SYNTHESIS IN PLASMA JETS: FROM CARBON FIBERS TO QUANTUM POINTS

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Recently, a variety of plasma facilities is used in synthesis of carbon nanomaterials – here, thermal and plasma-chemical processes are implemented. Well-established methods of obtaining, for example, fullerenes and nanotubes based on use of electric arc and laser evaporation, have proven themselves in laboratory studies; yet, they have a number of disadvantages leading to low productivity of the process. The advantage of using the plasma jet, as against these methods, is absence of temperature limitations: the reaction is possible far from equilibrium, high nucleation rate of the new phase exists at a low rate of its growth; possibility of choice of the the reaction products location and rate of condensation, of controlling the cooling rate of the plasma stream makes it possible to control the performance of the synthesis and to obtain powders with the desired composition, shape and nanoparticle size.

This paper presents the main results on the study of the optimal conditions for the synthesis of carbon nanomaterials in the plasma jet reactor (its detailed description is given in [1–3]).   
To generate the plasma jets, we engage the direct current plasma torch with expanding output – anode – channel electrode and the vortex stabilization of the plasma jet. Nitrogen, helium and argon are used as plasma-forming gases. As a carbon precursor, we might use either solid (carbon black with catalysts), or liquid (ethanol), or gaseous (propane-butane composition) components. A series of experiments determined the parameters of the plasma torch (current 200–400 A, plasma gas flow rate – 0.75–3.0 g/s), at which the current-voltage characteristics of the plasma torch increase. The temperature in the synthesis products collector domain (400–1000 ºС) was varied by its geometry (from cylinder to cone), and was controlled by thermocouples.

The synthesis products were characterized by electron spectroscopy, thermal analysis, Raman spectroscopy, IR spectroscopy, energy dispersive X-ray spectroscopy.

We found that carbon black nanotubes, 16–74 nm in diameter, are synthesized in pyrolysis of soot in jets of argon and helium plasma under the presence of dispersed metal powders of Ni, Co, Y2O3, whereas the carbon nanofibers up to 130 nm in diameter, with the mass content in the carbon deposit up to 34% are formed in these plasma jets under the presence of carbonyl iron. When ethanol is converted in nitrogen plasma, graphene is formed with a lateral size of up to 1500 nm. Use of the propane-butane composition in the helium, argon and nitrogen jets makes it possible, depending on the pressure in the reactor (350–710 Torr) and its consumption (0.1–0.3 g/s), to synthesize carbon fibers, graphene, hydrogenated graphene and N–graphene with mass content up to 90%, as well as the quantum dots up to 5 nm in size.

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References

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