Energy-saturated materials based on silicon and halogen-containing polymers

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The purpose of this study was to study the combustion process of highly dispersed silicon powder in a mixture with various fluorine-chlorine-containing polymers (fluoroplastics F-4, F-40, F-42, F-3, F-32) depending on the ratio of the components. Thermodynamic calculations were carried out using the TERMPS program and experimental studies of compacted samples were carried out when the fuel content varied from 10 to 90% wt. with determination of burning time and energy illumination in the wavelength range of 0.5-20 microns.

Industrial silicon powder of the Kr-1 brand, with an average particle size of 16-19 microns, was used as fuel. The preparation of the compositions was carried out according to the methodology accepted in the pyrotechnic industry. The samples were molded using the method of blind pressing on a PSU-50A hydraulic press in accordance with GOST 310-60 at a pressure of 100 MPa in a press tool with a diameter of 16.2 mm without a shell. The samples were tested in a vertical combustion chamber without air blowing.

Based on the results of thermodynamic calculations, it was established that the highest combustion temperatures are achieved with a silicon content of 20-25% wt. for systems with F-3, F-32, F-4 and 5-10% wt. silicon content for systems with F-40, F-42 in the case of using the mixture's own oxidizing elements. With the additional participation of an oxidizing agent, the combustion temperature increases over the entire range of changes in fuel concentration, with a sharp rise observed in the silicon content range of 10-30% wt. It should be noted that the highest combustion temperature is achieved for the silicon system with F-4. Among the condensed combustion products are carbon, silicon carbide and unburned silicon, which are formed by the interaction of reagents without the participation of the environment; silicon dioxide formed with the additional participation of the environment. The amount of a particular product depends on the silicon content in the pyrotechnic composition. Also among the combustion products there are substances in a gaseous state, fluorides and chlorides of silicon, oxides of carbon, and hydrogen in the case when atmospheric oxygen takes part in the chemical interaction.

As a result of experimental studies, an extreme dependence of combustion parameters with maximum values of linear combustion rate (1.8-3.0 mm/s) and energy illumination (180-380 W/m^2) was established at a fuel content of about 50 wt. percent. Concentration limits of flammability are 30-80% by weight fuel content. Within these limits, stable combustion is maintained, while the compaction coefficient becomes smaller with increasing silicon content. The highest values of irradiance are achieved for silicon systems with F-4 and F-40 and amount to 360-380 W/m^2. The nature of the resulting solid combustion products depends on the ratio of the components. Up to a fuel content of 50% wt. during combustion, sooty combustion products are intensively formed. Microscopic analysis of these products showed that they are thread-like formations. Further, when the silicon content increases to more than 50% wt. the amount of soot combustion products is reduced. A solid combustion product is formed in the form of regular rings.

It should be noted that pyrotechnic compositions based on silicon and fluoropolymers burn in the spin mode, in which a small luminous spot appears on the surface of a cylindrical sample, moving in a spiral along the outer part of the sample.