Atomic-layer thinning of graphene with low energy helium plasma implantation

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Abstract

In recent years, graphene, as a new carbon jewel, has caught more and more researchers eyes. The strong and increasing interest in studying graphene results from the fact that this atomically flat carbon sheet is one-atom-thick two-dimensional material formed by a network of sp2-bonded carbon atoms. This unique structural composition has brought in an significant number of specific features relevant to application fields as diverse as high electron mobility transistors(HEMTs), transparent conducting electrodes and novel composite materials, etc.

Most currently available methods for graphene synthesis involve micromechanical cleavage of graphite, liquid-phase exfoliation , chemical vapor deposition growth on metallic substrates and epitaxial growth on SiC . However, most of these methods obtain single-layer graphene(SLG) at random, and sometimes need a large number of chemicals and/or very strict conditions. The plasma technique is a promising method for preparing mass and large area SLG and few-layer graphene (FLG) from thicker multilayer graphene (MLG).

Here, we develop a simple method to thin MLG to SLG/FLG at the atomic layer scale in a He plasma environment by using a home-made plasma immersion ion implantation(PIII) system. This method could achieve a desired thickness of graphene through layer-by-layer or faster etching. the etching rate for multilayer graphene can be well controlled from 1 to 6 layers/min, or even faster by dominantly regulating the ICP power. Besides, the etching rate has always been constant during thinning process regardless of the thickness of the graphene flakes. Processes with different bias conditions are also studied to reveal the mechanism. Moreover, there is no reduction of lateral size or deep pits in the basal plane for the flake after He plasma implantation. Hence the He plasma implantation thinning method is a promising solution for modulating the electronic structure and transparency of graphene through precise removal of layers for device applications such as graphene field-effect transistors and transparent conducting film.

Keywords: graphene, thickness, plasma implantation, etching rate, Raman spectroscopy

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