The study of ceramic materials system SiC-YAG

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Abstract. Dense ceramic materials based on SiC with an oxide activating additive YAG by hot pressing at a temperature of 1850 °C were obtained. The oxides, melting, fill the space between the SiC particles, contributing to the compaction and mass transfer of the material in the process of hot pressing. It is shown that for a high compaction of the SiC – YAG material, a small amount of oxides is necessary - 9 wt. %

1. Introduction
SiC based ceramics find reaching use in technology and manufacturing applications. This is due to many of its key properties. In Structural applications, take advantage of its high hardness, high stiffness, low density, and low coefficient of thermal expansion. High temperature and thermal applications take advantage of the phase stability and high thermal conductivity. Since SiC is a semi-conductor, its electronic properties can be adjusted. Polycrystalline SiC based ceramics could find broader use if they could be machined easier by rendering them more electrically conductive. Higher conductively enables efficient electro-discharge machining (EDM) of complex shapes. Strength enhancement would allow for competition with structural Si3N4 based applications [1-3].

Solid-state junctions of carbide ceramics with platinum-group metals are relevant in a variety of areas of materials technology, including microelectronics, ceramic joining technology, metal–ceramic composites. Chemical interactions between the metal and ceramic layers in many applications can be an important consideration, acutely affecting the microstructure, properties, and performance of a particular system [4-5].

The functionality of the material is determined not only by its fundamental properties, but also by the correctness of the choice of initial components and technologies of their combination [6]. To obtain materials based on silicon carbide use a large number of sintering additives [7-11]. One of the most commonly used additives is Y2O3 - Al2O3, which at the sintering stage forms yttrium aluminum garnet [12].

Recently, in several papers [13-16], it was shown that α- and β-SiC powders, when adding Al2O3 and Y2O3, are compacted by the liquid-phase sintering mechanism at a relatively low temperature of 1850-2000 °C. In the Y2O3-Al2O3 system 3 modifications were recorded:

- 3Y2O3-5Al2O3 (garnet phase) of the cubic syngony;
- Y2O3-Al2O3 (perovskite phase) of the orthorhombic system;
- the monoclinic phase 2Y2O3-Al2O3.

In the present work, the physicomechanical properties of materials based on SiC, obtained by hot pressing in argon with sintering additive Y2O3-Al2O3, were investigated.
2. Experimental procedure
In this work, SiC powders were used to create the material:
- SiC-1, Chernogolovka, ISMAN RAS, grain size: 1 micron;
- SiC-2, St. Petersburg, mark M5, grain size: 1 micron.

To the initial powders of silicon carbide was added sintering additive in the amount of 9 wt.%, consisting of oxides Y2O3 and Al2O3, in a quantitative ratio of 3.5 wt.% and 5.5 wt.% respectively. This additive allows obtaining more dense materials with a high level of mechanical properties and high crack resistance [17].

Table 1. Sintering additives in the composition

| Al2O3 | Y2O3 | Humidity | General content |
|-------|------|----------|----------------|
| 5.50 %| 3.50 %| 1 %      | 6 %            |

Sintering additive was obtained from Y2O3, Al (OH) 3 * 6H2O. Powders mixed wet method in the environment of isopropyl alcohol in a planetary mill, with a ratio material: balls - 1: 5 for 30 minutes. Then the powder was dried in an oven at a temperature of 80°C, and then it was sieved through a sieve with a mesh size of 63 μm. After then the mixture was placed in a muffle furnace for 4 hours with a temperature of 1000°C. Received oxide additive was added in the amount of 9 wt.% powders SiC-1 and SiC-2.

Two different compositions were prepared that differ in the type of silicon carbide. The original components were mixed in a planetary mill according to the technology outlined above. The finished powders are preformed into a roasting billet. The raw material is a disk with a diameter of 25 mm, the weight of the powder was 8 g. A dense material based on SiC and YAG was obtained at the Thermal Technology Inc. hot-pressing facility. model HP20-3560-20. Calcination was carried out in a graphite mold at a temperature of 1800, with an exposure time of 60 minutes, in argon medium. Unlike nitrogen, sintering in an argon atmosphere can reduce mass loss and grain growth [18]. The specific pressing pressure was 30 MPa.

Table 2. Compositions of different samples and processing conditions

| Designation | Composition, wt.% | Firing mode |
|-------------|-------------------|-------------|
| SiC-1       | 91                | T = 1850 °C, 60 min shutter speed, p = 30 MPa, in the Ar environment. |
| SiC-2       | 91                |             |

The density of the material was determined by hydrostatic weighing in water. The true density was calculated by the additivity rule. For bending tests, specimens were produced. The research were carried out on an Instron 3382 unit with a load cell of 100 kg. Microhardness was measured on a Wolpert Wilson Instruments 401/402-MVD unit with a load of 0.98 N.

3. Results and discussion
Investigations of the influence of the type of sintering additive in the composition on the mechanical properties of the material and the microstructure were carried out. Result are presented in Table 3.
Table 3. Mechanical properties of materials

| Composition | Firing mode | Bending stress, MPa | Microhardness, GPa | Density, g cm\(^{-3}\) |
|-------------|-------------|---------------------|--------------------|--------------------------|
| SiC-1       | T = 1850 °C, 60 min shutter speed, p = 30 MPa, in the Ar environment. | 495.7 | 29.4 | 3.23 |
| SiC-2       |             | 509.5 | 47.53 | 3.27 |

Flexural strength A sample of SiC-2 (St. Petersburg, M5, granule size: 1 μm) showed the best result - 509.5 MPa.

The SiC-2 sample (St. Petersburg, M5, granule size: 1 μm) has the best microhardness indicators - 47.5 GPa.

The resulting material has high rates of physico-mechanical characteristics. The best result was shown by a sample based on SiC-2 (M-5 grade, with a granule size of 1 μm) with an oxide additive YAG in the amount of 9 wt.%. \(\sigma = 509.5 \pm 10\) MPa, \(HV = 47.5 \pm 0\), 2GPa, \(\rho = 3.27 \pm 0.1\) g/cm\(^3\).

4. Conclusion

In the work, the physicomechanical properties of materials based on SiC, obtained by hot pressing in argon with sintering additive Y2O3 - Al2O3, were investigated. The optimal amount of the activating additive is 9% by mass, its decrease leads to incomplete wetting by oxides of the SiC surface and, as a result, to a decrease in mechanical properties. Increasing the concentration of the additive to 20% leads to a decrease in the hardness of the material.

Further studies will focus on studying the microstructure of the obtained samples, as well as the effect of temperature on the physical and mechanical properties of the samples.

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