Fabrication of graphene by pulsed laser annealing from a graphene oxide thin film

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Abstract

A laser-based thin-film processing scheme for printing and annealing of graphene oxide is reported. This method is able to print and simultaneously reduce the graphene oxide to graphene. The resulting graphene thin film is with good transmittance and its resistance is dramatically reduced from 200 MΩ to 80 KΩ.

Introduction

Graphene, a two-dimensional graphite, exhibits remarkable electronic properties that qualify itself as a promising material for applications in the future electronic and optoelectronic devices. Several methods have been developed exclusively to prepare graphene. For examples, the methods of chemical vapor deposition [1], solvent thermal reaction [2], chemical reduction via graphite intercalation compounds [3] and through graphite oxide [4]. The above-mentioned methods are usually needed to be processed in a vacuum environment or in a chemical solution, and more frequently they must be executed at high temperature. Thus, they are not suitable for plastic, flexible substrates. Here we develop a laser thermal printing (LTP) method which can transfer graphene oxide with various thicknesses to flexible substrates and reduce them to graphene. The whole process can be executed in the ambient environment that is, therefore, suitable for flexible substrates.

Experiment

The experimental setup is schematically shown in Figure 1. Graphene oxide, GO, solution is first coated on a transparent glass support and is dried naturally in the ambient. A pulsed laser is then irradiating on the glass. Laser energy is absorbed by the support and the GO. With suitable laser energy and irradiation time, a thin film of GO will be remained on the support surface and the GO thin film will be reduced to graphene due to the thermal energy transformed from the absorbed laser energy.

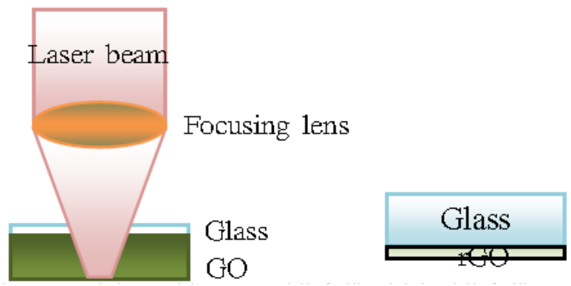
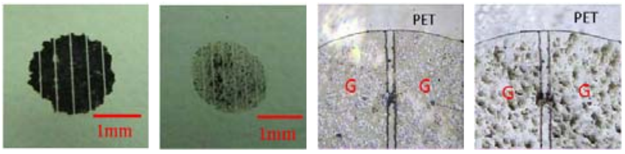


Fig. 1. Schematic showing the process of the laser processing of a graphene oxide thin film.

Results and Discussion

Figure 2(a) and (b) show the two laser printed and reduced graphene thin films, with different thicknesses, on PET substrates. By adjusting the intensity of laser irradiation energy, the thickness of the resulting graphene film can be regulated. The film shown in Fig. 2(a) is thicker than that in Fig. 2(b). Figure 2(c) and 2(d) respectively show the magnified front- and back-view images of figure 2(b). They demonstrate that the film's transparence to visible light of resulting reduced graphene oxide is good. The degree of transparence will later be quantitatively presented in Fig. 3(b). The observable defect points shown in Figure 2(d) are due to the non-uniformity of the transferred rGO films.

Figure 3(a) shows the surface morphology of the fabricated reduced graphene oxide thin film. The thickness for this case is 5 nm. Figure 3(b) shows the transparence of the fabricated graphene films reduced using different laser energies. For most cases, the spectral transparence of the wavelength ranging from 350 to 850 nm is over 80%.



(a) (b) (c) (d)

Fig. 2 Graphene oxide thin films printed on a PET substrate using the laser thermal printing process. (a) CCD image of a thicker resulting film. (b) CCD image of a rGO film with a thinner film thickness. (c) An enlarged top-view CCD image of (b). An enlarged back-view CCD image, taken from the PET side.

The resistance for graphene oxide film, before laser printing, is 200 MΩ (on the support) and it is reduced to 80 KΩ for Fig. 2(b) and 3 MΩ for Fig. 2(c), respectively. More detailed characterizations of the transferred graphene films will be systematically presented later in the conference.

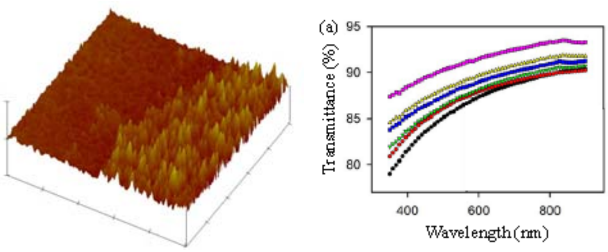


Fig. 3 (a) Surface morphology of a fabricated reduced graphene oxide thin film scanned using an AFM. The film thickness is about 5 nm. (b) Transparence of redcued graphene oxide thin films obtained using different irradiating laser energies ranging from 4.25 mJ to 4.90 mJ. The higher the laser energy, the more the more transparent resulting film is obtained. film

Conclusion

This study demonstrates a process of reduction graphene from graphene oxide using light irradiation from an Nd:YAG laser. The process is executable at room temperature and in the ambient and also applicable to the large area processing. A resulting thin film with thickness around 5 nm can be generated and it is measured to be with good transmittance to the visible light. The film resistance could be dramatically reduced from 200 MΩ at the graphene oxide state to 80 KΩ that resulting to the resistivity of $7.42\times10^{-3}\,\Omega$cm.

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