SYNTHESIS OF CARBON NANOSTRUCTURES BY THE METHOD OF LOW-TEMPERATURE CVD IN THE PRESENCE OF ELECTRIC FIELD

B.S. Medyanova[1-3*], G. Partizan[1-3], B.Z. Mansurov[2,3], A.K. Kenzhegulov[2,3], G.S. Suyundykova[1-3], B.A. Aliyev[1,2]

[1]Al-Farabi Kazakh National University, 050040, al-Farabi ave. 71, Almaty, Kazakhstan
[2] National Nanotechnological Laboratory of open type, 050012, Al-Farabi KazNU, Almaty, Kazakhstan
[3] Center for Innovative Technologies of the Institute of combustion problems, 050050, Polezhaeva str. 20, Almaty, Kazakhstan *E-mail: bmedyanova@gmail.com

Abstract. Trial experiments on the synthesis of carbon nanostructures on the copper buffer layer by the method of low-temperature thermal chemical vapor deposition in the presence of electric field were performed. The morphology and structure of the obtained samples were investigated by the methods of scanning electron microscopy and Raman spectroscopy. As a result of the experiments, the optimal technological parameters for the synthesis of carbon nanostructures under the influence of electric field were determined.

Introduction

In recent years, carbon nanomaterials with different shapes such as carbon nanotubes, nanospheres, nanofibers, and graphene have been widely investigated due to their peculiar properties that are a function of their structure, thus finding in turn applications in different fields [1]. The carbon nanomaterials with their excellent properties are ideal candidates for advanced applications in the area of electronics, membranes, wastewater treatment, batteries, capacitors, heterogeneous catalysis, as well as biological and medical sciences [2].

Different methods have been used for the synthesis of carbon nanotubes, such as chemical vapor deposition (CVD), plasma enhanced chemical vapor deposition (PECVD) alcohol catalytic chemical vapor deposition (CCVD), hydrothermal or sonochemical reaction, and high-pressure CO conversion (HiPco) [1]. The CVD method for obtaining carbon nanotubes (CNTs) has such advantages as a high yield of nanotubes and the possibility of synthesis at low temperatures (550-1000 ° C), which makes the process less expensive and more accessible for laboratory applications [2].

The growth of CNTs in the presence of electric fields was previously studied by many authors and there is a tendency to growth in the direction of the field in all cases [3]. It was studied that the electric field also has a significant effect on the chemical purity, morphology and yield of CNTs [4,5].

Experimental

The details of carrying out experiments by low-temperature CVD method in the presence of electric field was described in [6]. The time of deposition of the copper film varied from 30 s to 3 min. The experiments were carried out at various voltages on copper electrodes and the orientation of silicon wafers.

To determine the effect of the electric field, experiments were carried out with a voltage of 0 to 800 V. The pressure in the chamber and synthesis temperature remained constant at 300 mbar and 300 °C, respectively. The obtained samples were studied by SEM and Raman scattering (RS).

Investigation of the samples was carried out in the National nanotechnological laboratory of open type using spectrometer NT-MDT NTegra Spectra (laser wavelength λ = 473 nm) and microscope Quanta 3D 200i.

Results and discussion

The preliminary experiments carried out in [6] have shown that carbon nanostructures (CNs) are synthesized at low deposition times, whereas no growth occurs during prolonged deposition. Thus, samples sputtered at 30 s and 1, 2, 3 min were selected for further experiments. The study of the influence of the thickness of the copper buffer layer on the nucleation and growth of CNs showed that the most interesting results are shown by samples with deposition time of 3 min.

Figure 1 shows SEM images of these samples obtained at different values of the applied voltage. It can be seen from the figures that arrays of vertically aligned nanofibers were synthesized on all samples. Copper clusters are mainly located inside the growing fibers, in most cases in the middle. One can also notice that after a while a film forms on the surface of the fibers (Figures 1a, d), which in some cases prevents their growth, while in others it serves as a boundary between oriented and randomly growing nanofibers. Comparison of the figures shows that an increase in the voltage on the substrates leads to a decrease in the diameter of the synthesized CNs.

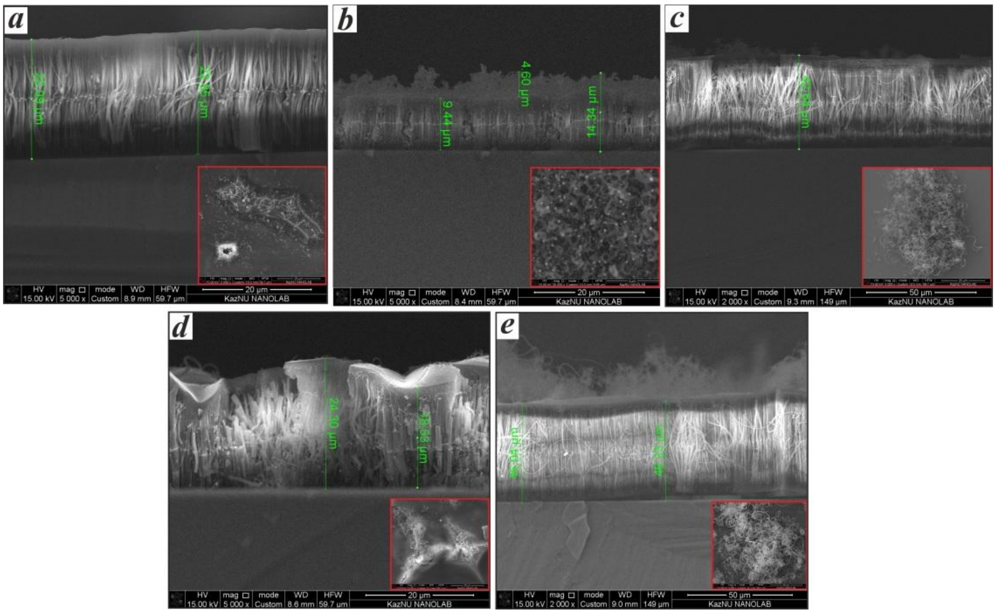

Figure 1 - SEM images of the cross section and surface (inserts in the lower right corner) of samples obtained on copper films with orientation [100] sputtered for 3 min at: a) 0 V, b) 200 V, c) 400 V, d) 600 V and e) 800 V.

The obtained samples were also investigated by the method of Raman spectroscopy. All samples predominantly exhibit the same spectrum. Figure 2 shows the spectrum of nanostructures synthesized at 200 V. Two main carbon peaks D and G are observed in the spectrum (Fig. 2) in the region of 1334.5 and 1598.5 cm^{-1}, respectively. The intensity of D peak is lower than that of G peak, which indicates a sufficient ordering of the sample. The second order peaks 2D and D + G are observed at 2655.6 and 2932.4 cm^{-1} in the high-frequency region of the spectrum, which also confirms the foregoing. According to the three-stage model of Ferrari and Robertson, the synthesized samples are carbon fibers with an amorphous structure [7].

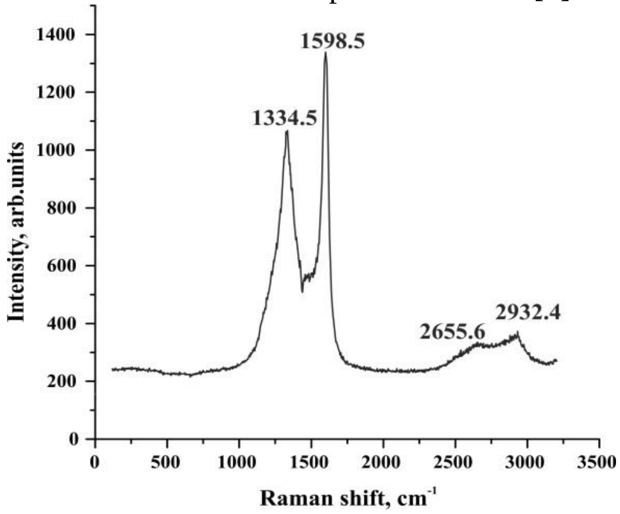

Figure 2 - Raman spectrum of sample obtained on a copper film with orientation [100] with a voltage of 200 V, sputtered for 3 min

The analysis of the obtained results showed that the optimum value of the electric field voltage for synthesis of array of nanofibers is 800 V.

Conclusion

In the course of the experiments, the effect of the electric field on the growth of carbon nanostructures at low temperatures was investigated. SEM studies showed that arrays of vertically aligned carbon nanofibers were synthesized at each voltage value on the substrates. In most cases, copper clusters are located in the middle of growing fibers. Analysis of the Raman spectra showed that the obtained nanofibres have an amorphous structure. It was found that the optimal value of the applied voltage for obtaining an aligned array of nanofibers is 800 V. The obtained samples will be further investigated by IR spectroscopy, X-ray diffraction and transmission electron microscopy for deeper study of the structure and understanding of the growth mechanism. Further research will be aimed at determination of technological parameters, under which the array of vertically aligned CNTs will be synthesized.

This work was performed with financial support of grants of Committee of Science of the Ministry of Education and Science of Republic of Kazakhstan IRN AP05132865.

References

1. Jia Z., Kou K., Qin M., Wu H., Puleo F., Liotta L.F. Controllable and Large-Scale Synthesis of Carbon Nanostructures: A Review on Bamboo-Like Nanotubes // Catalysts. – 2017. – Vol.7, I. 256. – P. 1-21.
2. Manawi Y.M., Ihsanullah, Samara A., Al-Ansari T., Atieh M.A. A Review of Carbon Nanomaterials’ Synthesis via the Chemical Vapor Deposition (CVD) Method // Materials. – 2018. – Vol. 11, I. 822. – P. 1-36.
3. Plaza E., Briceno-Fuenmayor H., Are´valo J., Atencio R., Corredor L. Electric field effect in the growth of carbon nanotubes // J. Nanopart. Res. – 2015. – Vol. 17, I. 246. – P. 1-11.

4. Bhoraskar S.V. et al. Effect of a focusing electric field on the formation of arc generated carbon nanotubes // Nanotechnology. – 2006. – Vol.17. – P. 5895–5902.

5. Bhoraskar S.V. et al. A new approach towards improving the quality and yield of arc-generated carbon nanotubes // J. Phys. D: Appl. Phys. – 2007. – Vol. 40. – P. 4829–4835.

6. Medyanova B.S., Partizan G., Mansurov B.Z., Kenzhegulov A.K., Suyundykova G.S., Aliyev B.A. Investigation of the influence of electric field on the growth of carbon nanostructures // Bulletin of the Kazakh-British Technical University. – 2018. – V. 16, No. 2. – P. 22-27 (in Russian).

7. Ferrari A.C., Robertson J. Raman spectroscopy of amorphous, nanostructured, diamond-like carbon and nanodiamond // Phil. Trans. R. Soc. Lond. A. – 2004. – V. 362. – P. 2477–2512.