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FEATURES OF PROCESSING SILICON CARBIDE AND LANTHANUM CHROMITE HEATERS ON A SOLAR FURNACE

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ABSTRACT

The possibility of using a concentrated flux of high-density solar radiation from the Large Solar Furnace (BSF) for the heat treatment of products made of silicon carbide and lanthanum chromite, which are resistive heaters for high-temperature electrothermy, has been studied. It is shown that the optical-energy parameters of the BSF make it possible to create a low-gradient (±300C) temperature field along the diameter (0.5 m) of the focal zone of the solar installation. Due to the absorption of the energy of concentrated solar radiation, the density of 150 - 200 W/cm^2 material is heated to a temperature of 1400 - 1700îC and the process of sintering of the ceramic product proceeds with a shrinkage of 8 - 10%. The mechanical and resistive characteristics of the materials processed in the solar furnace are close to the special Standard values. Thus, for silicon carbide material, the following values of compressive strength were obtained: 2100 MPa, and for lanthanum chromium material, 130 MPa. The electrical resistance-resistivity of the materials was 20 - 30 ohm cm for silicon carbide and 5 - 10 ohm cm for lanthanum chromite. The possibility of using solar heating for sintering products of heaters of electrothermal units is shown.

KEYWORDS: Processing Silicon Carbide, Lanthanum Chromite Heaters

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Original Article

INTRODUCTION

In modern electrothermy, high-temperature resistive heaters based on silicon carbide and lanthanum chromite are widely used, due to their extremely wide range of electrophysical, anti-corrosion and strength properties [1-3]. To obtain products from silicon carbide, the reaction sintering method is used, which allows the process to be carried out at lower temperatures, with the formation of non-porous materials containing 5–15% free silicon in the silicon carbide matrix. In addition, products from lanthanum chromite in the form of rods and pipes are obtained by sintering a mixture of lanthanum and chromium oxides in a stoichiometric ratio at a temperature of 1700°C [3-5].

As is known, synthesis in a stream of concentrated solar radiation has a strong effect on the defective structure of the structured material; thereby it will be possible to control the degree of defectiveness by varying the technological parameters of radiant heating [6–10]. The sun's rays are high-potential energy sources, since the apparent temperature of the sun's surface is about 5770 K, and its angular radius is quite small and is about 16 ang.min. It is these circumstances that create prerequisites for the use of mirror-concentrating systems in order to increase the flux density of direct solar radiation up to 10000 times and obtain high temperatures necessary for efficient absorption by the receiver and the implementation of technological processes (obtaining ultrapure materials and alloys, beam welding etc.) [11-13]. Two large ones in terms of thermal power (1000 kW), hence their name Big Solar Furnaces, were built in France and Uzbekistan. The functionality of such installations makes it possible to carry out in a wide range of flux density in a focal zone with a diameter of 0.7 m technological processes for producing hydrogen, laser radiation, materials of high purity and fine dispersion [14 - 20].

In this work, the possibility of using a concentrated solar radiation flux for sintering products of resistive heaters made of silicon carbide and lanthanum chromite is studied.

RESEARCH METHODOLOGY

For the manufacture of products from silicon carbide, the method of reaction sintering was used. To do this, a charge was made because of silicon and coke in a ratio of 1:2.3, mixing it with molten paraffin to obtain a slip mass. A preform of a certain shape was cast from the slurry under pressure.

Lanthanum chromite products were produced by semi-dry pressing based on a mixture of lanthanum and chromium oxides in a ratio of 2.13:1 with a binder of kaolin in an amount of 5 wt. % over 100 wt. %.

Figure 1 shows the technological scheme of the heater.

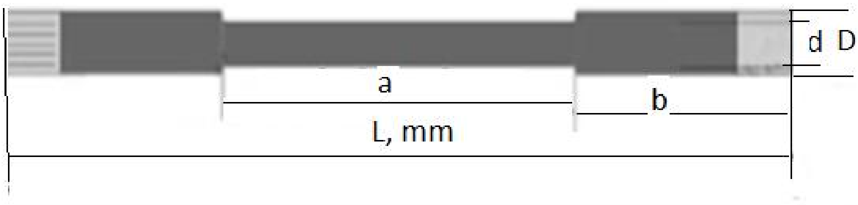

Figure 1: Technological Scheme of the Heater. d=12mm and D=16mm - small and large diameters, L=300mm - total length, a - heated zone, b - not heated zone

To determine the value of the flux density required for heating, we used the Stefan Boltzmann equation describing the radiation of heated bodies $Q = (1/\sigma)\varepsilon T4$, where ε- is the degree of emissivity (0.85 for silicon carbide and 0.90 for lanthanum chromite) σ=5.67x10-8 W/m^2K4 is a constant Stefan-Boltzmann. Calculations have shown that for heat treatment at 1800^0C silicon carbide materials require a flow density of 95-100 W/cm^2 and for lanthanum chromium materials 100-110 W/cm^2.

The hygrometric density of the thermally treated materials was 5.6–5.7 g/cm^3.

Apparent density, open and total porosity, water absorption were determined according to the State Standard 2409-2014.

Compressive strength measurements were determined according to the State Standard 8462-85 as a breaking force per 1 cm^2 of the initial section of the material at the moment of sample failure: $R_{comp} = P_{max}/F$, where Pmax is the maximum breaking load, N; F is the cross-sectional area of the sample, cm^2.

The electrical resistance - the resistivity of the materials was determined according to the State Standard 6433.2-71.

The temperature field was controlled by four thermocouples of the TPP-0192 type, installed according to the scheme shown in Figure 2.

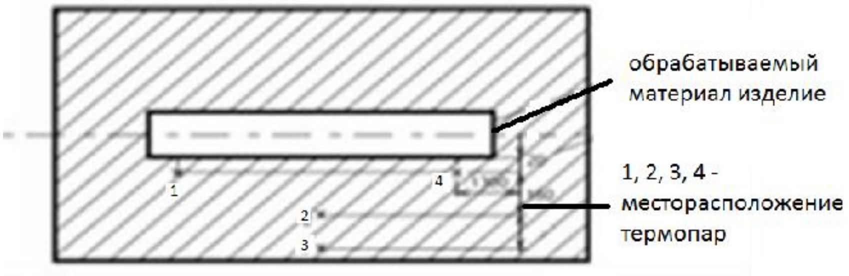

Figure 2: Thermocouple Installation Diagram.

As can be seen from Figure 2, thermocouples №1 and №4 were located at a distance of 20 mm from the surface of the active zone, № 2 and № 3 - at a distance of 180 mm from the surface of the active zone.

RESULTS AND DISCUSSION

Heat treatment of products was carried out on the Big Solar Furnace. To do this, a product of a certain shape was placed in the water-cooled surface of the melting unit located in the focal zone of the Big Solar Furnace. A concentrated flux of solar radiation with a density of 100 W/cm^2 was directed to the target - the product.

Figure 3 shows the time dependence of the temperature in the focal zone of the solar furnace, where the product is installed.

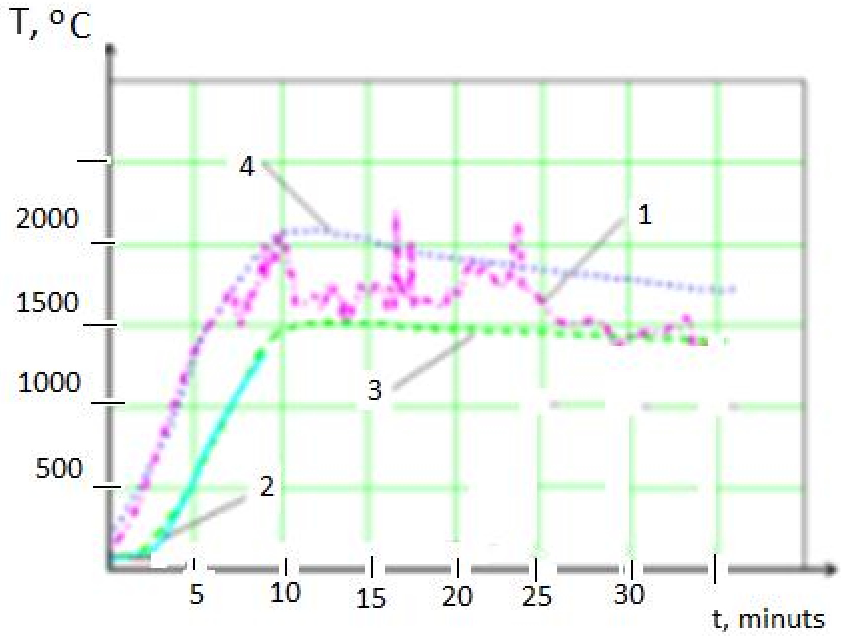

Figure 3: Time Dependence of Temperature in the Focal Zone of the Solar Furnace Where the Product is Installed

As can be seen from Figure 3, in the middle part of the solar furnace, the temperature reaches its maximum value (about 2050 °C) after about 10 minutes, and then it is maintained at the level of 1600-1700°C during the entire time of the experiment on target irradiation i.e. 45 minutes after the start of the test (thermocouple № 1). The temperature drop after 15 - 17 minutes can be explained by the deposition of the electrical heating material and the corresponding redistribution of heat. The drop in temperature after 15 - 17 minutes can be explained by the deposition of electrical heating material and the corresponding redistribution of heat. The change for heat supplied to the sample is noticeable, especially in the area adjacent to the electric heater (thermocouple № 4), and almost imperceptible at large distances (thermocouple №4). At a distance of 200 mm from the sample (furnace center), the temperature (thermocouple № 2) reaches 1450°C in about 9-10 minutes, and at a distance of 300 mm (thermocouple №3) in about 20 minutes.

Such temperatures are high enough to allow the sintering of silicon carbide and lanthanum chromite materials to proceed. The product target was irradiated for 45 minutes, after which the product samples were cooled in air on the surface of a water-cooled melting unit.

As the analysis showed, products after heat treatment in a solar oven show shrinkage for 8 - 10%. Large shrinkage is observed in the central part of the product.

As shown by measurements of the porosity of materials for silicon carbide products, the porosity is 20-25%, and for lanthanum chromite 15-20%.

The values of the ultimate strength of the material in compression were also determined, which amounted to 210 MPa for silicon carbide and 130 MPa for lanthanum chromite. The electrical resistance - resistivity of the materials was 20 - 30 ohm cm for silicon carbide and 5 - 10 ohm cm for lanthanum chromite.

CONCLUSIONS

Thus, the possibility of using a concentrated high-density solar radiation flux at the Big Solar Furnace for heat treatment of products made of silicon carbide and lanthanum chromite, which are resistive heaters for high-temperature electrothermy, has been studied. It is shown that the optical-energy parameters of the Big Solar Furnace allow creating a low-gradient (±30°C) temperature field along the diameter (0.5 m) of the focal zone of the solar installation. Due to the absorption of the energy of concentrated solar radiation, the density of 150 - 200 W/cm^2 material is heated to a temperature of 1400 – 1600°C and the process of sintering of the ceramic product with a shrinkage of 8 - 10% proceeds. The mechanical and resistive characteristics of the materials processed in a solar furnace are close to the State Standard values. So for silicon carbide material with a porosity of 20-25%, the following values of compressive strength of 210 MPa were obtained, and for lanthanum chromite with a porosity of 15-20% -130 MPa. The values of electrical resistance - resistivity of materials were 20 - 30 ohm cm for silicon carbide and 5 - 10 ohm cm for lanthanum chromite. These data suggest that the heat treatment of products in a solar furnace in a stream of concentrated solar radiation stimulates the sintering process of ceramic products used in high-temperature units of the electrothermal industry.

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