

# THE HELICAL CARBON NANOTUBES

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## Introduction

The carbon microfibers observed in many products produced for the last 5-6- decades attract attention due to the discovery of fullerene. The single-wall nanotube is thought to be a graphene sheet rolled up in the tube. However, the nanotube (NT) may be a fullerene elongated in the tube. Both approaches are correct. There are many disputable moments in this field of knowledge.

The search of new, more effective methods for nanotube synthesis makes scientists perform the hundreds of experiments. It is difficult to list all the current methods which applied to produce this product. However, the problem on the large-scale controlled synthesis of carbon nanotubes is still unsolved. In this paper we represent the experiment that allowed preparation of helical multi-wall NTs 30-60 nm in diameter.

## Experimental

The pyrolytic apparatus designed in laboratory 67 in Institute for Problems of Materials Science of National Academy of Sciences of Ukraine, was used to synthesize the nanostructural carbon by catalytic pyrolysis.

The acetylene and toluene vapour were used as sources for carbon. The process was carried out in the quartz reactor on Ni-Cu catalysts in the nitrogen flow.

Electron microscopic investigations of the products were performed on a transmission microscope.

## Results and Discussion

In the temperature range of 600-1200 °C carbon NTs and fibers were synthesized both from acetylene and toluene vapour. In the course of NTs synthesis from toluene vapour at 880 °C the dark-brown condensate forms in the more cooled part of the reactor.

When acetylene passes through the reactor, this liquid reacts with the gas phase and turns into fume. The fume is collected by the liquid seal.

Electron microscopy of the product collected revealed (see Fig. 1) that the helical nanofibers 30-60 nm in diameter formed in the given experimental conditions. The

spirals have different configurations, they can be straight (Fig.1a,d), interweave (Fig.1a,e), form Y-like shapes (Fig.1e,f).

There exist two variants in the formation of such nanostructures. The straight nanotube twists under mechanical loading and elastic bending. The second way consists in the spiral formation during NT growth. It may be possible due to alternating the pair defects, pentagon-heptagon, on the hexagonal lattice. Pentagon will induce the positive curvature, and heptagon - the negative one. Each pair of defects may twist the tube at 0-36° angles [1].

It is difficult to conclude about the mechanism of nanotube formation observing the photographs. However, we consider that the tubular spirals formed in the course of nanotubes growth. The organic compound produced by toluene pyrolysis and admixed into acetylene has a stronger effect on formation of the helical shape than turbulent movement of the product-containing gas mixture and its quick quenching in the liquid seal.

The main feature of the product prepared is the fact that none of the tubular spirals is fixed by one of its ends on the catalyst and does not have catalytic particles on its ends what contradicts the concepts about the mechanism of NTs growth.

## **Conclusions**

The method for preparation of helical nanotubes 30-60 nm in diameter has been proposed.

Further investigations will help to refine the technology for the purposeful synthesis of nanotubes which have a helical shape with the certain diameter and the pitch.

## **References**

[1] Simonis P, Volodin A. Comparative study of a coiled carbon nanotube by atomic force microscopy and scanning electron microscopy. Kluwer Academic. 2000: 83-91.

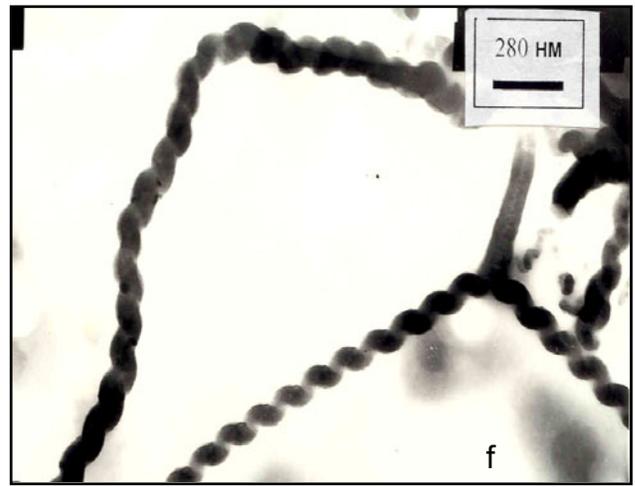
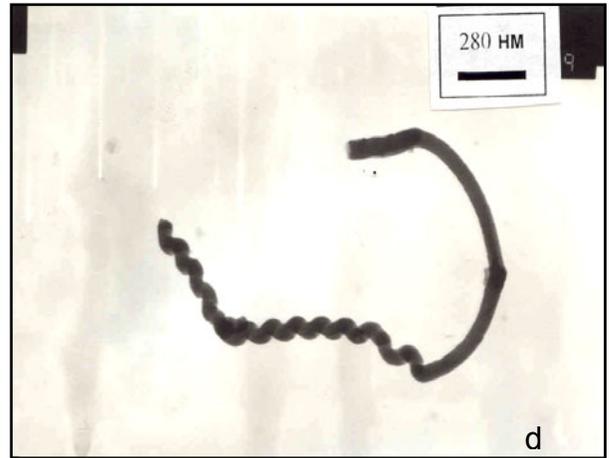
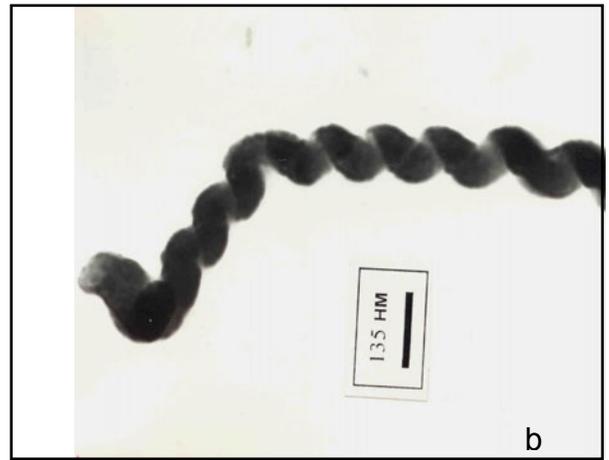
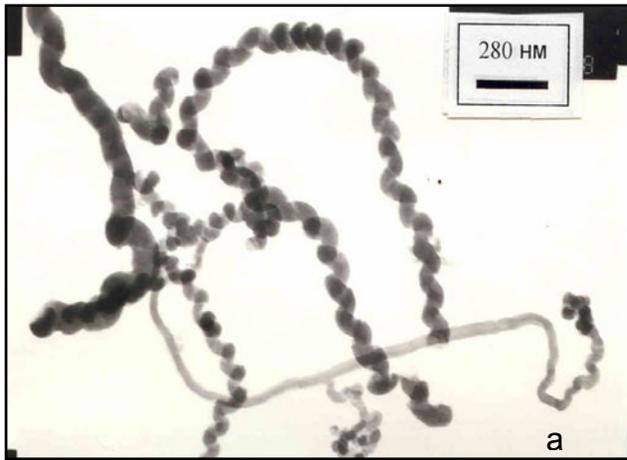


Figure 1. The transmission electron microscopy of synthesis products