ELECTRICAL EXPLOSION TECHNOLOGY FOR NOVEL CARBON NANOMATERIALS PRODUCTION

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Introduction

New spatial forms of carbon – fullerenes, nanotubes, nanowires and nanofibers attract significant interest since the time of their discovery due to their unique physicochemical and mechanical properties. Much investigation has been carried out in this field in the recent years. Hence, the problem of development of effective synthesis methods of carbon nanomaterials (CNM) as well as those of separation and purification remains of actual importance.

The purpose of this research is to study a possibility to manufacture CNM (fullerenes, nanotubes, amorphous carbon, etc.) using a high-energy plasmochemistry synthesis, namely exploding wires (EW) and spark erosion (SE) methods.

Results and discussion

EW and SE methods of high-energy plasmochemistry synthesis have been used for CNM manufacturing. Chemically pure (99.99 %) elements were used as the starting materials. X-ray diffraction (XRD) investigations were performed by means of a standard powder diffractometer using Cu K_{α} radiation. Electron microscopy investigations were conducted using the Hitachi H-800 microscope operated at voltage of 200 kV. Mass-spectrometer measurements were performed by the method of the field desorption using a high resolution device to find fullerenes and carbon clusters (up to 2000 amu) in synthesis products.

The results of the high-energy plasmochemistry synthesis of CNM using the EW method under different conditions are shown in the Table 1. The synthesis products were subjected to investigation using XRD analysis, electron microscopy, and mass-spectrometer analysis. The typical XRD patterns for the exploded materials – graphite and nickel - are shown in Fig. 1 and Fig. 2, respectively. It is immediately obvious that there is a presence of additional diffraction peaks at small angle values besides those typical for common graphite and nickel. This fact clearly demonstrates the appearance of new structural compositions in the synthesis products. A phase analysis performed shows that these diffraction peaks correspond to those for carbonic spatial materials with the fullerene-like structure of the C_{60}-C_{70} types. An electron microscopy investigation of both the liquid fraction and dried deposit shows a presence of nano-dispersive carbon particles, agglomerations of nanotubes and separate nanotubes (Fig. 3 a, b).

Table 1. Spectral composition of the fullerene-like clusters produced by EW method in the case of explosion of different materials in the toluene at the operational voltage of 4.5 kV

№	Explosive material	Spectral composition
1	C	463, 493, 542, 576, 658,740, 768, 852, 875, 919
2	Fe	304, 316, 328, 344, 356, 368, 721, 864
3	Ni	532, 560, 589, 623, 860

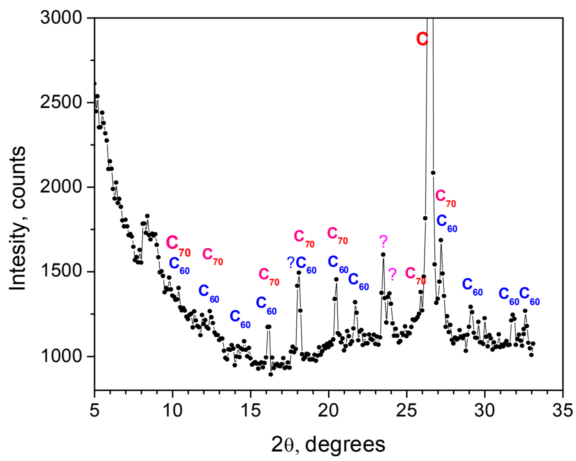

Fig. 1. Fragment of the XRD pattern of the graphite explosion products in the toluene at the operational voltage of 45 kV, Cu K_{α} radiation.

The fact of production of the fullerenes without the use of graphite as material for the synthesis is of significant scientific interest (Table 1, Fig.2). It can be explained as a result of a destruction of surrounding organic (toluene, benzol, benzene, alcohol, etc.) medium with following directional self-organization of destruction products and CNM formation under condition of the high-energy plasmochemistry synthesis (temperature and pressure values amount to 10^4 K and 300-500 MPa, accordingly). At the specified conditions there is the effective possibility to control the spectral composition of the synthesis products through variation of synthesis energetic parameters and surrounding medium. It should be particularly emphasized that there is a fundamental possibility to manufacture diamond-like nanomaterials at this conditions. The XRD study of synthesized CNM testifies that some diffraction peaks correspond to the diamond phases. But this assumption should be examined by the use of a set of investigation techniques, since the XRD patterns for graphite and diamond are very similar to each other in a number of cases.

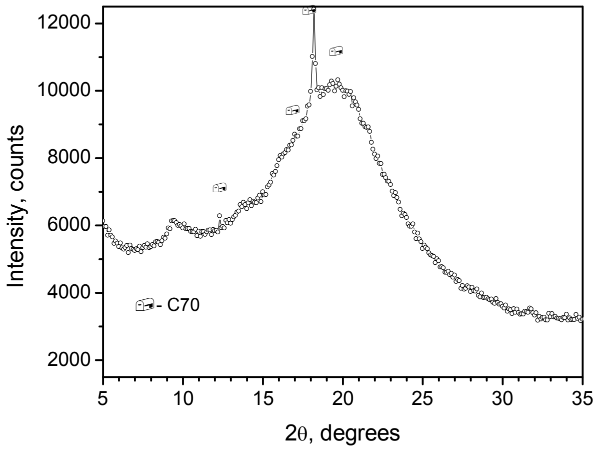

Fig. 2. Fragment of the XRD pattern of the nickel explosion products in the toluene. Polymerized liquid fraction, Cu K_{α} radiation.

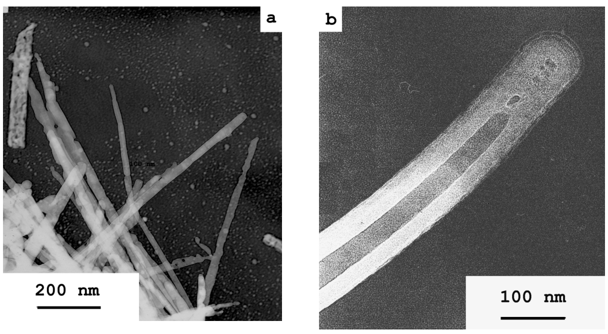

Fig. 3. Electron microscopy images of the graphite (a) and nickel (b) explosion products in the toluene:

a) agglomeration of nanotubes,
b) separated multy-walled nanotube.

It is worthy of note that EW products have very strong ferromagnetic properties in a number of cases. The magnetization curves are typical to those of ferromagnetic materials (Fig.4).

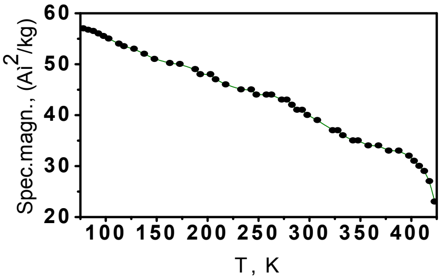

Fig. 4. The temperature dependence of specific magnetization of the graphite explosion products.

It was very important to explore the possibility of manufacturing of new forms of CNM using the SE method. SE method has a very high productivity and can be used for commercial purposes. The spectral compositions of the synthesis products obtained by the SE method using the graphite electrodes and different surrounding mediums are represented in the Table 2. It is well seen that a set of fullerene-like materials can be produced by the SE method, too.

Table 2. Spectral composition of the fullerene-like clusters produced by SE method.

№	Medium	Spectral composition,
1	ethanol	363, 376, 390, 404, 418, 432
2	benzine	447, 474, 477, 502, 532, 558
3	toluene	477, 506, 533, 561, 604, 828, 858, 881, 885

Conclusions

1. There were developed two new technologies for manufacturing of novel carbon nanomaterials (fullerenes, nanotubes, carbonic nanoclusters) based on the idea of high-energy plasmochemistry synthesis with the use of the methods of electrical wire explosion and spark erosion of graphite and metallic materials (nickel, iron, copper) in organic medium.

2. These methods allow to produce a wide spectrum of fullerene-like materials including the highest ones – C_{70} and higher (up to 1338 amu in our case). The fact of production of the fullerenes without the use of graphite as a material for the synthesis is of great scientific interest and importance. There exists an effective possibility to control the spectral composition of the plasmochemistry synthesis products through variation of the energy parameters of the synthesis and surrounding mediums.