REGULARITIES OF THE CHANGE IN THE PHYSICOMECHANICAL PROPERTIES IN THE Cr_2O_3-Al SYSTEM IN ACCORDANCE WITH THE SHS CONDITIONS

T. V. Chernoglazova, A. N. Baidel'dinova, and N. S. Sharipova*

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Based on a comprehensive study of combustion processes and variation of the phase composition and the structure of synthesized materials of the Cr_2O_3-Al system in a wide range of compositions, we established the regularities of the change in their physicomechanical properties and selected the optimal conditions for producing cermets and abrasives with high strength properties.

Physicomechanical properties of materials are governed by their phase composition and structure, which, with the SHS procedure, are formed at high temperatures and rates, which permits the production of materials with a unique combination of properties. For example, "rose corundum," synthesized from a Cr_2O_3-Al mixture of stoichiometric composition, has improved strength characteristics in comparison with corundum and chromium (III) oxide, widely used in industry [1].

In the current study the regularities of the change in the physicomechanical properties of products of SH synthesis in accordance with its conditions are considered, taking a Cr_2O_3-Al mixture of variable composition as a case in point.

The Al content and the compression pressure were varied over a wide range, and the heating temperature of the mixture T_h was varied from 25 to 1000°C. The self-ignition temperature changed from 850 to 1000°C here, and the SHS for lower values of T_h was initiated by a Nichrome spiral.

The SHS products for all considered compositions differ from the products of the reaction of alumothermal reduction of chromium (III) oxide

$$Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3 .$$

These are metallic chromium, a series of variable-composition Cr_2O_3-Al_2O_3 solid solutions, the intermetallides Al_2Cr, Al_2Cr_3, and $Al_{17}Cr_9$, and a certain amount of the initial Cr_2O_3. The SHS completeness and the amount of each phase are determined by the temperature in the combustion zone T_c and the process rate, which depend both on the Al content in the mixture C_{Al} and on T_h, i.e., on the relationship between the heat release and the heat loss to the surroundings. With increasing C_{Al} and T_h, the temperature T_c and the propagation rate of the combustion front rise, whereas the width of the synthesis zone decreases (Fig. 1).

A change in the combustion characteristics affects the phase composition of the synthesized materials. The amount of chromium and solid Cr_2O_3 solutions based on Al_2O_3 increases, their number is reduced from 4 to 2, the intermetallide content decreases and vanishes, and the initial Cr_2O_3 is absent. At $T_h = 1000$°C, there is self-ignition of all mixture compositions and the SHS proceeds under conditions maximally approaching adiabatic. At a certain

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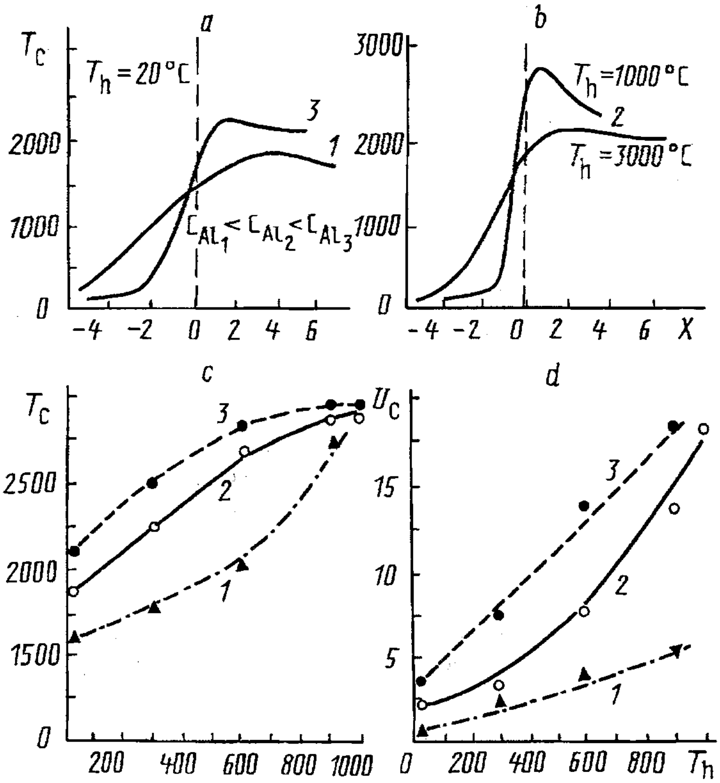

Fig. 1. Combustion characteristics of the Cr_2O_3-Al system for compositions with various Al contents: temperature profiles (a, b) and the combustion temperature (c) and the propagation rate of the combustion wave (d) as functions of the heating temperature. T_c, T_h, °C; X, mm; U_c, mm/sec.

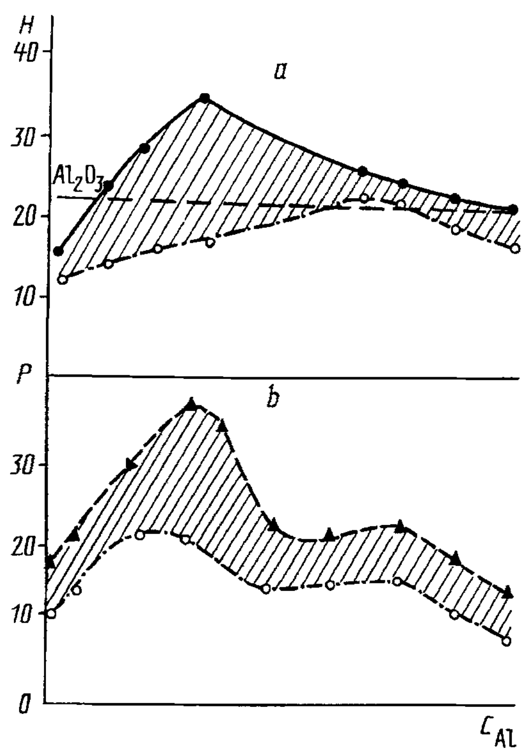

Fig. 2. Change in the microhardness H, GPa (a), and the grain strength P, kg (b), of synthesized materials as a function of the mixture composition (wt. %) at various compression pressures.

amount of Al, the specimen loses its shape, and phase separation occurs: metallic chromium flows down to the lower part, and the upper oxide part consists of two fused solid solutions.

The microhardness, strength, and abrasive capacity for all produced materials are determined, on whose basis the optimal synthesis conditions are selected.

It is clear from Fig. 2a that the dependence of the microhardness of the synthesized materials on the mixture composition and density passes through a maximum, in accordance with Kurnakov's rule. The microhardness of the basic phase attains 37 GPa, which at the level of values for boron carbide and is 1.7 times larger than the value for a corundum single crystal [2]. This is attributable to an increase in the activity of the interacting components. First, plastic deformation of crystals of both the oxidizer and the reducer causes a rise in the concentration of various types of defects, ensuring favorable conditions for diffusional movement of the metal and oxygen ions. Second, due to closer contact, the rate and completeness of the metallothermal reaction increase and higher temperatures are attained, cooling from which at a higher rate (100 deg/min) sets up nonequilibrium crystallization conditions, thus leading to structure dispersion. The sizes of blocks of coherent scattering diminish from 180 to 145 Å and from 635 to 346 Å for here solid solutions I and II, respectively. A consequence of the highly disperse plastic state of the material is low values of the crack resistance coefficients $k_{1c} = 0.5 + 1.6$ GPa/m$^{3/2}$, too.

The strength properties were assessed from the cracking load of abrasive grains, whose value for all the investigated grains is larger than that for diamond grains equivalent in size [3]. It is seen from Fig. 2b that there are two maxima on the curve: the first is related to high plasticity of the cermet grains and the second, to a more disperse structure of the oxide component.

High strength properties also reflect on the abrasive capacity which exceeds that for electrocorundum by 1.6 times and is close to the value for titanium carbide [4].

CONCLUSIONS

1. The course of SHS in the Cr_2O_3-Al system depends on its performance conditions, whose change allows the physicomechanical properties of the synthesized materials to be changed over a wide range.

2. Optimal conditions for SHS in the Cr_2O_3-Al system that permit the production of high-strength cermets and abrasives are found.

NOTATION

T_h, heating temperature of the mixture; C_{Al}, aluminum content in the mixture; T_c, combustion temperature; k, crack resistance coefficient.

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