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PECULARITIES OF MECHANICAL PROPERTIES OF HIGH-PURITY, IODIDE AND HAFNIUM GFE-1 IN TEMPERATURE RANGE 20-900°C

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Here is given the results of investigation of mechanical properties of high-purity hafnium, iodide hafnium and hafnium GFE-1 at temperature range 20-900°C. Taken results are testifying about considerable influence of methods of receiving hafnium, its purity and mechanical-thermal processing on mechanical properties. The characteristic abnormalities of mechanical properties in the temperature range 20-900°C for different purity hafnium are discussed.
KEY WORDS: hafnium, impurities, mechanical properties

ОСОБЛИВОСТІ МЕХАНІЧЧНИХ ВЛАСТИВОСТЕЙ ВИСОКОЧИСТОГО , ЙОДИДНОГО ТА ГАФНІЮ ГФЕ-1 В ІНТЕРВАЛІ ТЕМПЕРАТУР 20-900°С

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Представлено результати досліджень механічних властивостей високочистого, йодидного та гафнію ГФЕ-1 в інтервалі температур 20-900°С. Отримані результати свідчать про значний вплив засобів отримання гафнію, його чистоти та механіко-технологічної обробки на механічні властивості гафнію. Проводиться обговорення характерних аномалій механічних властивостей гафнію різної чистоти в інтервалі температур 20-900°С.
КЛЮЧОВІ СЛОВА: гафній, механічні властивості, домішки

ОСОБЕННОСТИ МЕХАНИЧЕСКИХ СВОЙСТВ ВЫСОКОЧИСТОГО , ИОДИДНОГО И ГАФНИЯ ГФЭ-1 В ИНТЕРВАЛЕ ТЕМПЕРАТУР 20-900°С

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Приведены результаты исследования механических свойств высокочистого, иодидного и гафния ГФЭ-1 в интервале температур 20-900°С. Полученные результаты свидетельствуют о значительном влиянии способов получения гафния, его чистоты и механико-термической обработки на механические свойства гафния. Проводится обсуждение характерных аномалий механических свойств гафния различной чистоты в интервале температур 20-900°С.
КЛЮЧЕВЫЕ СЛОВА: гафний, механические свойства, примеси

Recently, hafnium finds wide application in nuclear engineering, as structural material for VVER-1000 reactors and other types. A number of studies emphasize the effect of impurities, conditions and type of mechanical and heat treatment on the mechanical properties, structure, and texture of products from hafnium [1-3].

The purpose work was the study of peculiarities of mechanical properties of three types of hafnium: hafnium HFEs -1, the purity of which corresponded to TU U 14312708183-95 [1]; iodide hafnium [2] and high-purity [3], obtained by refining iodide hafnium method zone melting in high vacuum with electron beam heating, which significantly reduce the content of impurities (Table).

METHODS AND RESULTS OF INVESTIGATIONS

Fig.1 shows that even the most difficult cleaning hafnium from very similar chemical properties of zirconium has allowed to reduce the concentration of zirconium from 0,1% to 0,065% [3].

To obtain samples from hafnium HFEs -1 was used calcium thermal hafnium Ukrainian production. The original ingots was exposed to the beam remitting with subsequent hot forging, rolling and annealing in vacuum at 900°C.

For the study of mechanical properties of the plates EDM way cut out the samples with dimensions of working part 5×3×23 mm along and across the direction of rolling. Tensile test was conducted at facilities Instron-5581 at 20°C and 1246P-2/2300 in the temperature range 20-900°C in vacuum, in accordance with the requirements of GOST 9651-84 and GOST 1497-84.

The study of mechanical properties iodide hafnium was conducted on micro-samples with the size of the working part 1.2×2.0×15.0 mm, obtained from laminated in the longitudinal direction of ingots in strips of a thickness of

1.2 mm.

Tensile testing of high-purity hafnium was conducted on flat samples with dimensions of the working part 2.2×0.9×8.0 mm.

Table

The chemical composition of high-purity hafnium and hafnium GEF-1.

№	Element	The content of impurities, wt.%		
		Iodide Hafnium	High-purity Hafnium	Hafnium HFE-1
1	Hf	99.72	99.88	98.84
2	Zr	0.1	0.065	1.0
3	N	0.003	0.0012	0.005
4	Al	0.003	0.000025	0.005
5	W	0.0002	0.0001	-
6	Fe	0.007	0.000067	0.004
7	Ca	0.01	0.000007	-
8	O	0.028	0.021	0.05
9	Si	0.004	0.00068	0.005
10	Mg	0.0003	0.000005	0.004
11	Mn	0.0003	0.00001	0.0005
12	Cu	0.0002	0.000020	0.0005
13	Mo	0.07	0.00010	0.01
14	Ni	0.01	0.00015	0.02
15	Nb	0.006	0.00004	-
16	Ti	0.003	0.00003	0.005
17	C	0.03	0.027	0.01
18	Cr	0.003	0.000025	0.003

The results of tests of mechanical properties of hafnium in the temperature range 20-900°C presented in Fig. 1 and Fig. 2.

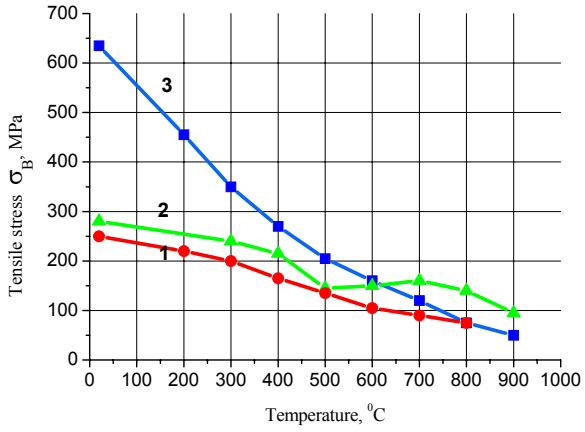

Fig.1. Temperature dependencies of strength properties of high-purity hafnium (1), hafnium iodide (2) and hafnium HFE-1 (3).

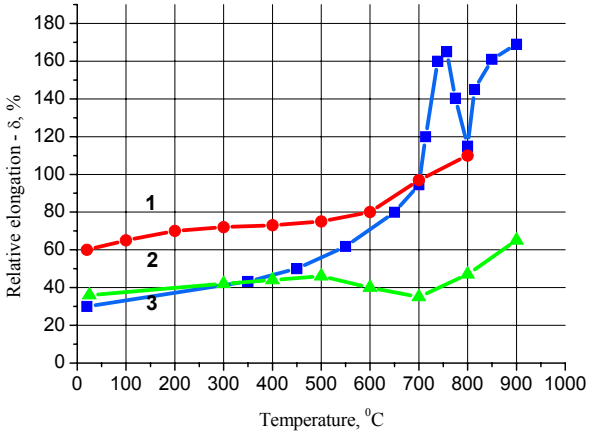

Fig.2. Temperature dependencies of plastic properties of high-purity hafnium (1), hafnium iodide (2) and hafnium HFE-1 (3).

For hafnium HFE-1the temperature dependence $\sigma_B(T)$ is characterized by a gradual decrease in strength with the temperature in the whole temperature interval from 20 to 900°C. For dependencies $\delta(T)$ smooth growth is only up to a temperature ~600°C, after which there is significant (abnormal) growth of $\delta(T)$, reaching a maximum value δ=160% at 750°C.

The temperature dependencies of strength and plastic properties for iodide hafnium characterized by the presence of anomalies in the temperature range 600-800°C, in which the failure of plasticity and increasing strength properties, peaking at 700°C. In addition, iodide hafnium manifested teeth nature of the curves stretch in the temperature range 600-800°C [2].

The results show that the strength $\sigma_B(T)$ decreases, and the plasticity $\delta(T)$ increases in the whole temperature interval 20-900°C without showing anomalous phenomena characteristic of iodide hafnium [2].

You can also note the lack of serration on curves stretch of high-purity hafnium and no maximum plasticity in the temperature range of 700 – 800°C, manifested for hafnium HFEs – 1.

DISCUSSION

The results indicate a significant influence of ways hafnium, its cleanliness and the subsequent mechanical and thermal processing on the mechanical properties of hafnium. In work [1] studied in detail microstructural features plates of hafnium HFEs-1 after rolling and annealing at a temperature of 900°C within 2 hours. Using scanning electron microscopy revealed the link between the test temperature, the nature of destruction and plasticity of hafnium. For example, if 20°C characteristics of plasticity for longitudinal rolling on 30% above, than at cross rolling. From the analysis of the received pole figures (0002) and (1010) α-phase hafnium, it follows that the deformation of the rolling at 850°C texture creates a high anisotropy, which may be due to the implementation of different mechanisms of plastic deformation.

It features plastic characteristics of hafnium HFE-1 at elevated temperatures can be attributed to a significant increase of plasticity in the temperature range of 700 - 900°C with a maximum δ(T) at 750°C where elongation up to 160%.This increase plasticity can be due manifested in this area temperature relaxation processes on the grain boundaries, which play a significant role in the development of superplasticity. The phenomenon of superplasticity is associated with the transition of grain boundaries in particular structurally unstable highly activated liquid like state, which can easily be ductile intergranular slip [5]. Such slippage is one of the main mechanisms of superplastic deformation, and its contribution to the total deformation exceeds 50% [4]. This effect is also confirmed by the presence of high internal friction for hafnium at this temperature. About the connection of superplasticity and growth of internal friction in the area of temperature grain boundary of the maximum of $Q^{-1}(T)$ research in [6]. Distinctive features of the mechanical properties of hafnium iodide is a manifestation of the temperature anomalies in the region of 600 to 800° C, where there is a failure of plasticity and strength increase with a maximum at a temperature of 700°C. The curves stretching "stress - strain" there is aliasing due to strain aging (effect of Portevin-Le Chatelier's principle) [7].

The reasons of failures of plasticity are complex and explanations are only hypothetically. The main reason for the anomalous effects, according to the authors [2], is the presence of impurities.

For high-purity hafnium may be noted the absence of anomalies in the temperature dependences $\sigma_B(T)$ and δ(T) within the temperature range of 20 to 800°C, and the lack of serration on the charts stretching. Purification of hafnium iodide contributes to a reduction in strength and increase ductility in the range of 700 - 800°C (typical for HFEs-1).

CONCLUSIONS

Thus, the results of the study of mechanical properties of hafnium show the complex nature of the influence of various factors on the deformation characteristics in the temperature range 20 - 800°C and noted the role of increasing purity hafnium in suppressing characteristic anomalies occurring during deformation iodide-containing hafnium and hafnium HFEs-1.

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