SYNTHESIS OF NANOTUBES IN THE LIQUID PHASE

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Introduction

In connection with the discovery of fullerenes, the work performed to produce fine metal powders, began in 80th of the last century by A.G.Dubov et al. [1-2], has an original continuation.

In the first work it was supposed that the fine particles resulted from the arc metal sputtering might change their properties depending on the synthesis conditions.

In their work [3-23] authors sum up investigations performed for ten years in Institute for physics of metals of National Academy of Sciences of Ukraine. It was noted that the arc parameters and the nature of the medium for synthesis affected the structure and properties of particles. Changing conditions for synthesis, one can change in the wide range properties of the product.

The work presented seeks to verify the hypothesis for possibility of carbon nanotube synthesis in the liquid medium which is a source for carbon.

Experiment

The technique of electric-spark metal sputtering (ESS) mentioned above has been used to verify this hypothesis. The original appararus designed in laboratory 67 in Institute for Problems of Material Science of National Academy of Sciences of Ukraine has been used.

According to [4], the main positive moments of the method used are:

1. High temperature in the arc zone - ~4000 ^{o}C.
2. High cooling rate of sputtered products - 10^{9}-10^{14} ^{o}C/c.
3. High dispersion level. The size of the particles produced is 1-100 nm.
4. High rate of nucleation at the low rate of the particle growth.

All these conditions are in a good agreement with conditions for synthesis of fullerenes and nanotubes by the arc graphite sputtering. Experiments have been performed in C_2H_5OH, benzene, toluene and hexane.

The reaction products have been analyzed using scanning and transmission microscopes.

Results and discussion

As authors supposed proceeding from the generally accepted concepts of mechanisms of the carbon nanotube growth, the dispersed nickel sputtered must catalyze the growth of these nanotubes. The source for carbon should be carbon from the hydrocarbon that transforms into the vaporous state in the arc zone. It was supposed to prepare single-wall nanotubes on the nickel particles 1-10 nm in size, and the layer of nanotubes up to 1 μm thick on the larger nickel particles.

Electron-microscopic studies have indicated that carbon nanotubes did not form on the nickel particles in the media chosen (Fig.1, a,b - alkohol, c,d,e,f - toluene, g,h - hexane).

However, when hydrocarbons mixed, carbon nanotubes up to 100 nm in diameter form on the surface of nickel microparticles. Nanotubes are not perpendicular to the surface (as after pyrolysis), but they are parallel to it. Tubes on the surface of particles form the continuous net (Fig.2,3).

In these conditions the carbon core sputtering has resulted in the solution which resemble fullerene extracts by color. We have failed to extract fullerenes from the mixture prepared chromatographically.

Conclusions

All the results obtained are of scientific and practical interest. The materials prepared require further investigations. The method proposed may be one of the most effective method to synthesize fullerenes and nanotubes.

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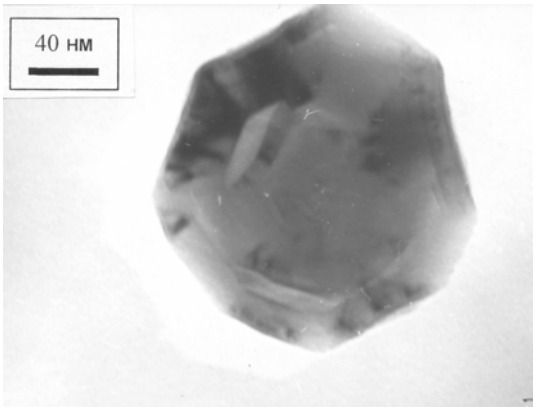

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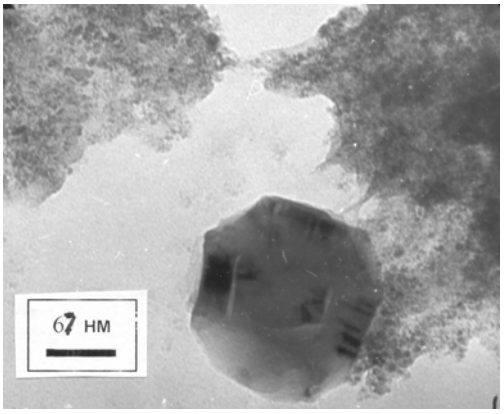

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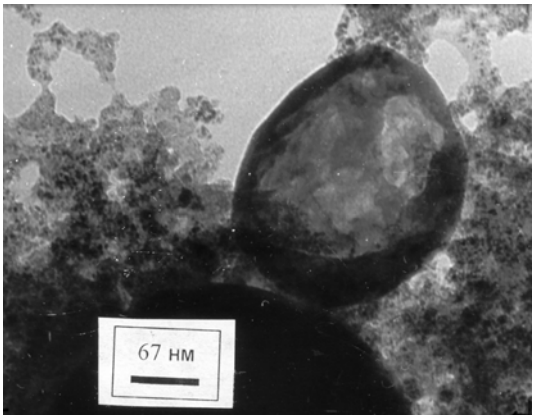

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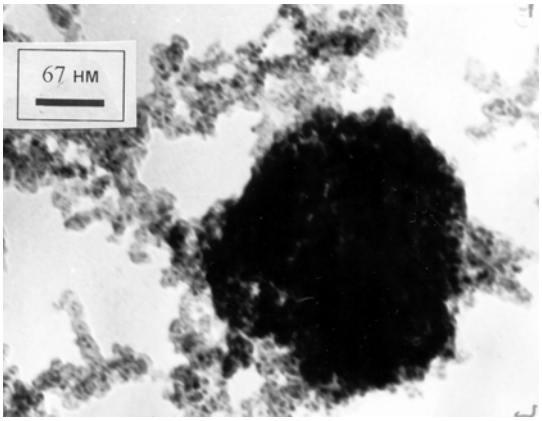

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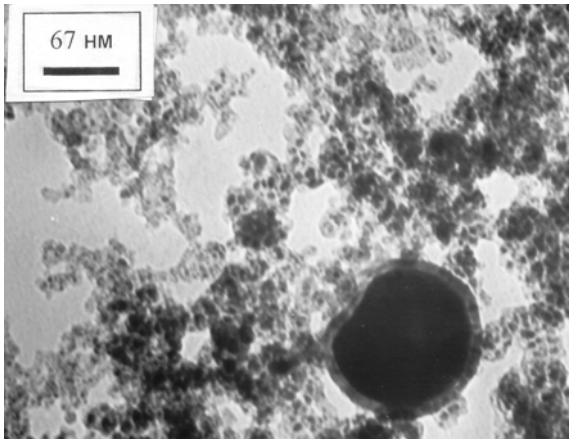

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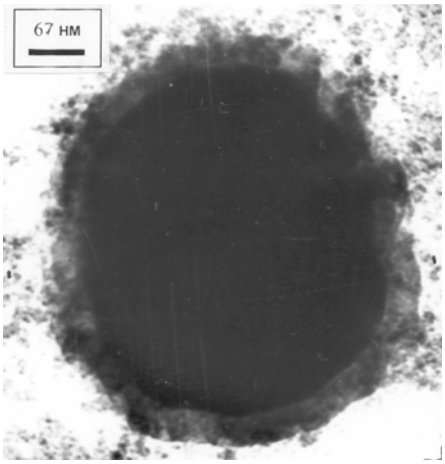

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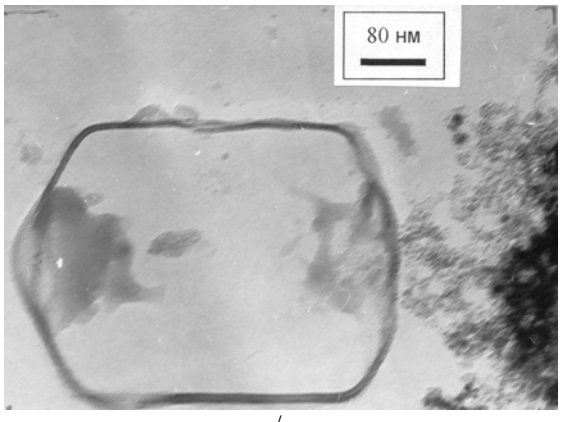

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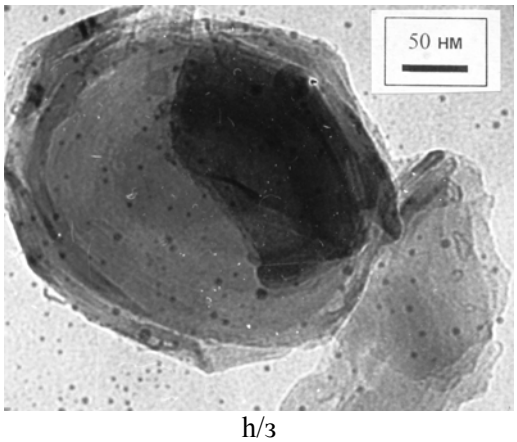

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Fig. 1/Рис. 1.

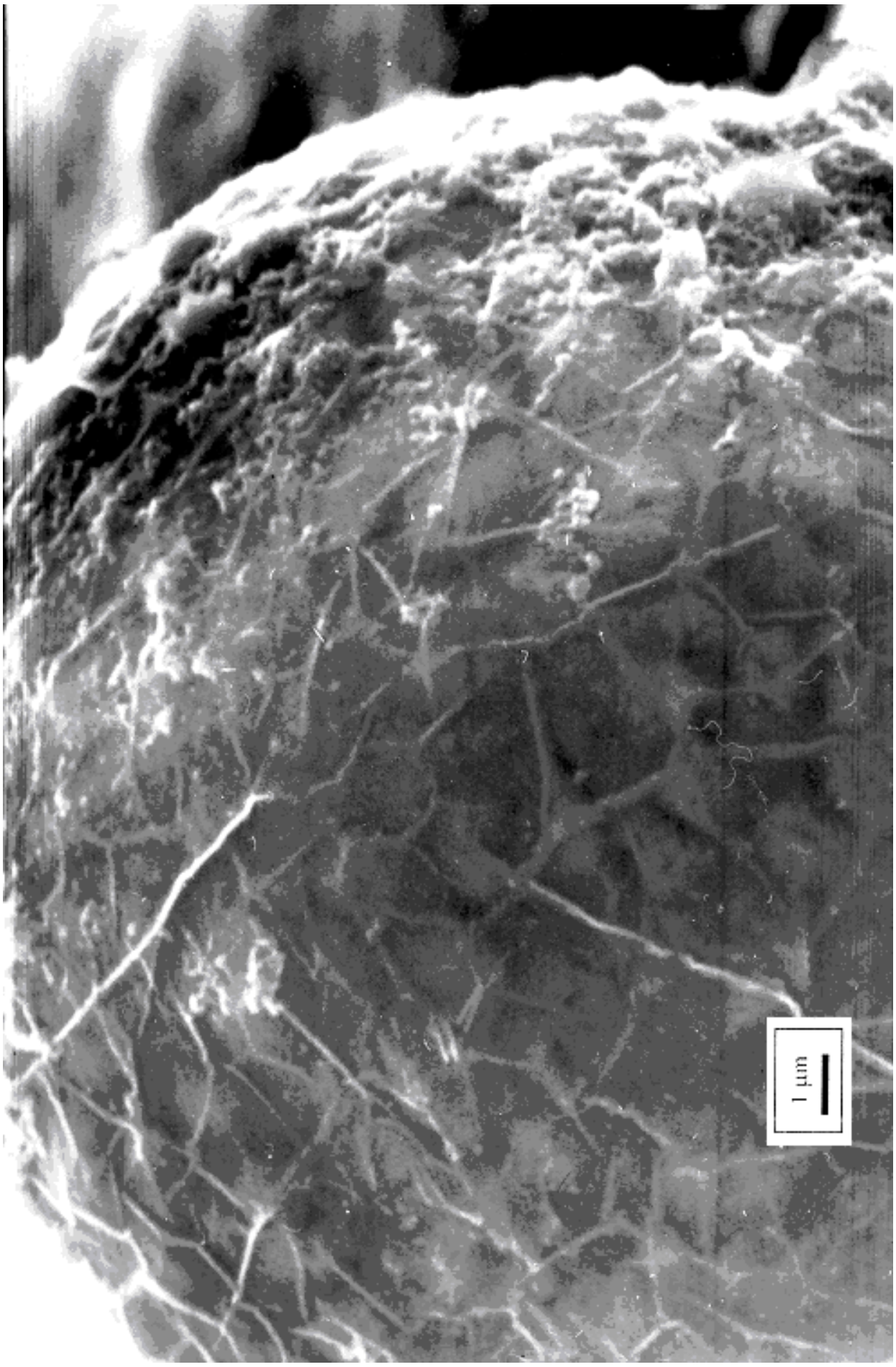

Fig. 2/Рис. 2

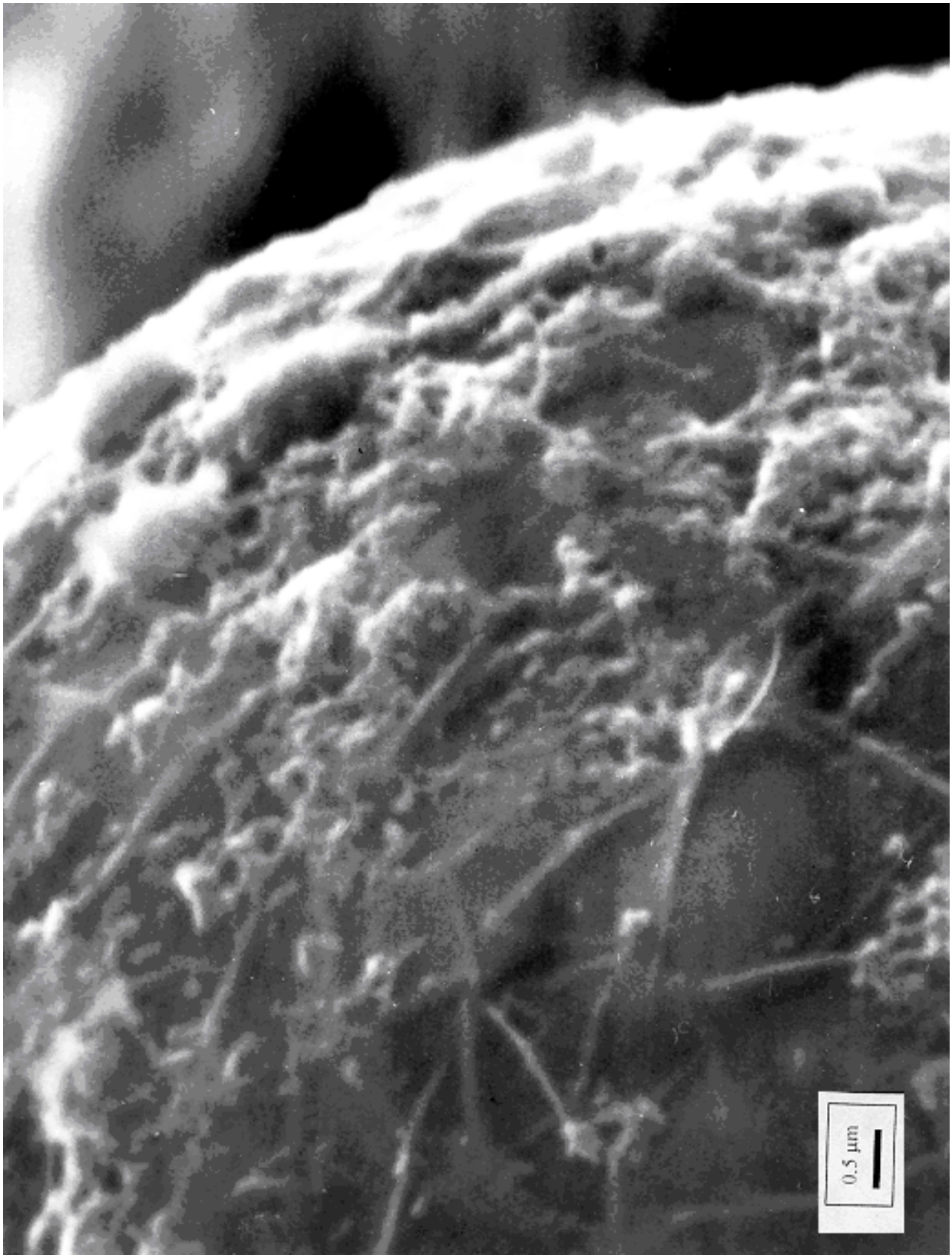

Fig. 3/Рис. 3