small samples and remains ineffective when performed on solid rods. Moreover, the fine grain structure which is obtained by means of this method is not stable under the influence of irradiation and thermal cycling.

A number of uranium alloys are already known which contain low percentages of alloying additions and which make it possible to overcome the disadvantages noted above. However, the preparation of such alloys makes it necessary to have recourse to a method of fabrication in which the as-cast alloy is subjected to an annealing treatment followed by quenching as performed either directly or in stages. Such a process obviously requires high capital outlay in plant and equipment and results in a correlative increase in the cost price.

The present invention relates to uranium alloys which carry low proportions of alloying constituents and which have a fine and uniform grain structure in the alpha phase, said alloys being intended to be directly employed in a nuclear reactor in the as-cast state and without any need of subsequent heat treatment.

The invention is concerned with uranium alloys which are characterized by the following composition by weight:

Molybdenum .. 0.10 to 0.30%.
Chromium ---- 0.05 to 0.20% and preferably between 0.05 and 0.15%.
Iron ----- 0.01 to 0.05%, the remainder consisting of nuclear pure uranium.

The method of fabrication of these alloys is extremely simple and economical since it consists only of melting and casting.

Melting is performed in a crucible, for example of graphite with a lining of aluminum oxide or of calcium zirconate.

The uranium metal and its addition elements are melted together in vacuo (for example a vacuum of 10^{-2} to 10^{-4} millimeters of mercury) and maintained in the molten state for a certain period of time in order to achieve homogeneity of the bath; the casting operation

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is then carried out, again in vacuo and at a temperature which is advantageously comprised between 1180 and 1450° C.

The casting is effected in molds which can either be at room temperature or which are preferably preheated, this latter case having the advantage of preventing the formation of pores during solidification of the metal. By way of example, the following temperature ranges can be employed for the preheating process: base of the molds: 300 to 800° C.; top of the molds: 600 to 1100° C., the top of the molds being always at a temperature which is higher than that of the base in order to prevent premature solidification in the top portion.

By virtue of their composition, the alloys of the invention are of particular interest in that they make it possible to obtain a fine grain structure in the alpha phase irrespective of the rate of cooling, said cooling rate being preferably comprised between 300° C./hr. and 700° C./hr.; the alloy has a fine alpha-phase grain structure even if the cooling rate reaches low values of the order of 120° C./hr.

It is thus possible to fabricate fuel elements in any shape which may be desired, for example rods, tubes or plates, the parts thus obtained being ready for immediate use after a conventional machining and graining process for the fabrication of fuel elements or plate elements.

The structure which is obtained in the as-cast state is uniform and the average grain size is 0.3 mm., and in all cases smaller than 1 mm.

These alloys have distinctly improved mechanical characteristics with respect to those of unalloyed uranium.

Accordingly, in the case of an alloy having the composition:

	Percent
Mo -----	0.22
Cr. -----	0.11
Fe -----	0.03

the following creep rates are obtained:

90×10 ⁻⁶ per hour at 500° C. under a stress of 12 kgs./mm. ²	40
170×10 ⁻⁶ per hour at 550° C. under a stress of 8 kgs./mm. ²	
2.6×10 ⁻⁶ per hour at 600° C. under a stress of 1 kg./mm. ²	45

In the case of unalloyed uranium, no measurement is possible inasmuch as such stresses are in excess of the ultimate yield strength.

Tensile tests show that, in the range of 400 to 600° C., the ultimate yield strength values are virtually three times greater than those obtained in the case of unalloyed uranium.

Tests for thermal stability of the grain structure have demonstrated that this latter remains stable up to a temperature of approximately 625° C.

Tests under irradiation have shown that the alloys in the as-cast state are capable of withstanding without deformation several thousand mwd./t. whereas under the same conditions of forming, unalloyed uranium is deformed to an excessive degree after only a few hundred mwd./t.

What I claim is:

1. A uranium alloy comprising by weight 0.10 to 0.30% molybdenum, 0.05 to 0.20% chromium, 0.01 to 0.05% iron, the remainder being uranium.

2. A uranium alloy in according with claim 1 containing by weight 0.05 to 0.15% chromium.

3. A uranium alloy in accordance with claim 1 containing by weight 0.22% molybdenum, 0.11% chromium, 0.03% iron, the remainder being uranium.

4. A nuclear fuel material comprising a casting of a uranium alloy comprising by weight 0.10 to 0.30% molybdenum, 0.05 to 0.20% chromium, 0.01 to 0.05% iron, the remainder being uranium.

References Cited by the Examiner

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