A new route towards low temperature production of continuous graphene film

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Abstract

One of the tremendous unique materials of our century, graphene, has already proved its excellent optical, mechanical, chemical and electrical properties on the micro scale level [1, 2].

According to the literature database graphene obtained by micro mechanical cleavage has demonstrated the best performances such as highest mobility, strongest half integer hall effect even at room temperature and strongest mechanical properties. Thus, graphene opens up possibilities for new applications (flexible screens and displays, etc.) or promises to be better alternative material for improving existing applications (energy storage, transparent electrodes, super capacitors, etc.) [1, 2]. Nevertheless graphene samples produced by scotch tape method suffice only for fundamental studies and cannot be used in industrial application because that technique has no reproducibility and there are difficulties to localize the flakes on the substrate and to control their size and shape [3].

For the large scale graphene production a chemical vapor deposition (CVD) technique is widely used nowadays to grow graphene films samples on different types of metal substrates. Mechanical and electrical characteristics of as-produced CVD graphene are typically lower compared to the properties of exfoliated graphene due to many reasons that are linked with the growth and transfer processes: small domain size, boundaries, wrinkles, scratches, damages etc [4]. Apparently, the main drawback of CVD method lies in necessity of additional graphene transfer process from metal to the insulating surface. However, the preeminence of that method are its capability of large scale production, low cost and possibility to control the size, location and shape of as-produced graphene material. At the same time, the CVD technique can further be improved as the growth mechanism of graphene on metal is still not completely understood and CVD method has many parameters that are to be optimized, [5]. Therefore, at the present moment the CVD process is the most popular technique for industrial fabrication of graphene, so that to date there are many variations of CVD set-ups, differences in their recipes and also enormous substrate's choices (metal type, thickness, crystallinity, surface preparation) [6].

In this report, we demonstrate new approach for the graphene film growth on platinum (Pt) thin film via modified CVD technique. Specific configuration of our CVD set-up allows us to perform the carbon deposition without hydrocarbons at the substrate temperature not higher than 700° C. Graphene formation occurs in a single CVD process, without breaking a vacuum, through the conversion step from continuous amorphous carbon film of uniform thickness (about 1-2 atomic layer). From the Fig. 1 one can see significant change of Raman spectrum corresponding to the graphene samples at different stages of our CVD process. Initial stage I corresponds to the formation of amorphous carbon film; for the stage II it is predominantly defective graphene film with small grains of nanometer size; and for the last stage III we obtain low defective uniform graphene film contained of big single crystal domains. Additionally, insets of fig. 1 show HR TEM images, which confirm the structural difference of as-produced graphene on the atomic scale between graphene samples of stage II and stage III. Similar SLG sheets conversion from aromatic monolayers was recently observed on Cu surface [7]. However, that method contains 3 consecutive steps of additional preparation (one of which is electron irradiation) and final long annealing step at 830°C in UHV.

Our work on developing a low temperature CVD set-up provides a new route of large-scale graphene film synthesis, which can be performed in the less costly CVD process, and does not required UHV and high temperature. That process guarantees to always form a continuous uniform film of graphene. Detailed investigations of the growth mechanism on thin Pt film for our graphene sample were analyzed by Raman spectroscopy and transmission electron microscopy (Fig. 1). By combination of different characterization techniques it was confirmed that crystallinity, structural quality and also electrical characteristics of our sample are similar to those of typical CVD graphene.

References

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Figures

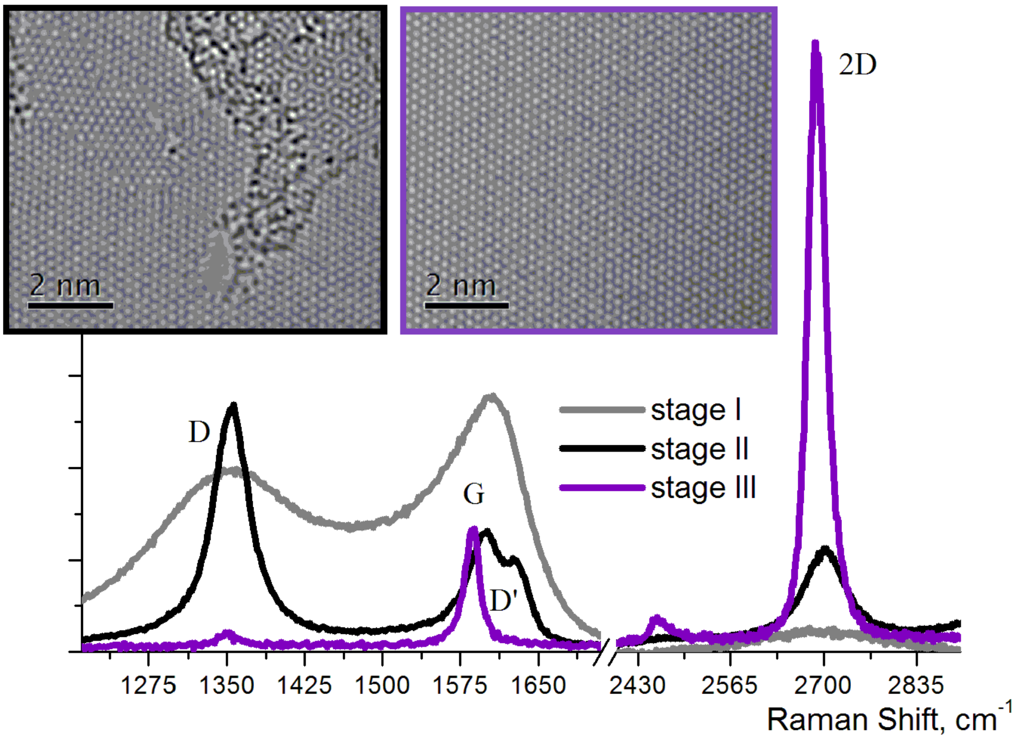

Fig. 1 Raman spectra of the carbon films at different stages of the graphene synthesis process. HR TEM images are also shown in the insets for the samples of stages II and III (in black frame is for the stage II; in purple frame is for the stage III). Complex study confirms that graphene sample of the last stage consists of low defective graphene film. Samples were transferred onto the silicon wafer for Raman investigation and onto carbon supported Cu TEM grid for TEM analysis.