Technology and characteristics of the transistor with a channel based on graphene

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Abstract. In this article we have studied the current-voltage characteristics of the graphene-based transistor. The test structure of graphene transistor was fabricated with the back gate. Graphene has been produced by chemical vapor deposition, and then transferred to the silicon dioxide on a silicon wafer. The channel of the transistor has been formed by etching in oxygen plasma through a photolithographic mask. Metals electrodes of the drain, source and gate were deposited by resistive evaporation in a vacuum. It was used titanium / gold with a thickness of 20/200 nm. In the case of the back gate, silicon dioxide was used, obtained by thermal oxidation of the silicon substrate. The field effect was demonstrated. With IV curves graphene parameters were defined.

1. Introduction

The unique properties of opened in 2004 2D material - graphene such as high mobility of charge carriers (theoretically up to 100 000 cm^2 / V·s), ideal electron-hole symmetry and line intersecting the zone at the Fermi level, defining the massless behavior of electrons, make it useful for various applications in solid state electronics and photonics [1-3]. The use of graphene as a channel of the transistor allows reaching the terahertz frequency range [4-6], as the threshold of the device is proportional to the frequency of the carrier mobility. To date, individual research groups obtained field-effect transistors with a channel based on graphene frequency range of more than 100 GHz [7-10]. However, in practice, the actual mobility of the samples of graphene films on the substrate is in the range from 100 to 10 000 cm^2 / V·s [9-11]. However, the unique properties of graphene, on the other hand, are a limiting factor in the production of transistors based on it. One of the main problems in the formation of such devices is the problem of preserving the possibility of effective management of the flow of charge carriers - field effect.

In this paper, a study of the current-voltage characteristics of the transistor structures with conduction channel based graphene film in order to obtain its basic parameters.

2. Experimental details

Graphene film was obtained by the method of chemical vapor deposition (CVD) at atmospheric pressure to a substrate of copper foil 60 microns thick, using methane as a hydrocarbon precursor. The synthesis was carried out at 1050 °C as a carrier gas was a mixture of argon and hydrogen. After synthesis process, copper foil is dissolved in a solution of $FeCl_3$. After washing in distilled water graphene film was transferred to the SiO2/Si substrate with a thermally formed oxide thickness of 300 nm [12].

Back gate contact to the silicon oxide film represented by a continuous metal layer to the reverse side of the plate. SiO2 film at the same time played the role of the lower gate dielectric. Graphene film etching to form a transistor structure was conducted in an oxygen plasma (200 W, 6 minutes) by the Diener Nano. Metal contacts drain, source and gate Ti/Au (20/200 nm) deposited by electron beam evaporation in Kurt J. Lescker PVD 250. The operating pressure in the chamber was $2{\cdot}10^{-7}$ torr. The resulting resistance of ohmic contacts defined by the test proposed in [13], was $5.6{\cdot}10^{-5}$ Ohm·cm^2. The resulting structure is shown in Figure 1.

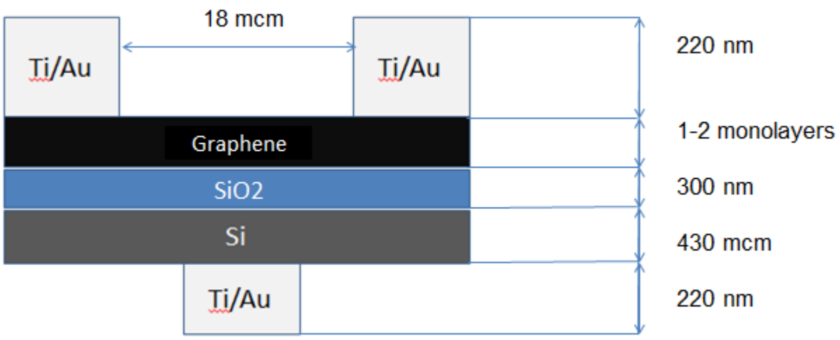

Figure 1. Schematic profile of the test channel transistor based on graphene film

3. Results and discussions

The study was carried out on the current-voltage characteristics of the installation of Agilent B1500, equipped with a manual probe station EP6 company Cascade Microtech.

To determine the necessary parameters for the current expression has been used:

$$I_d = \frac{W}{L} e \mu_0 n_s V_{ds}, \tag{1}$$

where W, L – the width and length of the channel, μ_0– mobility, e – the electron charge,V_{ds} – drain-source voltage, n_s – the concentration of charge carriers in the channel. The concentration of charge carriers in the channel was calculated using the 2 models: approximate the classic formula, and accurate, taking into account the state of the surface. The approximate formula is:

$$n_s \cong \sqrt{n_0^2 + \frac{C_{ox}^2}{e^2}\left(V_g - V_{NP}\right)}, \tag{2}$$

where n_0 – the concentration of charge carriers at the point of electrical neutrality, V_{NP} – of electrical voltage, V_g – gate-source voltage, C_{ox} – the linear capacitance gate dielectric. Substitute equation (2) (1) and comparing with the experimental points can be determined and the mobility of the charge carrier concentration at the origin (Fig. 2).

Same parameters were defined by Hall effects measurements (Table 1). We observe the convergence of the order of magnitude indicating that the applicability of the used model.

Table 1. Graphene parameters from Hall effect and IV curve.

	Mobility, cm2V-1s-1	the concentration of charge carriers, $10^{13}cm^{-2}$
Hall	18	1.56
IV curve	33	1.45

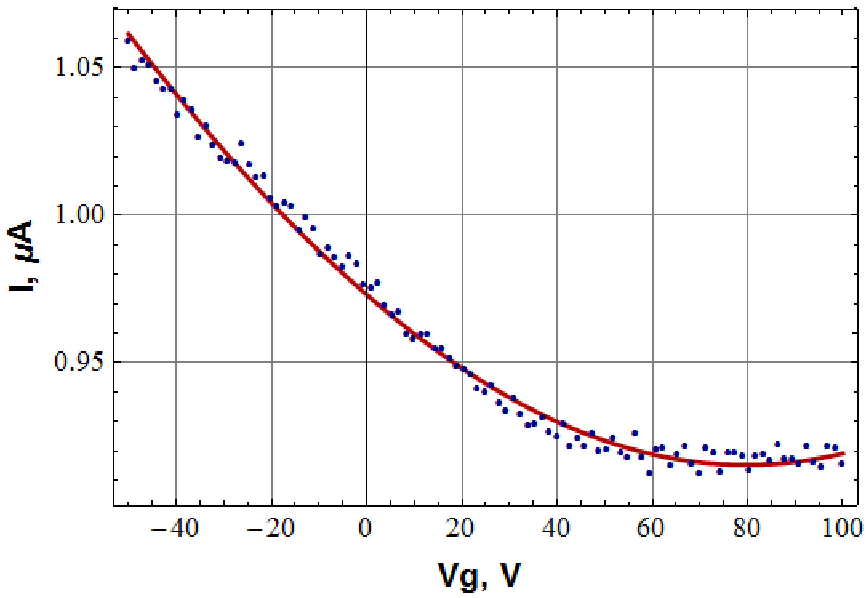

Figure 2. Comparison of the model with experimental data. Points – the experimental data, line – modeling. Model parameters: V_{ds} = 0.01V, μ_0 = 26 cm^{2}V^{-1}s^{-1}, n_0= 1.6 10^{13}cm^{-2}

4. Conclusion

Graphene field effect transistor was made. Main parameters of graphene, such as Dirac point, carrier concentration and mobility were determined from IV curves. The main results of the work was developing the technology of forming a channel and an ohmic contact to the graphene and demonstration of field effect. It is shown that the technology does not impair the properties of the graphene film. That is all the further work to improve the parameters of the transistor are reduced to improve film technology of graphene.

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