FILTRATION COMBUSTION OF NATURAL GAS FOR FORMING DENSE REFRACTORY CERAMICS*

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Progress in modern engineering is largely determined by the use of dense functional ceramics based on oxides (Al_2O_3, MgO), nitrides (Si_3N_4, AlN), oxynitrides (alones, sialons), carbides (SiC, TiC) and a number of other refractory inorganic compounds. Due to the combination of extreme strength characteristics, heat and corrosion resistance, these materials are widely used for chemical, energy, and aerospace equipment, and also as protective shields, cutting tools, etc. At present the calcination of powders in electric furnaces at temperatures above 1900K is often used to obtain dense ceramic materials with a melting point above 2300K. This process is accompanied by significant costs for electricity and sophisticated equipment, which leads to an increased cost of final products.

An efficient high-temperature heat treatment of materials uses heat from filtration combustion of gases (FCG). The term "FCG" means the wave exothermic transformation of gases during their filtration in porous condensed media. Compared with open gas flames, FCG waves are distinguished by the high power density (due to the increased rate of fuel combustion), the ability to concentrate thermal energy (due to the presence of a condensed medium), and the ability to achieve super-adiabatic combustion temperatures (due to heat recuperation).

A reactor, thermocouple and spectrometric temperature measurement methods were used to study the dynamics of heating of solids during the combustion of a fuel blend (natural gas (92 vol% CH4) + air (21÷35 vol% O_2)) covered with spherical granules ZrO_2 (with a diameter of ϕ = 5.8 mm and ϕ = 2mm). Varying the composition of the fuel blend (φ = 0.40÷3.00) and the specific thermal combustion power (w = 24÷300 W/cm^2) have been found to make it possible to control the propagation velocity of combustion from U_c = -0.18 mm/s (minus sign is combustion against the filtration flux) up to U_c = + 0.12 mm/s (plus sign is combustion along the flux) and the maximum heating temperature of materials in the range Tsm = 1230÷2210K. The Tsm values were shown to substantially depend on the U_c value, the filtration rate of the mixture and were largely determined by the enthalpy effects of the condensed medium. The filtration combustion rate limits and the optimal heating conditions were determined for the ceramic structures with a characteristic size D >> ϕ.

Powder briquettes were covered with granules to conduct test sintering and synthesis of refractory substances. According to the data obtained, the heat treatment of briquettes in the wave and behind the FCG wave at Tsm = 1900÷2200 K for 0.3÷1.0 hours provides sintering of Al_2O_3 and MgO samples (porosity reduction from 50% to 10%) and almost complete conversion a powder mixture of Si + 30wt.% C into a composite SiC-Si_2N_2O.

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