Electrical Conductivity and micro-Raman Sectroscopy of Graphene Layer Deposited on SiO_2 Dielectric and Subjected to Electron Beam Irradiation

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Modifying the properties of the carbon structures by radiation treatments attracts scientific interest as a promising method for the electronic properties tuning of the further nanoelectronic devices. This paper dedicated to the research of the electronic properties of the single layer graphene (SLG) subjected to the medium-energy electron-beam irradiation (EBI).

The SLG films had been grown by the CVD on Cu foil and transferred to the SiO_2(300 nm)/p-Si substrate. The Ni contacts (transfer length measurement set) were deposited on the SLG by the DC magnetron sputtering. The SLG region between Ni contacts was subjected by electron beam with energy of 20 keV with 1 A/cm^2 current density focused on an area of 2.5x 10^{-7} cm^2. Irradiation doses were in range from 1x10^3 – 7x10^3 µC/cm^2.

The micro-Raman spectra of initial graphene film measured between of the metal contacts showed prominent characteristic graphene peaks at 1580 cm^{-1} (G) and 2730 cm^{-1} (2D) along with a minor D peak at 1370 cm^{-1}. The peak intensity ratio (I_{2D}/I_G), which is 2.37 (average along of the film) with standard deviation of 0.68, is clearly indicating that the graphene has a monolayer thickness. Ratio of intensities of the D and G peaks indicates the quality of the material and for initial SLG film is 0.26 with standard deviation about 0.06. That is evidence of different defectiveness along of the film. Kelvin probe force microscopy (KPFM) technique [1] demonstrates heterogeneity of the film, which has a "grainy" structure with grain dimensions that approximately are 5-6 µm.

Frequency depended conductance measurements had been performed. The complete film conductivity σ could be represented as $\sigma = \sigma_{DC}+\sigma_{AC}(\omega)$, where σ_{DC} - is constant field contribution, $\sigma_{AC}(\omega) = A\omega^s$ - AC field contribution, that corresponds to Eliot model of hopping conduction [2]. The low-frequency (1-10 kHz) conductance σ_{DC} of the sample has decreased with irradiation dose up to 3 times. Carriers transport in AC field is limited by potential barriers (grain's boundaries) and intrinsic defects of the film (vacancies, dislocations). However, experimentally obtained values of power low ("s") are considerably higher then 1 for samples subjected to low-dose EBI, and at doses about 7x10^3 µC/cm^2 it decreses up to 0.26, that demands additional theoretical consideration.

The G line position of Raman spectra undergoes a blue shift , and full width at half maximum (FWHM) of the G line demonstrates narrowing with increasing dose up to 2x10^3 µC/cm^2, that can be associated with doping of the graphene layer [3]. A red shift of 2D line position with increase of irradiation dose attests electron doping of the graphene layer [3] that corresponds to positive charge generation in SiO_2 dielectric layer during electron beam irradiation. Additionally increase standard deviation for G line position along graphene channel with dose increase was observed that can be an indication on increase of doping fluctuation in graphene and can result in an increase of a carrier scattering in the graphene channel and reduction of graphene carrier charge mobility.

Thus, strong decrease of a conductivity of the CVD graphene layer on SiO_2 thin film at low-dose EBI probably associated with increase of a potential fluctuation in the SiO_2 layer and strong fluctuation of a charge concentration in the graphene layer.

References

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