Screwed Polygonized Scroll-Shaped Multiwall Nanotubes.

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Carbon films containing the needle-like multy-wall nanotubes (MWNT) (0.5-2 μm in length) besides the graphitic scales were prepared on the flat silicon or nickel substrates from hydrogen-methane gas mixture activated by dc plasma[1,2]. Here we present carefull investigation of the structure of the films with SEM and TEM.

Regularly needle-like tubes have the diameter of 10-50 nm while the size of internal channels varies within 2-10 nm. The most of tubes have at their ends or even in the middle one or several thin graphitic sheets tangentially attached to their side surfaces. The tips of needle-like nanotubes are not closed at the manner typical for MWNT prepared in arc discharge, which are usually closed with cup-like structures. In contrast to arc-discharge MWNY the ends of needle-like tubes are presented by wrinkled graphene sheets or flattened out tubule walls.

Some tubes have periodic contrast spots situated on the both walls along their axe. Dark field images show that sharp contrast spots in the bright-field images can be attributed to the (002) reflections of graphite. The presence sharp and intensive spots of (101) and (103) reflexes of graphite are evidence of the high order of mutual orientation of graphene layers. The tilting of the tubules around their axe leads to the dark sports movement along the tube image. The high-resolution image of the region of the high contrast spot allowed to see sharp contrast lines corresponding to the graphitic layers on one side of tube and weak contrast on the other side. All these data are characteristic of tubes of polygonal cross-section which are formed by rolling single graphene sheet. With the use of electron diffraction patterns of single tubules the modules of their chiral angles were measured. It should be mentioned that each polygonized tube is characterized by its own chiral angles as well screwing angles and number of flat poligone planes.

The film materials exhibit excellent field emission properties with the threshold average electric field of 1.5 V/μm, emission current density higher than 10^7 cm^{-2} at the average field of 5 V/μkm. The high efficiency of the field emission is explained in terms of rehybridization of interatomic bonds from sp^2 to sp^3 for atoms located at the bends of graphene sheets. Simultaneously, the energy barrier decreases due to this effect. The enhancement of the effective field on the ends of tip-like surface structures leads to the lowering of the field threshold, observed experimentally[1,2].

Fig.1. TEM image of carbon film produced in DC discharge in methane-hydrogen atmosphere.

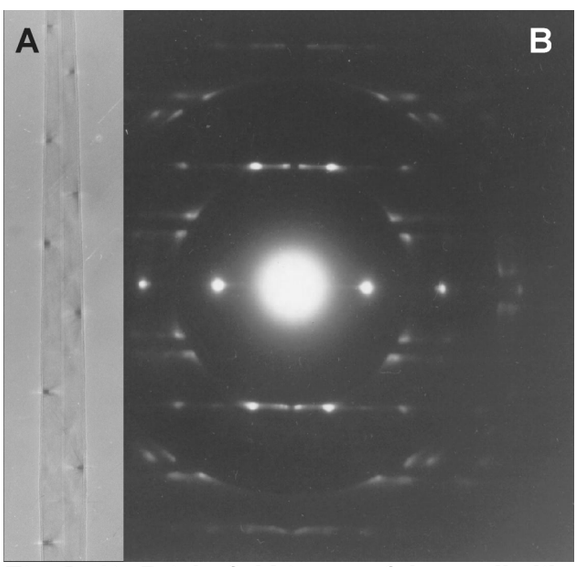

Fig. 2. ***A)****. Bright-field image of the needle-like nanotube with different pitch of periodical contrast,* ***B)*** *diffraction pattern.*

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References.

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