PATTERNING OF GRAPHENE ELECTRODES BY UNCONVENTIONAL LITHOGRAPHY

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Graphene as a building block material is used as an electrode to selectively oxidize the silicon substrate for the fabrication of new devices

Modellamento di elettrodi di grafene mediante litografia non convenzionale
Il grafene, come composto di base, viene utilizzato come elettrodo per ossidare selettivamente il substrato di silicio per la fabbricazione di nuovi dispositivi.

Graphene is a two-dimensional material and has been attracting much attention owing to its fascinating properties as an active layer for technological and electronic applications such as field effect transistor, sensors, memristor and etc.[1,2,3]. Most of the proposed devices require many complex lithographic steps or direct manipulation of graphene whose fabrication has often limited the application of graphene itself. Here we propose an original system where we demonstrate that graphene flakes (GFs), and patterned graphene film can be directly used as electrodes for nanofabrication by *in situ* local oxidation lithography (LOx)[4,5].
Graphene flakes are prepared by micromechanical cleavage[6] onto silicon substrates, then it is subsequently moved onto silicon substrates by means of a transfer process, based on a PMMA sacrificial layer. The patterned graphene films were molded by lithographically controlled wetting (LCW)[7] on silicon wafer. In LCW the stamp is gently placed in contact with a suspension of graphene flakes[8] thin film spread on a substrate, the fluid layer develops instability where the capillary forces pin the solution to the stamp protrusions, forming an array of menisci. As the critical concentration is reached by solvent evaporation, the solute precipitates from the solution onto the substrate inside the menisci, giving rise to a structured thin film that replicates the protrusion of the stamp.

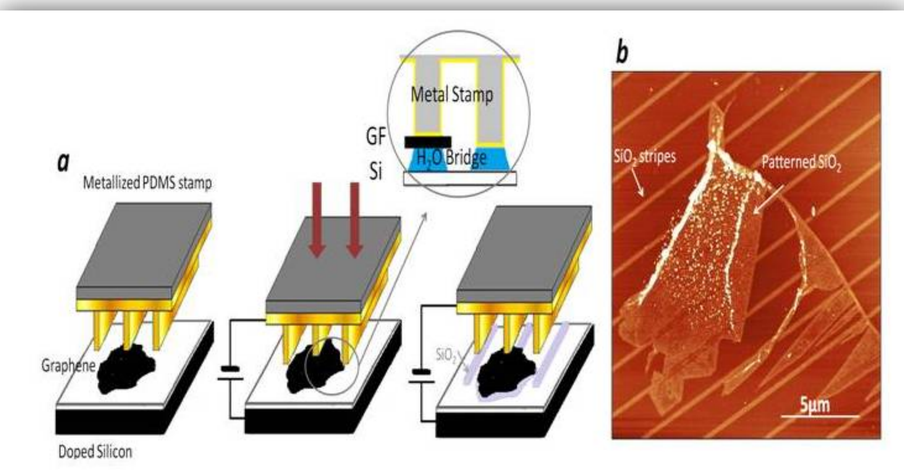

Fig. 1
a) The scheme of the local oxidation by using GFs as an electrode; b) AFM image of graphene flakes (GFs) deposited on doped silicon after plasma etching in oxygen atmosphere

In order to contact GFs deposited on doped silicon and patterned graphene film for selectively oxidation of silicon, we used the experimental set-up for parallel local oxidation[4], which is a robust electrochemical method for patterning and nanofabrication. The process is based on a conductive stamp, which is placed onto the graphene/Si surface in moist air environment (relative humidity >90%). Under these conditions a water meniscus forms between the stamp and the surface, resulting in an electrochemical cell, where graphene and the stamp constitutes the electrodes. So by applying an adequate bias under optimized condition an electrochemical reaction can occur and the part of silicon substrate underneath of graphene are selectively oxidized *in situ*. The scheme of the process is illustrated in Fig. 1a.

In order to investigate the integrity of GFs, samples were investigated by µ-Raman scattering and AFM before and after plasma treatment (Fig. 1b) which used to remove the graphene after processing. It is confirmed by morphology characterization and Raman spectra that Si is selectively oxidized underneath of graphene flake independently from the pattern of the stamp. So, after plasma etching we have no anymore graphene flake into the substrate and what remains is the patterned SiO_2 which produced by local oxidation process.

In this work, we have demonstrated the inherent simplicity of *in situ* fabrication by LOx combined with formation of the electrochemical cell limited to the contact area between the GFs and the silicon surface allows us the fabrication of SiO_2 film conformal to the GFs in a single step. Our system depicts that the fabricated nanostructures made of SiO_2 on silicon that replicate the GFs which previously were patterned onto silicon surfaces, can be used for the fabrication of novel electronic devices.

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