распределение фаз с заданным стехиометрическим составом, возможность активно влиять на размер и морфологию частиц, низкие энерго- и трудозатраты.

В работе представлены результаты исследований процесса плазмохимического синтеза СОК из диспергированных растворов ВОНР, включающих ацетон и смешанные водные нитратные растворы неодима (вместо урана), самария (вместо плутония) и магния.

Подготовленные растворы ВОНР подавались (300 л/час) через диспергатор в реактор плазменного модуля на базе ВЧФ-плазмотрона, где в воздушно-плазменном потоке при температурах ≥1000°С осуществлялся синтез СОК, затем в узле «мокрой» очистки происходило их резкое охлаждение («закалка») с образованием водных суспензий, которые отстаивали, фильтровали и прокаливали в течение 20 минут при температуре 150 °С.

В ходе исследований проводились лазерная дифракция водных суспензий СОК, сканирующая электронная микроскопия, БЭТ-анализ и рентгенофазовый анализ полученных порошков.

Установлено, что при расходе воды на «закалку», частоте диспергатора (50 Гц) и различных α = Sm/(Sm+Nd) увеличение доли матрицы в виде Y_2O_3 (10…30 %) в составе СОК «Nd_2O_3-Sm_2O_3-Y_2O_3» приводит:

- (при α = 0,1) к снижению размера частиц водных суспензий СОК с 12,1 мкм до 4,3 мкм, увеличению Sуд порошков СОК с 5,5 до 7,8 $м^2/г$ и снижению размера «зерен» в СОК с 147 нм до 115 нм;
- (при α = 0,3) к снижению размера частиц водных суспензий СОК с 13,6 мкм до 10,2 мкм, увеличению Sуд порошков СОК с 6,9 до 8,6 $м^2/г$ и снижению размера «зерен» в СОК с 118 нм до 93 нм;

Это позволяет утверждать, что плазменная переработка диспергированных растворов ВОНР в воздушно-плазменном потоке приводит к плазмохимическому синтезу наноразмерных СОК.

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SYNTHESIS OF OXIDE POWDERS FOR NUCLEAR FUEL IN PLASMA OF TORCH DISCHARGE

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Ceramic nuclear fuel made of UO_2 has a number of disadvantages: low thermal conductivity, high brittleness, tendency to crack, a short cycle of use, and a limited resource of the ^{235}U [1]. This has caused a slowdown in the development of nuclear energy in a number of countries.

A promising today is the creation of dispersion nuclear fuel, which is characterized by the absence of contacts between particles of fissile material due to their uniform distribution in the matrix and has the following advantages: high thermal conductivity and good mechanical properties, high enough fissile material burn, high radiation resistance and strength, localization of fission products in matrix [2].

Common disadvantages of the technologies used to obtain complex oxide compositions from solutions (usually nitric-acid) are: multi-staging, high cost of processing raw materials, inhomogeneous phase distribution, the need to use much chemicals.

At the same time, the technology of synthesis of oxides in air plasma has the following advantages: one-staging, homogeneous distribution of phases with a given stoichiometric composition, the ability to actively influence the size and morphology of particles [3, 4].

It should be noted that the processing of nitric-acid solutions in plasma is quite expensive. To reduce energy consumption, it needs to add any organic component into the solutions, which, when oxidizing in the air plasma, creates additional energy, allowing to increase the consumption of the processed solution and, thus, increase the yield of the target product.

The work represents carried out thermodynamic modeling of plasmachemical synthesis of complex oxide compositions from water-organic nitrate solutions (WONS), consisting of fissile material (inclusion) and matrix. Uranium dioxide was considered as a fissile inclusion, and magnesium oxide as the matrix material, acetone were used as organic component. The proportion of fuel inclusion in the target complex oxide composition was selected within the range of 95% – 85%, the proportion of the matrix within 5% – 15%.

Based on the modeling results, the optimal WONS based on uranyl nitrate, magnesium nitrate and acetone were calculated, and the optimal modes (WONS–air ratios) of the WONS plasma treatment were calculated. It was shown that with an excess of air, non-target products (UO_3, U_3O_8, U_4O_9) are formed from the initial solutions, with a deficiency of air – products of incomplete thermal decomposition of hydrocarbons in WONS (soot). It was shown that the optimal air fraction varied in the range of 69% – 71%.

The results of the studies can be used to calculate the plasmachemical synthesis of complex oxide compositions for dispersion nuclear fuel.

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COMPARISON OF Y_2O_3 AND ZrO_2 SYNTHESIZED FROM WATER NITRATE SOLUTIONS AND WATER-ORGANIC NITRATE SOLUTIONS

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One of the priorities in the development of modern material science is the technology based on nanosized powders, which is due to the desire for miniaturization of products, unique properties of materials in the nanostructured state, etc.

The most common technologies for producing such nanosized oxides are laser sublimation, chemical precipitation from solutions, hydrothermal method and sol-gel technology. Each method has its advantages and disadvantages, while the choice of technology is determined by the purpose of the powder, the state of its microstructure, method performance, complexity and cost of the equipment used. The disadvantages of the methods used to obtain nanosized powders include: multi-staging, long process duration, low productivity, the need to use a large number of chemicals, non-uniform distribution of phases in the powders, and high cost.

Taking into account above, the use of low-temperature plasma is promising for obtaining nanosized metal oxide powders. The advantages of plasma-chemical synthesis from water nitrate solutions (WNS) include: one-staging, high process speed, homogeneous phase distribution with a given stoichiometric composition, the ability to actively influence the size and morphology of particles, and the compactness of technological equipment. However, plasma treatment of only WNS due to high energy costs (up to 4.0 kW·h/ g) [1] is not widely used, and it is possible to significantly reduce energy consumption and increase productivity by introducing an organic component in the composition of the initial WNS.

Firstly, the optimal compositions of water-organic nitrate solutions (WONS) based on acetone and WNS $Y(NO_3)_3$, as well as acetone and WNS $ZrO(NO_3)_2$ were calculated. For this, the values of lower calorific value were determined for various mass fractions of acetone in WONS. Secondly, in order to determine the optimal modes of the process under study, the influence of the mass fraction of the air plasma coolant on the adiabatic combustion temperature of WONS was determined.

The studies were carried out using plasma module based on the high-frequency generator. For plasma treatment, WONS-1 and WONS-2 were prepared according to the optimal compositions determined for them, while the concentration of $Y(NO_3)_3$ and $ZrO(NO_3)_2$ salts was 97 g/100 ml of water and 57 g/100 ml of water, respectively. The prepared solutions were processed in a high-frequency torch plasma. During the plasma treatment, after liquid evaporation and crystallization of the salt, yttrium and zirconium oxides were formed as a result of thermolysis, which were quenched in centrifugal bubblers. The obtained oxide powders were sent for analysis.

To study the main parameters of the obtained powders, scanning electron microscopy, BET analysis, and X-ray phase analysis were performed. The obtained results were compared with data [3] on the parameters of yttrium and zirconium oxide powders obtained by plasma-chemical synthesis from WNS (without the addition of an organic component). From the analysis of the presented data, it follows that the powders obtained by plasma-chemical synthesis from WONS-1 and WONS-2 are comparable in a number of parameters (CSR size, specific surface area) with powders obtained by plasma-chemical synthesis from WNS solutions. However, zirconia powders obtained by plasma-chemical synthesis from a WONS-2 solution are in the tetragonal and cubic phases, and obtained from WNS in the monoclinic phase, which is explained by the use of quenching in the first case. In this case, the inclusion of the organic component in the composition of the WNS leads to an increase in powder productivity by 2.5–4 times and a decrease in energy consumption for producing 1 kg of nanosized powders by 5–8 times.