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Graphene on SiC substrates: growth, investigation and sensors application

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Epitaxial graphene layers were produced by thermal degradation of semi-insulating SiC substrate surface. The film uniformity was studied by the methods of Raman spectroscopy and atomic force microscopy. On the basis of these films prototypes of a gas and a bio sensor were made. It was shown that sensitivity of the sensors to the concentration of NO_2 molecules is better than 5 ppb and sensitivity to the concentration of fluorescein is at the level of 1-10 ng/mL.

It was shown in [1] that graphene is capable of sensing even the adsorption of a single molecule. Depending on their charge and the conductivity type of the graphene film, added gas molecules behave as donors or acceptors. That is they change the concentration of mobile carriers. Adsorbed molecules also create additional scattering centers and change the carrier mobility. As a result, the resistance of the film either decreases, or increases, depending on the type of the adsorbed molecule [2, 3].

The graphene films used in the present study were grown on semi-insulating 6H-SiC substrates by thermal decomposition of SiC at the temperature of ~1700ºC. Prior to growth of graphene, the substrate was etched at 1600ºC in the atmosphere of hydrogen to remove from the surface its defective layer. The results of measurements by Auger and Raman spectroscopies confirmed the presence of single-layer graphene on the silicon carbide surface.

The sensor structure was formed on the graphene film by laser. Excess amounts of graphene were removed from the substrate surface by etching in oxygen-argon plasma. Ti/Au (5/50 nm) ohmic contacts were fabricated by the lift-off photolithography. Relative measurements of the resistance of the graphene-based sensor were made in the presence of NO_2 in the gas mixture (gas supply periods are designated by light gray bands) at 20ºC. Since the NO_2 desorption rate at room temperature is very low, the sensor was annealed at 110ºC after each exposure in order to return it to the initial state. The sensors developed in this study demonstrated sensitivity to the NO_2 concentration at the level of 1-0.01 ppb.

The results, obtained in the course of development and the results of testing of the graphene-based sensor for detection of protein molecules are also presented. The sensor was fabricated by the

technology previously developed for the gas sensor. The working capacity of the biosensor was tested with an immunochemical system constituted by fluorescein and monoclonal antibodies (mAbs) binding this dye. The antibodies were attached to the graphene surface via amino groups formed by a number of electrochemical reactions. The biosensor was placed in a buffer borate solution to which fluorescein molecules were added. The attachment of fluorescein molecules to the antibodies located on the graphene surface changed the total resistance of the graphene film. It was found that the sensor is sensitive to the fluorescein concentration at the level of 1-10 ng/mL and to the concentration of conjugate of bovine serum albumin with fluorescein on the order of 1-5 ng/mL. It is shown that the device is highly promising for early diagnoses of various diseases.

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2. R. Pearce, T. Iakimov, M. Anderson, L. Hultman, A. Lloid Spetz, R. Yakimova, Sensors and Actuators B **155**, 451, 2011.