STUDY OF STRUCTURE AND PHYSICAL AND MECHANICAL PROPERTIES OF CERAMICS BASED ON ALUMINUM OXINITRIDE

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ИССЛЕДОВАНИЕ СТРУКТУРЫ И ФИЗИКО-МЕХАНИЧЕСКИХ СВОЙСТВ КЕРАМИКИ НА ОСНОВЕ ОКСИНИТРИДА АЛЮМИНИЯ

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Аннотация. *Проведен синтез оксинитрида алюминия путем сжигания нанопорошка Al в воздушной атмосфере. Полученный продукт обрабатывали в планетарной мельнице с целью измельчения и повышения однородности смеси. Разработана технология производства высокоплотной прочной оксинитридной керамики, которая включает синтез порошка* Al_2O_3*-AlN-AlON и последующее горячее прессование в инертной атмосфере. Полученная керамика имела следующие физические и механические свойства:* E_{IT} *= 286,5 ГПа,* H_{IT} *= 13,2 ГПа, σ = 602 МПа.*

Introduction. Aluminum oxynitride is an aluminum compound of oxygen and nitrogen which is described by the formula $Al_{23}O_{27}N_5$ [1, 2]. This compound was synthesized relatively recently - in the 50's last century. At present ceramics from aluminum oxynitride are tried to be obtained using different technological methods [3].

Liquid-phase synthesis is carried out using the ultrasonic spray pyrolysis method. In this case, the process of synthesis of aluminum oxynitride powders using organic compounds included controlled thermal destruction of the mixture of components with further crystallization of the product obtained at temperatures of 900-1350 ° C [4].

The third method consists in sintering a mixture of Al_2O_3 and AlN powders (40:60) with activation of the sintering process under pressure. Powders prepared by the method of plasma-chemical synthesis were used as starting materials [5].

Experimental part. Nanopowder Al (NP), obtained by the method of plasmachemical synthesis (PCC), was burned in an air atmosphere. As a result of self-propagating high-temperature synthesis (SHS), a product containing Al_2O_3, AlN and AlON was obtained.

For grinding, increasing homogeneity and technological characteristics, the combustion product was processed in a planetary ball mill "Activator 2SL" for 20 minutes at a rotational speed of grinding vessels of 30 Hz. As milling bodies were used zirconium balls.

The granulometric composition of the powder was analyzed using a microscope "secant" method, and the "Jenaval" microscope was used. This method determines the dimensions of only those particles that intersected by the line of the eyepiece micrometer of the microscope, while the linear dimensions of the "cross sections" of the particles are recorded.

Figure 1 shows the distribution diagram of the powder mixture particles by their size.

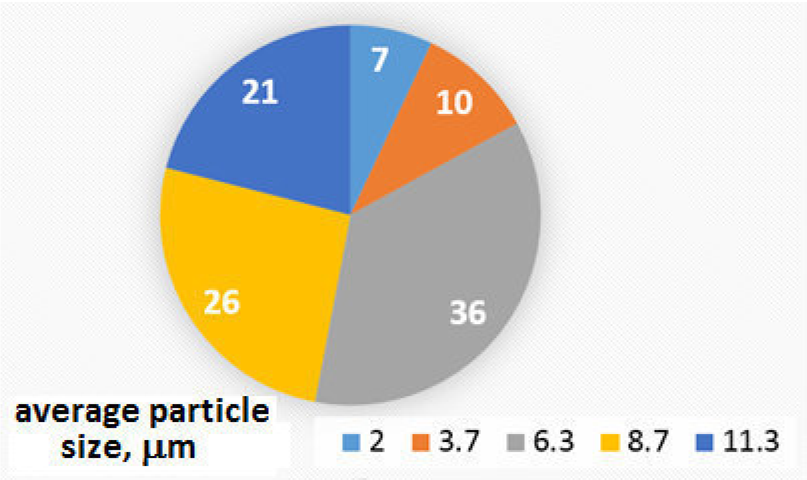

Fig. 1. Diagram of the distribution of particles of a powder mixture of Al_2O_3-AlN-AlON by their dimensions

The relative density of the samples Θ was also calculated in accordance with the formula:

$$\theta=\frac{\rho}{\rho_т}\cdot 100\ \%\ ,$$

where $\rho_т$ is the theoretical density of the ceramic.

Samples were polished with diamond pastes, the obtained microsections were examined using the “Labomet-M” microscopic complex.

The indentation was carried out with the instrument Nano Indenter G 200. The Berkovich pyramid was used as an indenter, the load was 500 mN (50 g). The device design allows displaying the diagram of the displacement of indenter into surface of the samples on the monitor in real time. The strength of the sintered ceramics was determined using the Scratch-Testing technique also with the Nano Indenter G 200. The method consists in applying on a controlled surface a scratch of a specified length of 200 µm under the action of a linearly increasing load (from 0 to 4 g), and then determining the depth and width of the scratch profile. The strength of the samples was calculated from formulas:

$$\sigma=\frac{F_n}{A_s \sin\alpha}\quad и\ A_s=\frac{a^2}{2\sqrt{3}\sin\alpha}+\frac{ah}{\cos\alpha},$$

where F_n is the normal load, A_s is the projection area of the print from the Berkovich pyramid, a and h are the width and depth of the scratch profile at a distance of 200 µm, respectively, α is the angle for the Berkovich pyramid of 65 °.

Table 1 shows the physical and mechanical characteristics of sintered ceramics.

Table 1

Physical and mechanical characteristics of oxynitride ceramics Al_2O_3 – AlN - AlON

Relative density Θ, %	Young's modulus E_{IT}, MPa	Nanohardness H_{IT}, MPa	Strength σ, MPa
97	286537	13160	602

Figure 2 shows photography of the microstructure of oxynitride ceramics. Aluminum nitride is a light component, the dark constituent, obviously, is aluminum oxynitride.

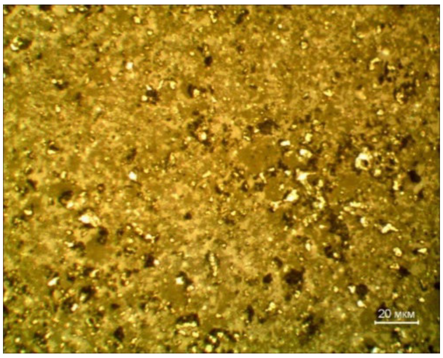

Fig. 2. Photo of the microstructure of hot-pressed ceramics based on aluminum oxynitride

Conclusion. In the course of the work, aluminum oxynitride was synthesized by burning the plasma-chemical nanopowder Al in an air atmosphere to obtain a mixture of Al_2O_3, AlN, AlO_xN_y. The resulting mixture was processed in a planetary mill in order to grind and increase the homogeneity of the mixture. The granulometric composition of the powders was determined microscopically, it was shown that the powder mixture is mainly represented by particles whose size varies within the range of 6.3 ... 11.3 μm.

A technology has been developed for the production of high-density strong oxynitride ceramics, which includes the synthesis of Al_2O_3-AlN powder by burning NP Al and subsequent hot pressing in an inert atmosphere. The resulting ceramics had the following physical and mechanical characteristics: E_{IT}=286537 MPa, H_{IT}=13160 MPa, σ=602 MPa.

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