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SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS OF HIGH-TEMPERATURE LIGHT REFRACTORIES

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Data on the synthesis of light high-temperature refractories of various compositions in the SHS regime are presented. Optimum conditions for the synthesis are determined; the physicochemical properties of the refractories produced are studied.

Light refractory materials are of great importance in modern engineering, mainly as heat insulation and thermal protection. The ceramic industry currently produces refractories withstanding a maximum temperature of 1700°C. However there are fields of application for refractories, for example, in constructing aircraft, where high resistance in an oxidizing atmosphere at elevated temperatures (2400°C), strength, wear resistance, low thermal conductivity, and lightness of the material are required.

The aim of the given work is to obtain high temperature light refractories in the combustion regime (SHS technology), i.e., a promising technology for developing new high-melting products. Organizing the production of technical ceramics by the SHS method does not involve high energy consumption. This method also has other advantages, such as simplicity of the equipment, rapidness of the process, high productivity of the method, and purity of the products.

Since we needed to produce light high-temperature ceramics ($T = 2400$°C) using SHS synthesis, for the investigations we chose the following refractory oxides: MgO, $T_m = 2800$°C; ZrO_2, $T_m = 2700$°C; Cr_2O_3, $T_m = 2340$°C. Ceramics based on spinels, in particular, on the magnesian spinel $MgAl_2O_4$ ($T_m = 2135$°C) and the chromium spinel $MgCr_2O_4$ ($T_m = 2350$°C), also have high refractoriness. The above led us to choose the compositions for producing highly refractory ceramics. For an MgO-based refractory the limiting values of the oxidizer, the reductant, and the filler are determined. The components are chosen taking into account the highly refractory alumomagnesian spinel-based materials formed in them during the solid-phase process of mixture combustion. The porous structure of the refractory material is formed by several processes. Using a mixed reductant in the composition contributes to formation of a white refractory material with reflectivity close to unity. The heat-insulating properties are improved by decreasing the thermal conductivity, which, in turn, is changed by varying the ratio of the mixture components and the conditions of forming and synthesis. On the basis of ZrO_2 we prepared a system in which we used MgO as a stabilizer to prevent cracking of the ceramics. It was of interest to produce refractory ceramics based on Cr_2O_3 in combination with other refractory oxides. The optimum composition of the mixture was established, the basic phases of the synthesized ceramics being $MgCr_2O_4$, $MgAlCrO_4$, and MgO, which impart high refractoriness to this system.

To produce refractories with high physicomechanical characteristics, we studied the influence of compacting pressure (2.5-15 MPa). The investigations were carried out on the basis of the above compositions of the initial mixture. For example, as the compacting pressure increases, the density increases. In parallel with this the linear burning rate of the specimens decreases. Porosity and strength as functions of compacting pressure are also studied. It was established that as the compacting pressure increases, the specimen strength increases, and the porosity decreasing correspondingly.

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Use of binders can also contribute to the hardening of refractories. However, in this case an extremal character of the dependence on the impurity concentration can be observed.

The refractory specimens synthesized on the basis of a sulfate mixture were machined: drilled, turned, and milled. These operations are performed qualitatively at 3000 rpm. The reflectivity was measured on an SF-18 instrument. The specimens reflect in the region 400-500 nm. For white ceramics the reflectivity approaches unity; the emissivity is about zero. The linear thermal expansion coefficient is from $1.148 \cdot 10^{-5}$ to $9.725 \cdot 10^{-6}$ K^{-1}. The measurement was carried out in the interval 25-1250°C; the heating rate was 10 K/sec. The refractoriness was from 1900 to 2200°C.

The water absorption of the specimens was determined according to All-Union State Standard (GOST) 2409-80 and was from 60.1 to 80%. Thus, we selected the optimum mixture composition and the conditions for synthesizing refractories based on magnesium, zirconium, chromium, and spinelides. The light refractories produced have an apparent density of 0.6-1.3 g/cm^3, a porosity of 60-90%, a compressive strength up to 18 MPa, and a bending strength of 20-120 MPa. We studied the influence of the mixture particle dimensions, the compacting pressure, the mixture heating temperature, the organic and inorganic binders, and the burning additions on the physicochemical characteristics of the refractory materials: porosity, gas permeability, thermal conductivity (1.1-1.9 $W/m \cdot K$), the coefficient of linear thermal expansion ($1.15 \cdot 10^{-5}$ - $9.7 \cdot 10^{-6}$ K^{-1}), and heat resistance.

The familiar methods of producing refractories that are stable in an oxidizing atmosphere at high temperatures are noted for high power intensity and long processes. The SHS method is promising in this respect. The important feature of the SHS method is the possibility of controlling the physicochemical characteristics and producing refractories of a specified shape. The basic SHS products are refractory spinels and oxides. SHS ceramics based on magnium and chromium oxides are the most promising for producing refractories with a working temperature of 2200°C. The chemical composition of the refractories is established by X-ray phase analysis. Layered ceramics for increased bending strength are synthesized. The influence of fibers on strength is studied. Plasma and laser treatment of the surface is performed. The optimum synthesis conditions are selected for variously shaped specimens, plates, products of intricate shape, etc. The influence of different factors on the composition homogeneity and the reproducibility of results is studied.

Thus, the given work pioneered the production of light refractory ceramics, having a melting temperature up to 2200°C in an oxidizing atmosphere, by the SHS method.