# METHOD FOR SYNTHESIS OF HELICAL CARBON NANOTUBES

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## Introduction

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 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 NTs is still unsolved. In this report we represent the experiment that allowed preparation of helical multi-wall NTs 30-60 mn in diameter.

## Experimental

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

Acetylene and toluene vapor 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 $^{o}$C carbon NTs and fibers were synthesized both from acetylene and toluene vapor. In the course of NTs synthesis from toluene vapor at 880 $^{o}$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.) that helical nanofibers 30-60 nm in diameter formed in the given experimental conditions. The spirals have different configurations, they can be straight (Fig.a,d), interweave (Fig.a,e), form Y-like shapes (Fig.e,f).

There exist two variants in formation of such nanostructures. The straight NT 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$^{o}$ angles [1-23].

It is difficult to conclude about the mechanism of NT formation observing the photographs. However, we consider that the tubular spirals formed in the course of NTs 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

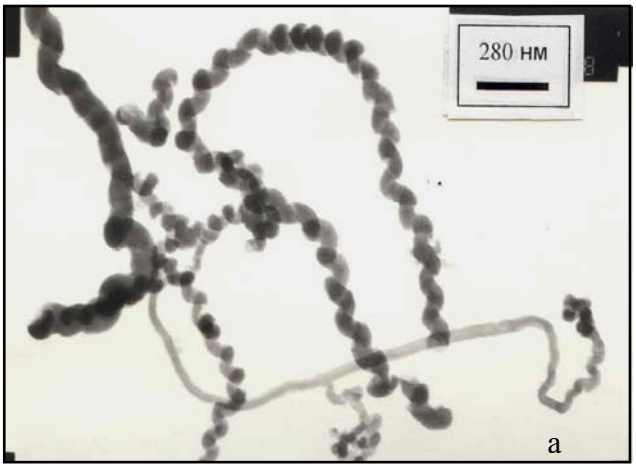
Method for preparation of helical nanotubes 30-60 nm in diameter has been proposed.

Furthes 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. Schur DV, Zaginaichenko S Yu, Adejev VM, Voitovich VB, Lyashenko AA, Trefilov VI; Phase transformations in titanium hydrides, International journal of hydrogen energy, 21,11,1121-1124,1996, Pergamon
2. Schur DV, Tarasov BP, Zaginaichenko S Yu, Pishuk VK, Veziroglu TN, Shul'ga Yu M, Dubovoi AG, Anikina NS, Pomytkin AP, Zolotarenko AD; The prospects for using of carbon nanomaterials as hydrogen storage systems,International journal of hydrogen energy,27,10,1063-1069,2002,Pergamon
3. Tarasov BP, Shul'ga Yu M, Fokin VN, Vasilets VN, Shul'ga N Yu, Schur DV, Yartys VA; Deuterofullerene C 60 D 24 studied by XRD, IR and XPS,Journal of alloys and compounds, 314,1,296-300,2001,Elsevier
4. Tarasov BP, Fokin VN, Moravsky AP, Shul'ga Yu M, Yartys VA, Schur DV; Promotion of fullerene hydride synthesis by intermetallic compounds, Hydrogen energy progress, 2, 1221-1230,1998,
5. Schur DV, Zaginaichenko S Yu, Matysina ZA, Smityukh I, Pishuk VK; Hydrogen in lanthan–nickel storage alloys,Journal of alloys and compounds,330,70-75,2002,Elsevier
6. Matysina ZA, Schur DV; Hydrogen and solid phase transformations in metals, alloys and fullerites, Dnepropetrovsk: Nauka i obrazovanie, 420p (in Russian),2002,
7. Matysina ZA, Pogorelova OS, Zaginaichenko S Yu, Schur DV; The surface energy of crystalline CuZn and FeAl alloys,Journal of Physics and Chemistry of Solids,56,1,9-14, 1995,Elsevier

8. Schur DV, Lavrenko VA, Adejev VM, Kirjakova IE; Studies of the hydride formation mechanism in metals,International journal of hydrogen energy,19,3,265-268,1994,Elsevier
9. Schur DV, Matysina ZA, Zaginaichenko S Yu; Theoretical study of interstitial atoms distribution in the bulk and at the surface of crystal. Surface segregation,Journal of alloys and compounds,330,81-84,2002,Elsevier
10. Schur DV, Matysina ZA, Zaginaichenko S Yu; Study of physico-chemical processes on catalyst in the course of synthesis of carbon nanomaterials,Hydrogen Materials Science and Chemistry of Metal Hydrides: Proceedings of the NATO Advanced Research Workshop on. Alushta Crimea, Ukraine, 16-22 September 2001,235,2002,Kluwer Academic Pub
11. Schur DV, Tarasov BP, Shul'ga Yu M, Zaginaichenko S Yu, Matysina ZA; Research of Fullerites Hydrogen Capacity,Hydrogen Materials Science and Chemistry of Metal Hydrides: Proceedings of the NATO Advanced Research Workshop on. Alushta Crimea, Ukraine, 16-22 September 2001,1,2002, Kluwer Academic Pub
12. Matysina ZA, Zaginaichenko S Yu, Schur DV, Pishuk VK; Theoretical investigation of isopleths of hydrogen solubility in transition metals,Journal of alloys and compounds, 330,85-88,2002,Elsevier
13. Trefilov VI, Schur DV, Pishuk VK, Zaginaichenko S Yu, Choba AV, Nagornaya NR; The solar furnaces for scientific and technological investigation, Renewable energy, 16,1,757-760, 1999, Elsevier
14. Трефилов ВИ, Щур ДВ, Загинайченко СЮ; Фуллерены-основа материалов будущего, 2001, Laboratory 67
15. Schur Dmitry V, Zaginaichenko Svetlana Yu, Veziroğlu T Nejat, Javadov NF; The Peculiarities of Hydrogenation of Fullerene Molecules C60 and Their Transformation, Black Sea Energy Resource Development and Hydrogen Energy Problems,191-204,2013, Springer Netherlands
16. Schur DV, Dubovoi AG, Anikina NS, Zaginaichenko S Yu, Dobrovol'skij VD, Pishuk VK, Tarasov BP, Shul'ga Yu M, Meleshevich KA, Pomytkin AP; The production of utrafine powders of fullerites by the salting out method,Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Alushta-Cremia-Ukraine, September, 16-22, 2001,
17. Kharlamov AI, Loytchenko SV, Kirillova NV, Kaverina SN, Vasilev AD, Fomenko VV, Zolotarenko AD, Kazimirov VP; Tubular and filamentous nanostructures of hexagonal silicon carbide, Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine, 572-574,2001,
18. Slys IG, Berezanskaya VI, Schur DV, Zaginaychenko SYu, Rogozinskaya AA, Adejev VM, Zolotarenko AD; Making the point metal coatings on the particles of hydride-forming intermetallides, Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine,404-405,2001,
19. Muratov VB, Meleshevich KA, Bolgar AS, Zolotarenko AD; Application of dynamic c-calorimetry method for investigation of enthalpy at hydride dissociation,Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine,342-343,2001,
20. Anikina NS, Schur DV, Simanovskiy AP, Zolotarenko AD, Dubovoy AG, Ivanchenko NV; Problem on fullerene production by electric arc method, Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine,590-591, 2001,
21. Pishuk VK, Schur DV, Bogolepov VA, Savenko AF, Zaginaichenko SYu, Zolotarenko AD, Mar'yanchuk IV, Prikhod'ko AB; Problem on production of highly dispersed extra pure powders, Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine,586-587,2001,
22. Lavriv LV, Anikina NS, Simanovskij AP, Zolotarenko AD, Schur DV; Features of fullerene extraction wth toluene, Proceedings of VII International Conference "Hydrogen Material Science and Chemistry of Metal Hydrides", Ukraine,596,2001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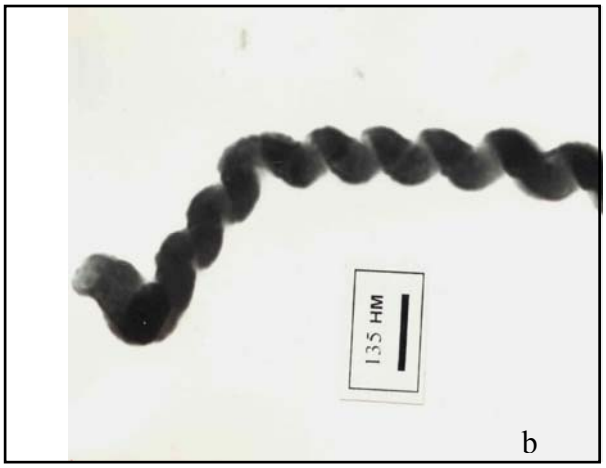
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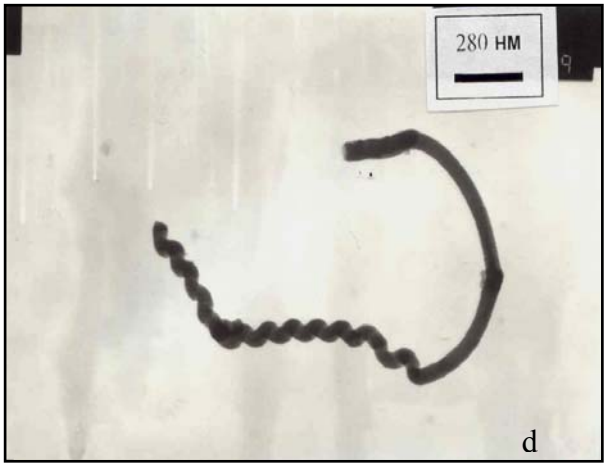
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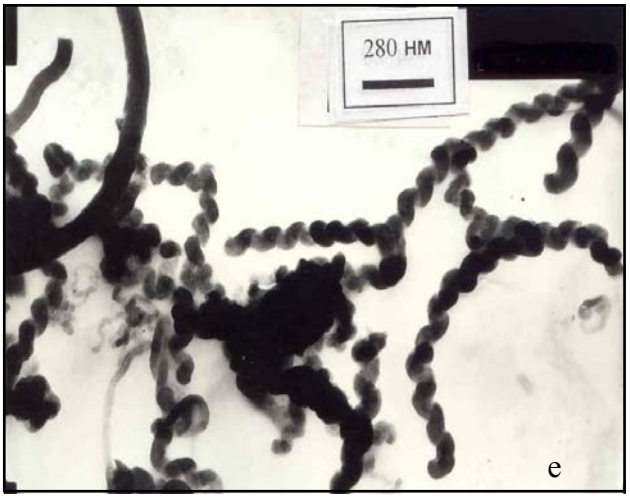
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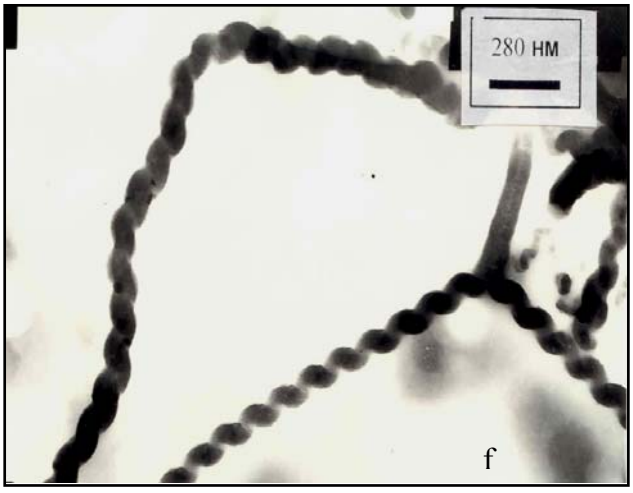
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