High yield fabrication of graphene resonators array with poly-Si sacrificial layer

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Graphene features high robustness and carrier mobility. Its Young's modulus has been reported to be around 1TPa[1], which rivals much of the mostly used material in the semiconductor industry. Such characteristic makes graphene ideal for applications in high frequency resonators and radio-frequency electronics. Due to its high surface to volume ratio and signal to noise ratio, graphene resonator is extremely suitable for mass, force, and charge sensing[1]. The barriers to high-yield graphene resonator fabrication range from reliable growth of large area graphene sheet to the processing of the resonators. Although initially, graphene resonators have been manufactured from exfoliated graphene, the advance in chemical vapor deposition (CVD) of graphene makes mass production possible. Van der Zande reported the batch fabrication of graphene resonators array from CVD grown graphene[2]. The graphene is either transfered onto pre-patterned oxide trenches or released by wet etching the oxide layer.

This paper demonstrates the possibility of using poly-Si as a sacrificial layer for graphene resonator fabrication, giving a yield of over 95%, since poly-Si is easier to etch and can be removed in gaseous phase by XeF_2, which avoids the surface tension induced damage during the drying period of wet release. In this work, CVD grown graphene has been transferred to a poly-Si/SiO_2/Si substrate (Figure 1(a) (i)). The substrate has been designed to enhance the visibility of graphene under optical microscope following a method reported elsewhere[3]. Graphene strips have been patterned by oxygen plasma (ii), and Ti/Al has been deposited on top of graphene bridge by lift-off to form contacts and also serve as anchors (iii). Finally, the poly-Si layer has been etched by XeF_2 for 2min to release the graphene bridges (iv). Figure 1 (b) and (c) are the optical images taken after step (ii) and (iii) respectively. After release, the graphene is barely visible under optical microscope, however distinguishable under scanning electron microscope (Figure 1(d)). The optical transparency is consistent with the previous report that fluorinated graphene is a semiconductor whose band-gap varies with component of fluorine atoms[4]. The graphene bridge has been investigated by Raman spectroscopy before and after XeF_2 release (Figure 2), which reveals that defects have been introduced by fluorination. I-V characterization shows that the graphene becomes almost non-conductive after exposure to XeF_2 for 2min (Figure 3). The frequency of the resonator and the influence of fluorination and de-fluorination on mechanical properties will be characterized further and reported.

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[1] J. Scott Bunch, et al, Science 315, 490 (2007)
[2] A. M. van der Zande, et al, Nano Lett 10, nl102713c (2012)
[3] T. Chen, et al, J. Vac. Sci. Technol. B 30, 06FJ01 (2012)
[4] J. T. Robinson, et al, Nano Lett. 10, nl101437p (2010)

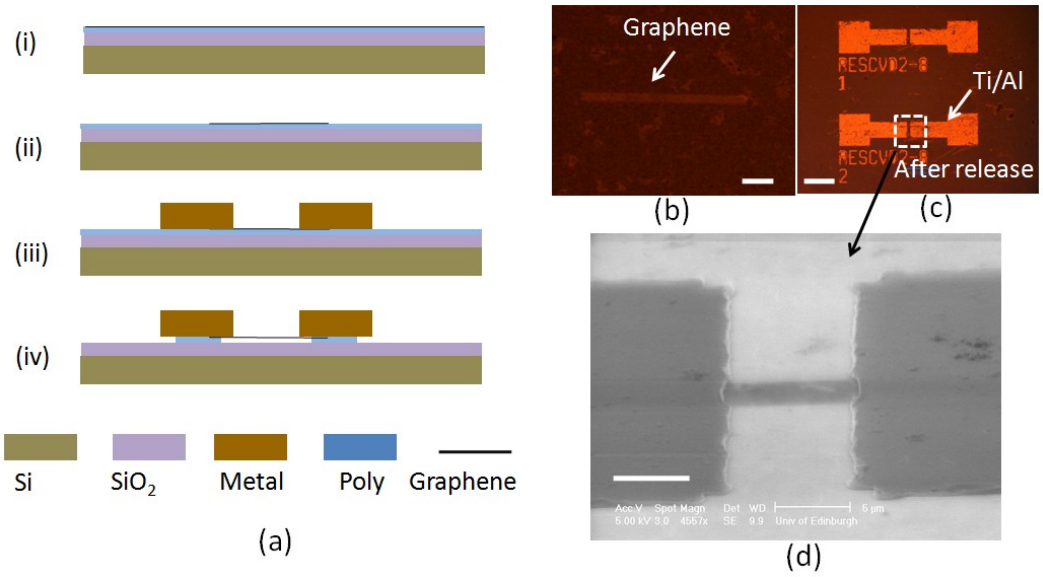

Figure 1 (a) Fabrication process of graphene resonator. CVD grown graphene has been transferred to poly-Si/SiO_2/Si substrate (i). The graphene is then patterned to strips by oxygen plasma (ii), see also optical picture in (b). Ti/Al has been deposited by lift-off process to form contact and anchor (iii), see optical image (c). In the last step, poly-Si has been removed by XeF_2 to release the graphene bridges (iv), see SEM picture in (d). The scale bars in (b), (c) and (d) are 20µm, 80µm and 5µm respectively.

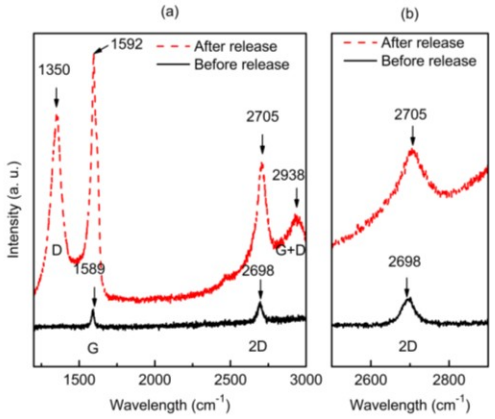

Figure 2 Raman spectrum of graphene before and after XeF_2 release. (a)After release, defects related D band D+G band appear alongside G and 2D band, indicating lattice damage caused by XeF_2. (b) Symmetric profile of the 2D band proves that the graphene is mono-layer.

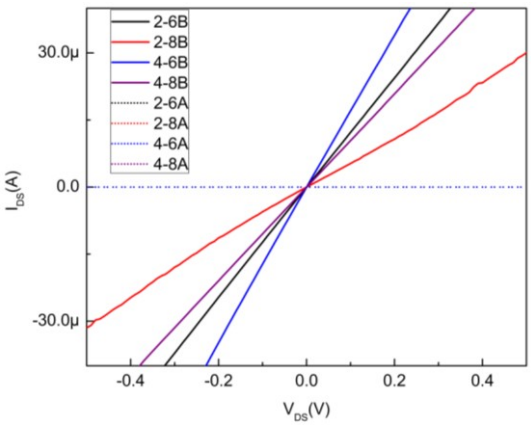

Figure 3 I-V curves of the graphene bridges whose sizes are 2-4µm wide and 6-8µm long. The four solid lines are taken before release, while the four dashed lines are taken after release and show almost zero current.