Synthesis of Nanostructures in Chlorine-Containing Media

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ABSTRACT

This work demonstrates a possibility to produce such materials by the new method for synthesis of carbon nanostructures using arc evaporation of materials in liquid medium. The possibility to produce chlorine-filled nanostructures is illustrated by the example of synthesis in chlorine-containing media. The proposed method may be one of the most efficient methods for synthesis of carbon nanostructures.

Keywords: arc graphite evaporation, dichlorethane, carbon nanostructure, morphology

1 INTRODUCTION

Modification of carbon nanostructures by different chemical elements opens an opportunity for synthesis of materials of a new generation for different applications. Filling carbon nanotubes with one or other element will allow for conferring different mechanical, electrical, magnetic and other physical and chemical properties on the nanotubes.

This work demonstrates a possibility to produce such materials by the new proposed by authors [1-3] method for synthesis of carbon nanostructures using arc evaporation of materials in liquid medium.

The possibility to produce chlorine-filled nanostructures is illustrated by the example of synthesis in chlorine-containing media.

2 EXPERIMENTAL

Synthesis in the liquid phase has been carried out on the setup designed specially for these studies. The setup allows metal and graphite electrodes to be evaporated in the liquid medium at the temperature of medium 4 to 340 K using an electric arc. The arc temperature near a cathode may be as mush as $1.2 \cdot 10^4$ at currents 200 to 300A. The product can be cooled at the rate of 10^{-9} K/c to 4K in the liquid phase.

The electronic control block is simple in operation and gives a possibility to vary and measure voltage and electric current. These changes in their turn allow the action on the conditions of the plasma-chemical process, which proceeds in the reactor, and the profound effect on the morphology and the yield of product.

All the chemical reagents used in synthesis have been subjected to preliminary purification and rectification. Graphite of MPG-7 grade has been used. Preliminary graphite rods have been annealed in vacuum. Metallic rods have been melted repeatedly in an arc furnace in argon medium of spectral purity.

The synthetic products have been investigated by scanning and transmission electron microscopy. The liquid phase has been studied by a spectrophotometer and mass spectrometry.

The variety of properties of different resulting carbon materials is conditioned by the electronic structure of a carbon atom. The electron density redistribution, the formation of electronic clouds of different modifications around the atoms, the hybridization of orbitals (sp^3-, sp^2-, sp- hybridization) are responsible for the existence of different crystalline allotropic phases and their modifications.

The proposed method gives a possibility to produce the wider range of materials by varying conditions of their synthesis. This method allows the change of the chemical composition of electrodes and the medium in which the synthesis is carried out (see Fig. 1). At present time different research groups the world over are engaged in such studies [4-14]. The electrodes may contain or not contain carbon or consist of graphite doped with any element. The liquid phase in its turn may have different chemical compositions that affect significantly the structure and the composition of the forming nano-objects.

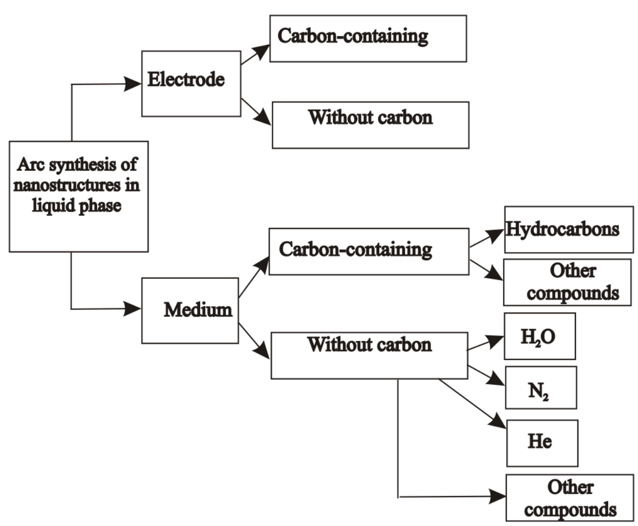
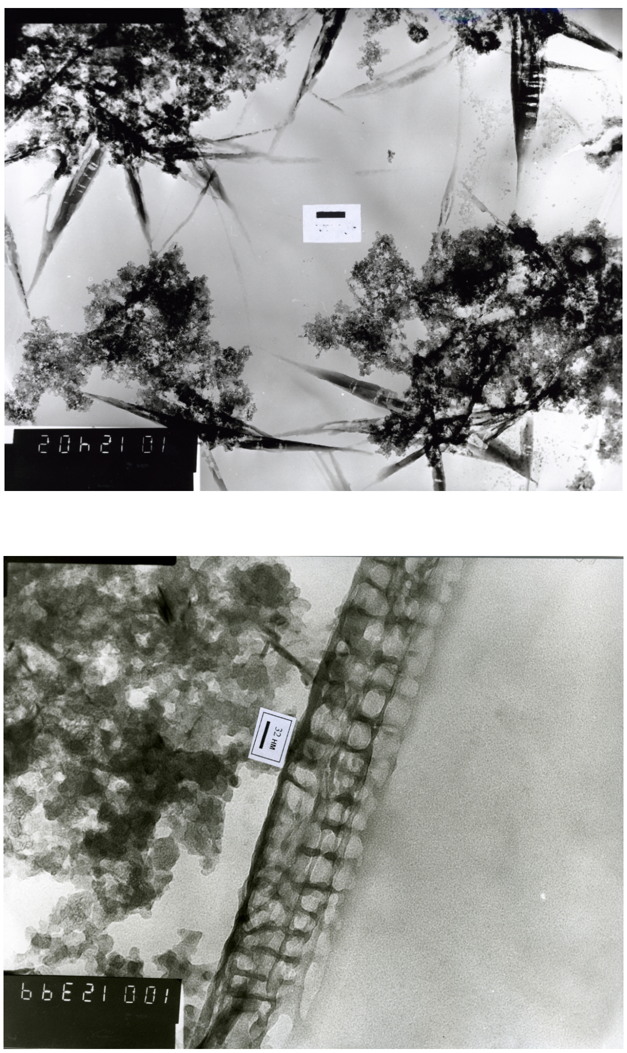


Figure 1: Scheme for possible combinations of medium and electrode materials in synthesis of nanostructures by the arc method in the liquid phase.

In the course of the arc synthesis when carbon atoms derive sufficient amounts of energy, they pass from the graphite surface into the gas phase as separate atoms or groups of atoms [6]. These atoms form in certain technological conditions a new carbon structure determined by the synthesis conditions. As this takes place, the atoms spend the derived energy for constructing this structure. The further existence of this carbon nanostructure, the conservation or the change in the initial morphology and geometrical dimensions of a nucleus are determined by the thermodynamical and technological conditions for the nucleus stay in a particular medium.

During simultaneous evaporation of graphite and different elements they interact or nanostructures are doped with the element.

Nanostructures of different morphologies (see Figs. 2 and 3) and different volume filling are formed by graphite evaporation in chlorine-containing liquids.



Figere 2: Carbon nanostructures produced in CCl_4.

Encapsulated nanotubes produced in dichloroethane are shown in Fig. 3. Their morphology and volume structure are in complete agreement with the mechanism of the fast formation of a nanotube and its simultaneous encapsulation proposed by Loiseau et al. [6].

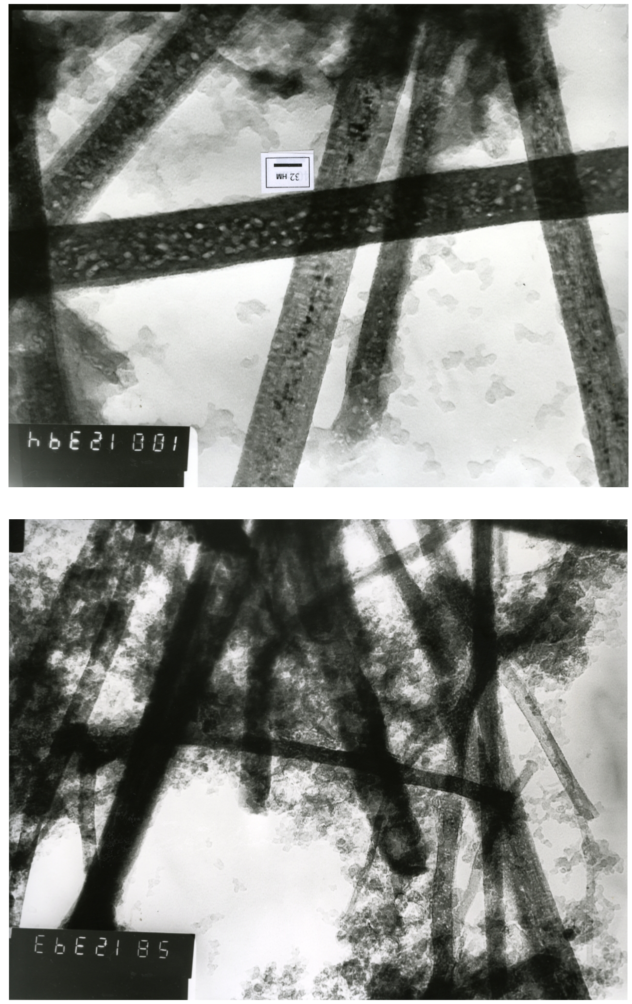


Figure 3: Carbon nanotubesfilled with a chlorine-containing compound (the tubes have been produced in dichlorethane).

3 CONCLUSIONS

Based on the experimental data and the theoretical calculations we have attempted to consider the conditions and the mechanism of the processes proceeding in synthesis of carbon nanostructures.

The possibility to produce chlorine-filled carbon nanostructures by the arc synthesis of nanostructures in the liquid phase has been demonstrated.

All the obtained results are of scientific and practical interest. The produced materials invite further investigations. The proposed method can be one of the most effective methods of fullerenes and nanotubes synthesis.

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