Laser Assisted Nanoperforation of Graphene for Water Treatment Applications

John Parthenios[1]
S. Katsiaounis[1,2], N. Chourdakis[1], J. Polizos[1], and K. Papagelis[1,2]

[1]*FORTH/ICEHT, Stadiou Str. Platani, 26504 Patras, Greece*
[2]Dept. of Physics, Univ. of Patras, *26504 Patras, Greece*
jparthen@iceht.forth.gr, kpapag@upatras.gr

Abstract

Single layer graphene is impermeable to all atoms and molecules due to its two-dimensional array of tightly packed carbon atoms. To generate permeability, molecular selectivity and ultrahigh molecular fluxes, pores of specific sizes in the nm scale, and with sufficient areal density should be drilled onto the graphene lattice [1]. Nanoporous graphene has been proved as an ideal membrane for gas separation, water desalination, and other water treatment applications [2].

However, eliminating carbon atoms from graphene lattice in a highly controlled manner is extremely challenging. A plethora of different processes for nanopore fabrication have been proposed including chemical growth, chemical reaction/ etching, template-assisted fabrication, bombardment with ion or electron beams and oxygen plasma etching [2]. However, the scaling up of these methods towards nanopore membranes for use in industrial and commercial processes remains a significant challenge.

In this work a technique for nanoperforation of CVD grown graphene based on fs laser treatment of graphene, is proposed. CVD graphene is placed onto Si/SiO_2 using conventional dry transferring techniques. Then, it is treated in air with 80 fs laser pulses at high repetition rate. By focusing the train of fs laser pulses onto graphene, circular patterns are formed. A characteristic example is given in figure 1. These patterns are formed due to the synergy of thermal and ablation effects, occurring in different time scales and affect different regions of graphene within the spot of the Gaussian beam [3]. The ablation effects destroy the graphene network forming pores with diameters ranging from a few nm up to 70 nm, an order of magnitude lower than the diffraction limit. Pore diameters and their aerial density are strongly dependent on the laser treatment parameters (laser wavelength, power, focusing, and irradiation time). Yet, thermal effects become important due the high repetition rate of the fs laser resulting in graphene inflation of a region around the ablation area periphery (bright ring in figure 1b).

By adjusting focusing, laser power and exposure time the optimization of the nanopore production process can be achieved. The proposed method can be easily scaled up for creating porous graphene membranes in various area scales from μm^2 up to m^2 provided that the quality of the transferred CVD graphene is exceptional.

We gratefully acknowledge the Greece-Russia bilateral joint research project MEM-Q supported by GSRT funded by National and European funds (proj.no./MIS T4ΔΡΩ-00030/ 5021467).

References

[1] Celebi, K. et al. Science 344, (2014) 289
[2] Sun, P. et al. Adv. Mater. 28, (2016) 2287
[3] Korte, F., et al., Applied Physics A: Materials Science & Processing, 77 (2) (2003) 229.

Figures

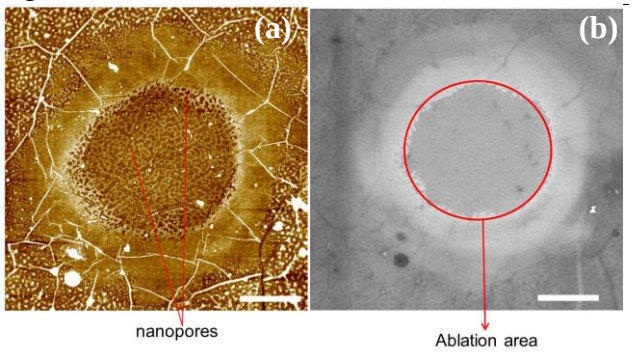

Figure 1: (a) AFM and (b) SEM image of a laser patterned spot of CVD graphene on SiO_2. The ablation area diameter (red circle in b) is 2.5 μm. Nanopores are detectable only in the AFM topographic image (a). Scale bars are 1 μm.