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Anticorrosion Protection of Uranium

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Uranium in atmosphere conditions is non-stable. Sloughing products are being generated on its surface during storage or use. These corrosion products make many difficulties because of necessity to provide personnel safety. Besides uranium corrosion may cause damage of parts.

The first works devoted to uranium corrosion were performed in the framework of the USA Manhattan Project in the early forties of last century. Various methods of uranium protection were investigated, among them the galvanic one was the most studied. Later on the galvanic technology was patented. The works on this problem remains urgent up to the present time. ..

In Russia, many methods of uranium corrosion protection, mainly from atmosphere corrosion, were tried on. In particular, such methods as diffusion zinc and paint coating were investigated. In the first case, a complex intermetallic U-Zn compound was formed but its protection was not reliable enough that is why an additional paint coating was necessary. Therefore, this protection system was inconvenient and uncertain.

In the case of paint coatings another problem appeared. It was necessary to find such a coating which gas-permeability would prevail over water-permeability. Otherwise significant uranium corrosion occurs. This circumstance together with low mechanical resistance of paint coatings does not allow to use paint coating for long-term protection of uranium.

Currently, there are following methods of uranium protection: ion-plasmous, galvanic and thermo-vacuum annealing.

Ion-plasmous coatings.

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One could use this method to obtain such metal coatings as Cu, Ni, Ti, Al and some other. Before metal applying, a proper surface preparation is needed. The doubtless advantage of this method is good adhesion of coating to uranium. However, the coating is porous and to ensure reliable protection one must increase coating thickness

At the same time this method has some drawbacks: the coating is not uniform, especially if detail has complex configuration. This reason drops significantly method advantages. Besides, equipment to be used is rather expensive. Moreover , it is natural that the problem of utilization of uranium details with metal coating arises.

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Galvanic method.

The galvanic method in detail has been investigated mainly in the USA. [1,2] It is necessary to notice some peculiarities of uranium protection with the help of metal coatings. Only Zn could protect uranium from corrosion efficiently. Other metals (Cu, Ni, etc.), being cathodes in relation to uranium, can provide good protection only when coating is pore-free, i.e. in enough thick layers (40-50 microns). In this case uranium becomes an anode in relation to Cu , for example and does not corrode if only coating is non- porous. When uranium is coated with Zn, the latter corrodes itself.

Another distinctive feature of uranium is its high inhibitive properties. This opposes generation of high-cohesive coatings. Therefore it was always a difficult problem to apply galvanic high-cohesive coating to uranium. To present day many questions remain. Taking into account all mentioned above, RFNC-VNIIEF developed a proper technology enviromently appropriate at the same time

The scheme of technology is presented in the fig. 1. It is very simple and low-waste technology, because it is based on use of diluted sulphuric acid. Wastes are utilized without any troubles.

Sceme of the low-waste copper plating technology

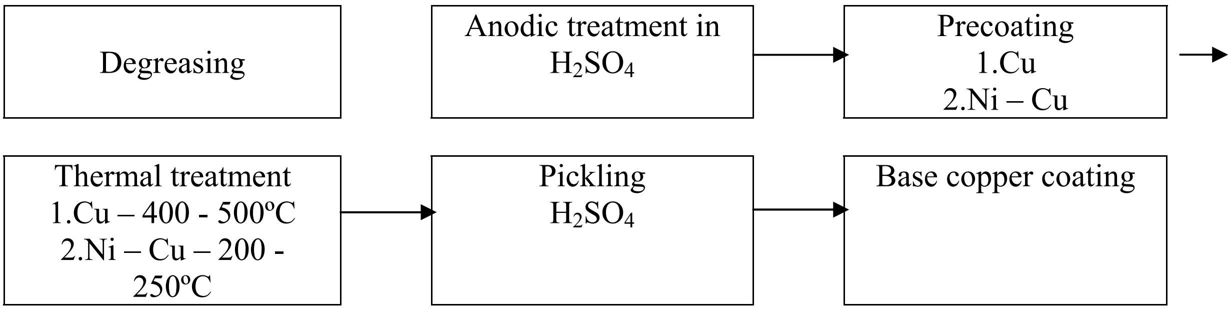

Fig. 1

The thermal annealing of precoating under 400 - 500ºC (Cu) or under 200 - 250ºC (Ni – Cu) provides high adhesion of coating [3,4,5].

There are also some drawbacks, mentioned above: the coatings applied to complex details are not uniform, and during detail utilization there is a necessity of coating removal.

Thermovacuum annealing

US patent #3547709 (1970) pointed out that thermo-vacuum annealing of uranium at temperature 600-650ºC in conditions of oxygen deficiency resulted in high corrosion-protective properties of uranium surface[6] This phenomenon was investigated in [7], carried out in Israel, too.

This method is unique, because all surface of a detail, including remote places, is exposed to processing, in the absence of any other elements on uranium surface. Thus, some kind of "self-protection" occurs. At present the phenomenon has not been

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investigated up to the end because of complex physico-chemical proccesses taking place during the annealing. It is supposed that carbon contained in uranium takes a significant part in this proccess. Carbon migrates to uranium surface forming uranium monooxycarbide with regular lattice without vacancies. As a result, a vacancy diffusion mechanism becomes more complex and is replaced by interstitial mechanism raisinf the corrosion resistance. This supposition needs experimental arguments. .

The authors investigated the thermo –vacuum annealing of uranium from the point of reliable anti-corrosion protection of uranium.

At first the original USA variant of annealing was tested. Some problems appeared with precise dosage of oxygen ; moreover, corrosion resistance was unsatisfactory.

RFNC-VNIIEF developed its own simple and reliable technology of uranium thermal annealing, which is carried out either in vacuum, or in inert atmosphere.

The experiments demonstrated that after thermo-vacuum annealing under plus 600ºC uranium became stable to all types of oxidizing corrosion in the atmosphere. Moreover uranium was stable in such aggressive media, as in water vapor without oxygen [8].

Uranium resistance to oxidizing after thermovacuum annealing is limited by temperature plus 80º. If the temperature is higher than plus 150-160ºC there is no difference in corrosion rates of ordinary and thermo-annealed uranium.

Corosion protection of active zones of neutron reactors

The greatest difficulties are caused when enriched uranium heated up to 500ºC needs anticorrosion protection. In this case various metal coatings are not reliable because of brittle intermetallide formation.

The reliable protection may be provided only up to the temperature plus 400 - 500º C with the help of galvanic copper coating since intermetallides are not formed in this case.(to compare: Ni intermetallides are formed at temperature plus 300 - 350ºC).

If temperature does not exceed plus 80ºC, thermovacuum aneeling is acceptable. at temperature plus 600ºC provides high stability of uranium surface to all kinds of oxidizing corrosion in air.

Keywords : uranium corrosion, protection, galvanic coating, thermo-vacuum annealing.