Conference Paper

Formation of Structured Graphite Layers for Hetero-epitaxial Graphene Synthesis

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Abstract

The results of experiments on the deposition of structured graphite layers in a glow discharge with a hollow cathode on Ni(111) substrate, which is a promising matrix for hetero-epitaxial synthesis of structurally homogeneous graphene, are described. The technique shows good repeatability. The resulting layers of nano-crystalline graphite have good homogeneity, high field emission, a lot of 'needles' of vertically growing graphene on its surfaces.

Keywords: graphene, hollow cathode, glow discharge, nc-graphite

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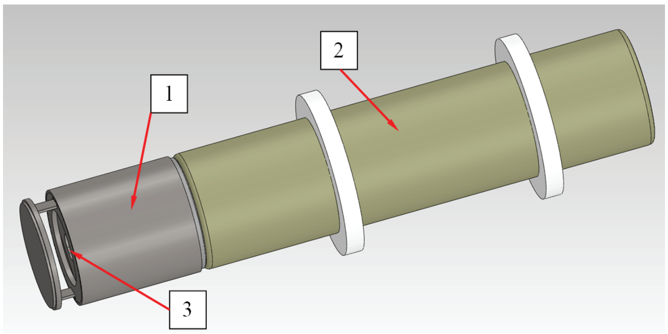
1. Introduction

Graphene is one of the promising materials of a wide range of applications due to its unique electrical, optical and mechanical properties. Most properties and their applications are described in detail in [1–4]. Now, the obtaining methods of the graphene [5] are actively being developed, such as mechanical [6–9] and chemical [10–11] layering of graphite, CVD methods [12], plasma deposition [13], epitaxial synthesis on various substrates [14–26]. However, a critical problem remains the controlled synthesis of homogeneous structurally perfect single-crystal graphene films for nanoelectronics.

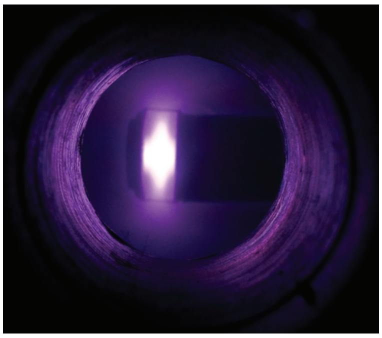
This work is connected with the development of the deposition method of the structured graphite on the Al_2O_3/Ni(111) interface for further obtaining the single-layer and multilayer graphene with a minimum density of defects of the crystal structure on a single-crystal sapphire substrate by the method of hetero-epitaxial synthesis. At the present stage, a technique has been developed for depositing layers of structured carbon on the surface of the Ni monocrystalline.

2. Method of Coating

The deposition of graphite layers on the substrates is carried out in a glow discharge with a hollow cathode in an atmosphere of a carbon-containing gas. The model of the cathode/sample holder and the photo of the discharge are shown in Figure 1.



(a)



(b)

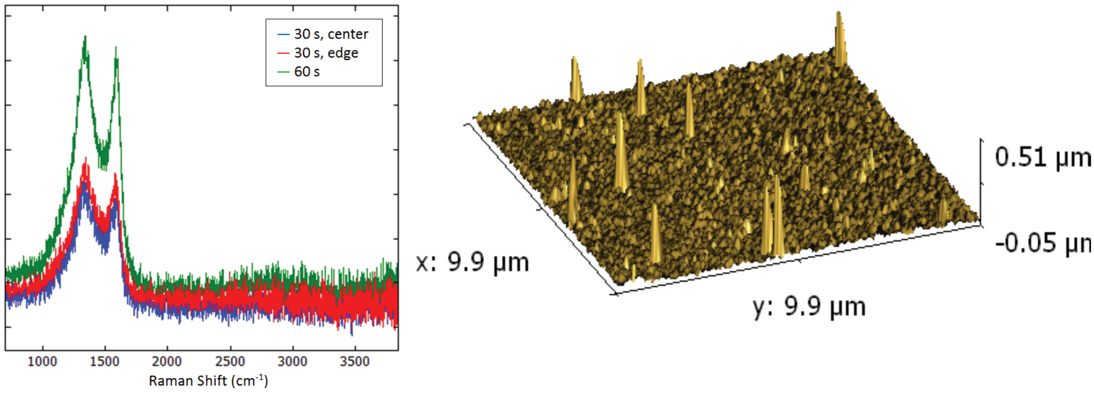
Figure 1: The sample holder/cathode (a) and the appearance of the discharge (b): 1 – electrode/sample holder, 2 – ceramic tube, 3 – sample.

The samples of Al_2O_3/Ni(111) are placed into the vacuum chamber pumped to a pressure of 0.001 Pa. Then, the sample is annealed in a hydrogen atmosphere at a pressure of 1 Pa and a temperature > 300°C for 30 minutes. Next, a carbon-containing gas is injected to a pressure of 10 Pa; the glow discharge with a hollow cathode (Figure 1(b)) is ignited. The layers of structured graphite are deposited during 10–60 seconds (the thickness of the layers is from 200 to 800 nm). The phase of the deposited graphite strongly depends on the temperature of annealing the samples, the temperature during the deposition and the cooling rate. In our case, the optimum temperature during the deposition was 700°C, the cooling rate was 40°C/min, which were obtained experimentally.

3. Experimental Results

Analysis of the structure, thickness and uniformity of the resulting layers is carried out using Raman spectrometer (RS) RamMics and the atomic force microscope (AFM) SmartSPM. The thickness of the layers used for the further synthesis of graphene is 200–700 nm with an average roughness of 1.5–15 nm. Examples of analysis of deposited layers are shown in Figure 2.

The crystal structure of the samples is uniform in accordance with the measurements RS and corresponds to nanocrystalline graphite [27]. Also, there are a lot of vertically growing graphene planes on the surface found by AFM. The thickness of the



(a) (b)

Figure 2: Raman spectra of the deposited carbon layer (a) and atomic force microscope topographical scan of the carbon surface (b).

planes is less than the thickness of the AFM probe (Figure 2(b) shows the result of AFM image convolution).

Nanocrystalline graphite is a promising field emission material for manufacturing, for example, field emission cathodes. In our case, it is assumed that the presence of vertically growing graphene will increase the emission current. The study of the emissivity of test samples showed that it has a current density 900 μA/cm^2 at the electric field strength of 10 kV/mm, which is comparable with the values for modern samples of the field emission cathode. The measured field emission is stable, without hysteresis.

4. Conclusions

The technique for the formation of nanocrystalline graphite layers by depositing carbon from the gas phase due to the hollow cathode discharge onto the Al_2O_3/Ni(111) interface has been developed for further processing of hetero-epitaxial synthesis of structurally homogeneous graphene for nanoelectronics. The method showed good repeatability confirmed by RS and AFM measurements. The field electron emissivity of the obtained nc-graphite is also measured. The current density is comparable with the values for modern samples of the field-emission cathodes, so it makes possible to use a similar material for manufacturing field emission cathodes.

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