INFLUENCE OF THE FREQUENCY OF THE PULSE PLASMA GENERATOR ON THE PARAMETERS OF CARBON NANOTUBES [[1]](#footnote-1)\*)

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The method of plasma enchanced chemical vapor deposition (PECVD) is the most promising method for producing carbon nanotubes (CNTs) for instrument applications. It is characterized by such advantages as the possibility of the formation of carbon nanotubes at the catalytic centers (CC) in predetermined places on the substrate, synthesis at low temperatures, and the ability to vary the geometric parameters of carbon nanotubes in a wide range [1]. An analysis of the literature shows that the parameters of the plasma generator initiated at the stage of activation of the catalytic centers and the growth of CNTs, such as frequency, power, waveform, affect the geometric parameters of the grown CNTs [2]. These dependences require additional research in order to establish patterns of controlled growth of CNTs for instrumentation applications, in particular, the creation of gas sensors [3]. In this work, experimental studies of the influence of the plasma generator frequency on the parameters of the formed CNT arrays in the Ni / Cr / Si structure are carried out.

A Si (100) substrate with deposited Cr and Ni films 100 and 10 nm thick, respectively, was used as the initial structure for the growth of CNTs. To generate a plasma initiated perpendicular to the surface of the sample by applying a voltage between the capacitor plates formed by the heating table with the sample and a metal gas duct above it, a Pinnacle Plus + (Advanced Energy) power supply was used, the frequency range of which is to control the frequency of rectangular pulses of 0-350 kHz.

At a plasma generator frequency of 0 Hz (direct current), CNTs grow with an average diameter of 55 ± 21 nm. In this case, CNTs are well oriented; only a slight deviation from the growth direction perpendicular to the substrate is observed. With a gradual increase in the frequency of the plasma generator (up to 70 kHz), the separation of the tubes in the array into thicker (84 ± 17 nm) and tubes of smaller diameter begins to appear. In this case, the former are still formed predominantly vertical, however, they begin to acquire periodic fractures. At the same time, thinner tubes begin to lose their “vertical” position, and their number decreases. With a further increase in the frequency of the plasma generator to 140-350 kHz, the ongoing disorientation of the growth of CNTs is observed, randomly located tubes predominate in the array, which may be due to insufficient exposure time of the discharge plasma to create the conditions for directed growth of CNTs.

The results showed that by changing the plasma frequency it is possible to directly influence their geometric parameters during the growth of CNT arrays. These results can be used to create sensitive elements of CNT-based gas sensors.

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References

1. Q. Zhao, Z. Xu, Y. Hu, F. Ding, J. Zhang, “Chemical vapor deposition synthesis of near-zigzag single-walled carbon nanotubes with stable tube-catalyst interface”, Sci. Adv., Vol. 2: e1501729, 2016.
2. K. Moore , D. Tune , B. Flavel, “Double-Walled Carbon Nanotube Processing”, Adv. Mater., Vol. 27, pp. 3105–3137, 2015.
3. A. Bandodkar, I. Jeerapan, J. Wang, Wearable Chemical Sensors: “Present Challenges and Future Prospects”, ACS Sens., vol. 1 (5), pp. 464–482, 2016.

1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/XLVII/Pt/ru/GT-Rudyk.docx) [↑](#footnote-ref-1)