RAMAN SPECTROSCOPY STUDY OF THE CHARGE CARRIER CONCENTRATION AND MECHANICAL STRESSES IN GRAPHENE TRANSFERRED EMPLOYING DIFFERENT FRAMES

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The charge carrier concentration (n) and relative strain (ε) in graphene synthesized by chemical vapor deposition and transferred to the surface of SiO$_2$/Si substrate using two different frames, polymethylmethacrylate (PMMA) and paraffin, followed by complex processing were compared. The positions of Raman-active modes were analyzed using a correlation method. The charge carrier concentration in graphene was lower if paraffin was used rather than PMMA. Further liquid-phase and heat treatment used to remove the paraffin frame led to an increase of n up to $1.2 \cdot 10^{13}$ cm^{-2}. No clear trend in the change of n was observed for graphene samples transferred using a PMMA frame, regardless of the type of processing. The scatter of ε values for graphene transferred with paraffin followed by liquid-phase and heat treatment in vacuum was greater than for graphene transferred with PMMA and treated similarly, i.e., from −0.01875 to −0.1448% and from −0.04375 to −0.0875%. Besides the transfer frame material itself, a combination of processing methods had a decisive impact on the quality of the graphene. Optimization of these parameters made it possible to increase the efficiency of the graphene-transfer technique with a simultaneous improvement in the performance of graphene nanoelectronic devices.

Keywords: *graphene, Raman scattering, chemical vapor deposition, polymethylmethacrylate, paraffin, heat treatment.*

Introduction. Chemical vapor deposition (CVD) of graphene onto a metal surface is the most promising method for preparing samples over large areas because it is inexpensive and efficient and produces high-quality products. The Cu substrate onto which CVD of graphene is most often performed is a catalyst from which the synthesized graphene must be transferred onto a target substrate for further use in micro- and nanoelectronic devices. As a rule, the transfer uses a polymeric frame that ensures the transferred material remains intact [1]. In this instance, the electrophysical properties of the graphene are mainly determined by traces of polymer formed during the transfer that act as a source of additional scattering of charge carriers and limit their mobility, resulting in degradation of the characteristics of the developed devices [2]. A frame that helps to preserve the integrity of the transferred material, effectively removes the graphene from the surface, provides the minimal concentration of charge carriers, and creates a lower concentration of surface defects (wrinkles) must be selected to improve the performance of electronic devices based on graphene.

Polymethylmethacrylate (PMMA) is widely used as a frame to transfer graphene because of its availability and simple handling [3, 4] and the ability to use it in lithography to create graphene-based electronic devices. However, the large adsorption energy of the polymer with graphene, the high reactivity of the former with the formation of a covalent bond between stable radicals of PMMA and defects (vacancies) in the graphene at elevated temperatures, and its low solubility in all known solvents hampers removal of traces of the frame after the transfer [5]. Additional treatments including exposure to UV light [6], vacuum annealing [7], and the action of organic solvents such as Me$_2$CO [8] can increase the efficiency of decomposing traces of the polymer.

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