Optical properties of epitaxial graphene on the SiC substrates

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Abstract

Recently graphene has been studied by a great number of groups all over the world. Nowadays there are a lot of manufacturing techniques of graphene such as micromechanical cleavage, chemical vapor deposition on metals and chemical tearing from graphite. Growing graphene on silicon carbide is a promising method to produce this material for electronic applications. It can be performed by sublimation of SiC and chemical vapor deposition of carbon on SiC. Carbon deposition on SiC technology was developed and patented at the Institute of Electronic Materials Technology.

The main aim of this work is to determine the influence of various parameters on the properties of epitaxial graphene grown by sublimation and deposition techniques on SiC substrates . Raman spectroscopy is the basic technique to study graphene. Using Raman spectroscopy one can analyze the number of carbon layers, strain in graphene structure and the level of carrier concentration.

In the present work various measurement techniques and data analysis methods were shown. The system enabling the determination of the average parameters of carbon structures, using histogram analysis of Raman bands were presented. The second method was the analysis of the local parameters on the chosen parts of the sample. It allowed studying graphene parameters on the terraces and SiC steps in a precise manner.

Based on the obtained results the average growth rate of carbon structures grown on carbon face of SiC in relation to argon pressure in the reactor and growth time were established. It was shown that in this case the basic process determining growth of graphene layers is two dimensional diffusion of silicon from SiC to steps and defects. The statistical analysis of the Raman maps in comparison with the optical measurement technique of the carbon structure thickness proved, that using Raman spectroscopy one can determine the number of graphene layers for the samples grown on carbon face of SiC.

Raman spectroscopy studies in a wide range of temperatures showed that the graphene layers grown by the sublimation technique are more strongly pinned to the SiC substrate than those grown by the deposition technique. This is inextricably linked with the nucleation process of carbon structures – for the sublimated samples nucleation starts mainly on defects and steps. Because of the sublimation process this area is more deteriorated and rough, while carbon is released from defects. As a result, carbon structures are pinned to the SiC surface. In the deposition technique carbon structures may nucleate from defects, but the pinning is not that strong. It was also demonstrated that carbon structures grown by sublimation technique are much more strained than those grown by the deposition technique. This is associated with the already mentioned stronger influence of SiC substrates on the carbon structures, which blocks strain relaxation. This effect is not present in the case of graphene layers grown by the deposition technique, which means that they are less strained.

The analysis of Raman maps obtained in microscale shown significant decrease of carrier concentration in the area of steps with respect to area of terraces. It may be the result of a different crystallographic orientation of the terraces and steps. The effect was much more visible for the samples grown by deposition technique than for sublimated samples. It may be a result of higher SiC substrate degradation in the sublimation process.

The analysis of the initial growth phases of graphene by sublimation of SiC on the silicon face showed that the first grown carbon layer is the buffer layer on terraces, after the growth of which graphene starts to appear on steps. On the other hand, after growth of the buffer layer sublimation on terraces is stopped, so further growth is realized by moving carbon from steps to terraces. The results obtained for the deposition technique suggest that it is hard to grow a pure buffer layer using this method. Comparison of the Raman spectra and the statistical analysis proved that the spectra of the buffer layer can be analyzed in a manner similar to that of amorphous carbon. Studies of the buffer layer indicated that it is not homogenous on the surface of a particular sample and that there are significant differences for samples with a pure buffer layer grown in different conditions. It stems from a different degree of saturation of the buffer layer with of sp^2 and sp^3 bonds.

Raman measurements of the graphene samples intercalated by hydrogen proved that the buffer layer is converted into graphene. The differences between graphene on the buffer layer and graphene obtained by buffer layer activation were observed. The Raman bands of intercalated graphene are narrower and the 2D band is higher with respect to the G band than for graphene on the buffer layer. It means that the interaction between hydrogen intercalated carbon structures and the substrate is weaker.