Synthesis of silicon carbide in arc discharge in fuel oil

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Abstract. In this work, an experimental physical setup is proposed and a method for the synthesis of silicon carbide in an electric arc drowned into the thickness of hydrocarbon raw materials is described. Silicon carbide and carbon nanotubes were found in the deposits at the cathode. The resulting sample was analyzed using an optical microscope. And also confirmed the hardness of silicon carbide

1. Silicon carbide (SiC) is a stable compound, second only to diamond in hardness. It is this property that makes silicon carbide an indispensable abrasive material. At the same time, the possible applications of silicon carbide are much wider. It is worth mentioning that silicon carbide has excellent semiconductor properties, due to which it has wide applications in power electronics, as light-emitting diodes, and others. For each field of application of silicon carbide must be found its own technology for its synthesis. For example, extreme synthesis methods are completely unsuitable for use in nanoelectronics, in which uncontrolled structure and shape formation of crystals occurs and it is almost impossible to control the synthesis process.

Today, many technologies for the synthesis of silicon carbide are known. It is worth mentioning, for example, the Acheson’s technique, based on the phenomenon of evaporation of the synthesized material by passing an electric current (hundreds thousands of amperes) by the resistance immersed in the mixture of constituent elements and their subsequent condensation. This method of silicon carbide synthesis is quite simple, low-cost, does not require the creation of particularly high pressure and temperature values, uses common components and allows you to get tons of the final product. However, the uneven heating of the furnace does not allow us to predict the result of synthesis.

CVD is one of the most suitable methods used for the production of silicon carbide in various forms of thin-film powders, fibers and nanorods in the Si-C-HCl system. A CVD process under argon atmosphere pressure using CH₃SiCl₃ and H₂ as precursors without metal catalysts is also possible. In this way were obtained nanowires of silicon carbide of cubic syngony of sufficiently high purity and uniform diameter of about 70 nm.

Also known a plasma-chemical synthesis method, which allows to obtain highly dispersed carbide powders. The characteristics of the powders obtained depend on the raw materials used, the synthesis technology and the type of reactor. The particles of such powders are most often single crystals with sizes from 10 to 100-200 nm or more. The main conditions for obtaining nanoparticles by this method
are the reaction far from equilibrium and a high rate of formation of solid phase nuclei at a low rate of their growth.

2. The search for new ways of controlled synthesis of silicon carbide in simple and reliable ways is relevant for both researchers and manufacturers. In this paper proposed a technique for the synthesis of silicon carbide using a recessed arc discharge. The experimental physical setup includes a ceramic vessel with hydrocarbon raw materials, into which a cathode-anode electrode system, a high-current electric power source, and measuring devices are lowered. The anode is a cylindrical graphite with a diameter of 12 mm, and the cathode is an iron rod with a diameter of 8 mm. In the graphite rod drilled several small holes, into which embedded silicon fragments.

Arc ignition between the electrodes immersed in the hydrocarbon feedstock can be carried out either by applying a high-voltage pulse, or by directly short-circuiting the electrodes with each other. In both cases, an arc discharge is ignited in a limited volume, the walls of which are surface boiling raw materials. Complex molecules are delivered to the discharge region from the surface of the boiling cavity, which limits the plasma region of the arc discharge. Under the influence of an electric arc, complex hydrocarbon molecules are decomposed into light fractions. The pressure in the plasma region is slightly different from the atmospheric pressure, due to the high viscosity of fuel oil. Just this pressure allows to maintain a plasma region inside the hydrocarbon feedstock. The efficiency of such a discharge for the decomposition of hydrocarbons and the synthesis of carbon nanostructures was proved in [1-4].

At high plasma temperatures, complex hydrocarbon molecules are broken down into smaller fractions, as well as the formation of atomic carbon. At the same time, silicon and carbon atoms evaporate from the anode surface. In the plasma, these atoms are charged and follow to the electrodes, where they combine either into nanotubes or silicon carbide. The presence of ions leads to high interaction rates. The presence of coolant in the form of fuel oil determines the place and speed of quenching. This makes it possible to obtain powders with a given composition, shape and particle size. Plasma chemical synthesis provides high rates of formation and condensation of the compound and a sufficiently high performance.

3. The experiment lasted for 120 seconds at a current of 100A and a voltage of 20V. During the experiment was maintained a constant distance between the electrodes. The arc discharge was carried out in the thickness of hydrocarbon raw materials. The light hydrocarbons released in this process, containing hydrogen, methane and acetylene, were collected in special containers. During the experiment was formed a growth of about 1 cm^3 on the cathode. This growth was analyzed using an optical microscope, the images of which are shown in (Fig. 1-2).
As can be seen from the images, the deposits at the cathode contain a large number of silicon carbide nanoparticles. In some areas of the sediments, the presence of carbon nanotubes is noticeable. In the future, the obtained samples were tested for hardness. For example, after pushing the sample slightly along the surface of the glass, a deep crack will remain on the glass. Figure 3 shows traces of individual nano and microparticles of silicon carbide formed as a result of rubbing these particles located between the surfaces of two glasses.

**Figure 3.** Microscopic image of traces of nanodispersed silicon carbide formations on glass.

4. **Conclusion.** Therefore, the use of an electric arc discharge drowned in a liquid hydrocarbon raw material makes it possible to synthesize silicon carbide of the required size and in large quantities. If the size of silicon carbide samples can be predicted by the duration of the discharge, then the quality can be achieved by adjusting the current value.

The results of studies of the electric arc decomposition of heavy hydrocarbon raw materials using recessed electrodes have shown the practical feasibility of such a discharge for the production of silicon carbide.

5. **Acknowledgments**

This work was financially supported by the RFBR and the Government of the Republic of Tatarstan in the framework of the research project № 18-43-160005 p.

**References**

[1] G R Ganieva, B A Timerkaev. Petrochemicals, 2016. T. 56. No. 6. P. 651-654...

[2] G R Ganieva, D I Ziganshin, M M Aukhadeev, B A Timerkaev. Journal of Engineering Physics and Thermophysics. 2014. 87 (3):699-703 DOI: 10.1007/s10891-014-1062-9

[3] A O Sofronitskiy, AA Andreeva, BA Timerkaev. Journal of Physics: Conference Series 669 (2016) 012062, 1-4.

[4] B A Timerkaev, G R Ganieva, A A Kaleeva, Z K Israfilov, A O Sofronitskii. Journal of Engineering Physics and Thermophysics. 92(5), 1248-1252, 2019. DOI 0.1007/s10891-019-02040-3