SYNTHESIS OF CARBON NANOSTRUCTURES IN LIQUID HELIUM

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Introduction

At present synthesis of carbon nanostructures is mainly performed in different scientific groups by any one method. For this reason not everyone has possibility to compare peculiarities of synthesis of the same product by different methods.

The most of investigations of physical and chemical peculiarities of nanostructure formation and morphology of nanostructures has been performed by two methods: pyrolysis of hydrocarbons and arc evaporation of graphite in liquid phase.

It should be also noted that while the first method was applied earlier to produce different carbon pyrofibers and therefore it has been studied sufficiently, the second method of arc synthesis attracted a deserved attention of scientists as the method for synthesis of carbon nanotubes (CNT) only after Iijima's work has been published in 1991. This method requires the explanation of many unintelligible moments. Vagueness in understanding a mechanism of the nanotube growth hinders the progress in developing more controllable technologies for synthesis of these materials.

Peculiarities of carbon nanostructure synthesis and the effect of temperature and cooling rate of the product on its formation and morphology have been investigated in this work. We have compared the peculiarities of formation of the nanostructures synthesized by the arc method in gaseous and liquid helium to understand the effect of the state of medium on the process of nanostructure formation.

Experimental

Synthesis of carbon nanostructures by pyrolysis and arc discharge in the gas phase has been performed by the known methods [1-4]. Synthesis in the liquid phase has been carried out on the installation designed specially for these studies. This installation allows metal and graphite electrodes to be evaporated in the liquid medium at the temperature from 4 to 340 K using an electric arc. The arc temperature near a cathode may be as much as $1{,}2\cdot10^4$ K at currents of 200-300A (Fig. 1) and the product can be cooled at the rate of 10^{-9} °/s to 4 K in liquid phase [6-9].

The electronic control block is simple in operation and gives the possibility to vary and measure voltage and electric current. These changes in its turn allow the action on the conditions of the plasmo-chemical process, that 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.

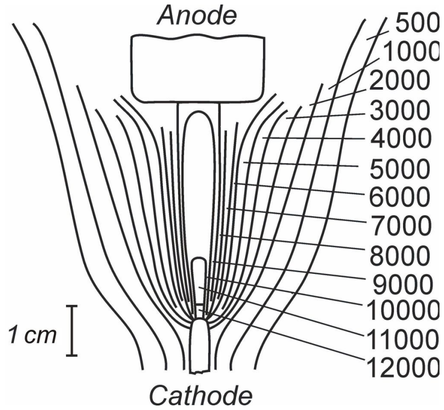


Fig. 1. Temperature distribution (in K) in different parts of the electric arc between the carbon electrodes at strength of current equal to 200A [5].

The graphite rods have been annealed preliminary in vacuum. The metallic rods have been remelted repeatedly in an arc furnace in argon medium of spectral purity.

The synthesis products have been investigated using the scanning and transmission electron microscopy. The liquid phase has been studied by spectrophotometer and mass spectrometry (these results are not discussed in the present work).

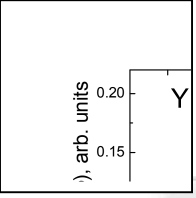
Results

The product produced by the arc evaporation of graphite in liquid helium has no deposit and without additional purification it contains up to 85-90% of carbon nanotubes. Such results are not always achieved using different methods for nanotubes purification (Fig. 2).

Different nano-objects can be synthesized under changes of the regime of synthesis and application of catalysts. In the course of synthesis the foamy particles (Fig.8) are formed during the evaporation of highly dispersed graphite dust. Their conglomerates range up to 1-5 μm.

Conclusions

From the aforesaid, it might be assumed that the discussed method of carbon nanostructure synthesis is sufficiently productive. It allows the production of nanostructures and composites based on them with different morphology, different properties and consequently for different applications. In this case during the reaction many carbon nanostructures, that are interpreted to be the by-product, have no time to form or grow because of a high rate of the temperature change.



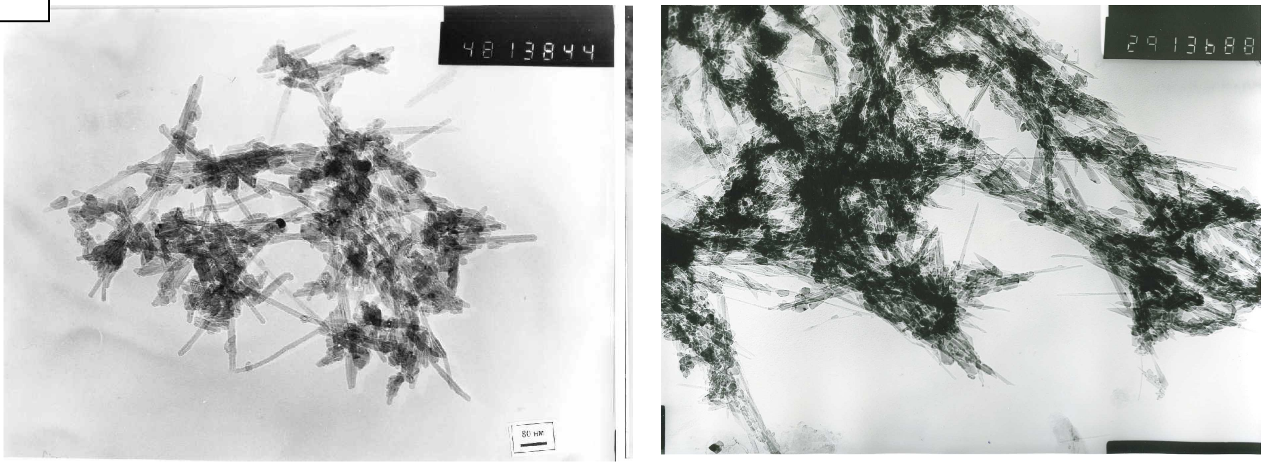


Fig. 2. Carbon nanotubes produced in liquid helium (demonstrated without additional preparation: fragmentation, washing, extraction, purification etc.).

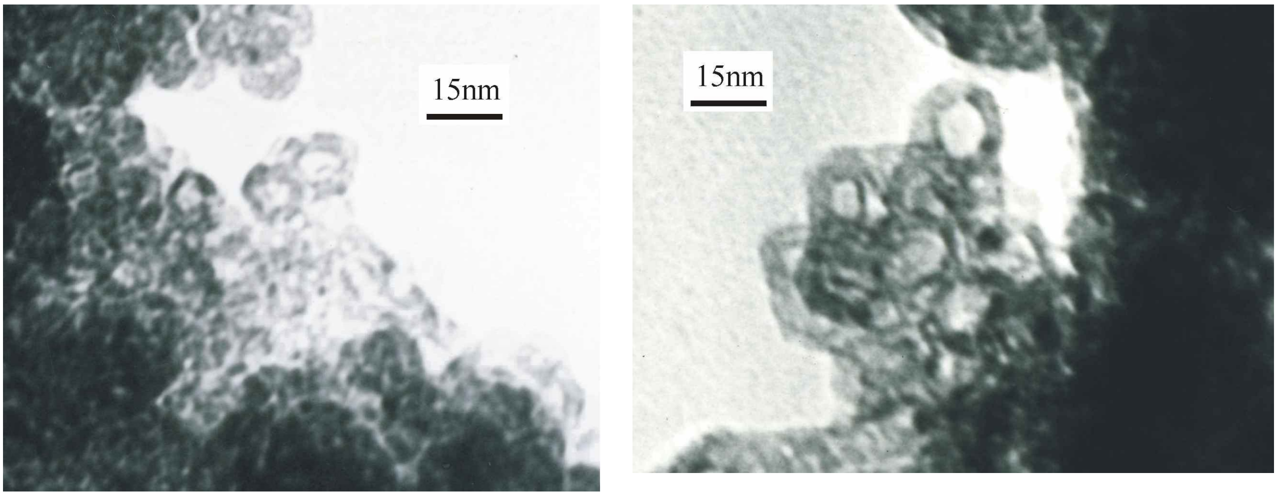


Fig. 3. Carbon nanostructures produced in liquid helium

Acknowledgement

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