REGULARITIES OF SHS PROCESSES IN A MULTILAYER POWDER SYSTEM Ti – Al – C

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High-temperature electric heaters (1000 – 1800 °C) made of molybdenum disilicide and silicon carbide are used for firing and sintering cermets, ceramics, glass, ferrites, etc. However, they are very fragile and cannot withstand thermal shocks. Nanolaminant MAX phases combine the properties of both ceramics and metals. They have high electrical conductivity, at the level of many metals, are resistant to high temperatures, and withstand thermal shocks. This makes them suitable candidates for high temperature electric heaters. One of the most interesting MAX phases are Ti_3AlC_2 and Ti_2AlC, which have high Young's modulus, fracture toughness, and bending strength. To obtain these materials, the method of self-propagating high-temperature synthesis is widely used.

Therefore, one of the goals of this work was to develop a method for producing conductive materials based on the MAX phase of Ti_2AlC for electric heaters with high operating temperatures. Since heaters made of $MoSi_2$ and SiC are manufactured in a protective atmosphere (nitrogen, argon), the technology is quite complex and requires special equipment. Therefore, one of the tasks was to develop a method for producing heaters in air.

In the work, powders of titanium, aluminum, carbon black, mixtures of Ti + C, 2Ti + Al in various combinations were applied layer by layer in the form of a suspension in isopropyl alcohol onto ceramic plates through a stencil with a thickness of 0.5 to 1.7 mm. The sample was dried in air at room temperature. Then it was heated in an electric oven with a linear increase in temperature (100 - 160 degrees / min.). The temperature in the sample was measured using a type K thermocouple (TC) and recorded using an ADC on a computer. X-ray phase analysis of the synthesis product was carried out on a portable RIKOR diffractometer provided by the Tomsk Common Use Center SB RAS. The microstructure of the coating was studied using an Axiovert optical microscope (Karl Zeiss, Germany).

The process of thermal explosion in single-layer samples (Ti, Al, C, Ti + C, 2Ti + Al mixtures), two-layer Ti/C, 2Ti + Al/C, TiC/Al and three-layer Al/Ti/C samples has been studied (Fig. 1 a). It has been established that the initiation temperature of the process is significantly less than for pressed samples. This can be explained by the oxidation of carbon black powder, aluminum or titanium in air. This leads to an increase in temperature in the layers and initiation of the process. In addition, the process occurs in ignition mode, not thermal explosion. Many foci appear on the surface of the layer, which move chaotically across the surface (Fig. 1.b). And since the temperature is measured at a point, the sample continues to heat up. In this case, the measured temperature will depend on the distance that the source has traveled to the thermocouple.

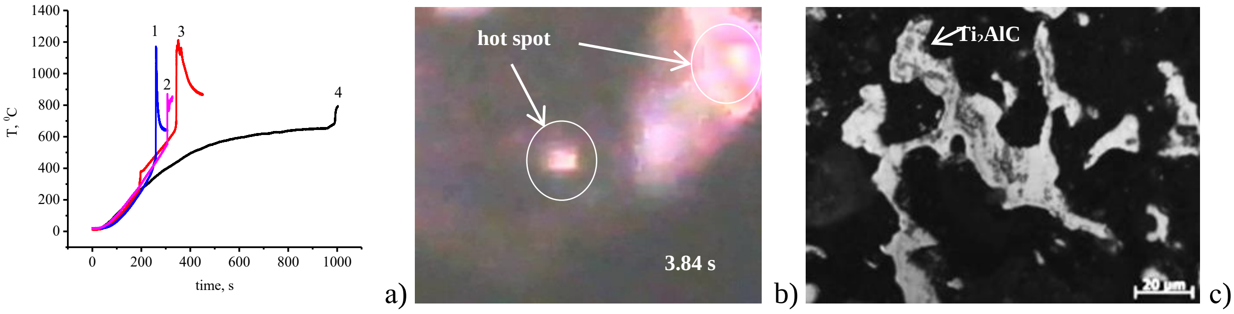

Fig. 1. Thermograms of samples: 1 – 2Ti+Al, 2 – TiC/Al, 3 – Ti/Al, 4 – Al (a); video frames for the Ti/C sample (b); micrograph of a section of an Al/Ti/C sample (c).

X-ray phase analysis of the samples was carried out, which confirmed the formation of the target Ti_2AlC phase. The electrical resistivity of the samples was measured. Microphotographs of thin sections of samples also confirm the formation of the phase Ti_2AlC (Fig. 1 c). Ti_2Al samples have a minimum resistance (7 Ohm × cm), and Al/Ti/C have a maximum resistance (33000 Ohm × cm). This allows them to be used as conductive coatings and electric heaters. A prototype of the electric heater was manufactured and tested.