CATALYST FREE PECVD NANOCRYSTALLINE GRAPHENE ON INSULATOR

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The unique electrical and optical properties of graphene have attracted application as transparent electrodes, transistors and photodetectors. However, the small flake size of mechanical exfoliated graphene has limited its scalability to large area production. Recently, large area graphene is produced through chemical vapour deposition (CVD) and epitaxial growth method [1]. CVD of graphene on insulator or metal-catalyst is considered low cost and process flexible. This is because graphene film quality and deposition rate can be controlled through process parameters such as temperature, gas flow rate and gas mixture. Large area CVD graphene on metal-catalyst such as Ni or Cu is amongst other established method [2] but film transfer and metal etching can ultimately affect device performance. Therefore, the research attention is now focussed on catalyst free CVD graphene process on insulator materials.

In this work, we present a plasma based CVD method of depositing large area graphene on SiO_2 surface at different temperature and RF power. The plasma enhanced chemical vapour deposition (PECVD) approach produces nanocrystalline graphene (NCG), which has potential application as transparent conductors and sensor devices. The deposition process is carried out using the Oxford Instrument Agile 1000 system and on 300 nm thick PECVD SiO_2 on 150 mm diameter silicon wafer. The gas mixture ratio of H_2:CH_4 is 1:1.2, plasma RF of 100 W and the deposition temperature is done at 900 °C, 950 °C and 1000 °C. The deposition rate of the NCG deposited at 900 °C is 1.2 nm/min, 950 °C is 1.8 nm/min and 1000 °C is 1.9 nm/min. The rate is determined by measuring the NCG thickness using white light ellipsometer, as shown in Figure 1. The NCG film is then analysed using Raman spectroscopy with 532 nm excitation laser wavelength and the distinct D, G and broad 2D bands of the NCG have been observed in Figure 2. The nanocrystalline nature of the graphene is characterised by the split of the D (1350 cm^{-1}) and G (1594 cm^{-1}) band, with strong D peak signifying disorder in the sp^2 carbon lattice. The 2D (2694 cm^{-1}) band is identified with the thickness and crystalline nature of the graphene and the combination D+G (2946 cm^{-1}) band of graphitic disorder in the film [10]. By varying the RF power and introducing LF power of 300 W and 100 W to the process, we are able to demonstrate an increase in the deposition rate to > 3.8 nm/min whilst maintaining the NCG Raman characteristics. Preliminary optical transmission measurement has shown > 88 % transparency from 200 nm to 800 nm for all NCG wafers. Future work is to attempt deposition at lower temperature range from 550 °C to 900 °C and improvement of the D and 2D Raman peaks.

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References

[1] Samuel Grandthyll, Stefan Gsell, Michael Weinl, Matthias Schreck, Stefan Hufner and Frank Muller, J. Phys. Condens. Matter., vol. 24, pp. 314204, (2012).

[2] Ivan Vlassiouk, Pasquale Fulvio, Harry Meyer, Nick Lavrik, Sheng Dai, Panos Datskos, Sergei Smirnov, Carbon, vol. 54, pp 58-67 (2013).

[3] R. Saito, M. Hofmann, G. Dresselhaus, A. Jorio, M. S. Dresselhaus, Adv. in Phys., vol. 60, no. 3, pp. 413-550, (2011).

Figures

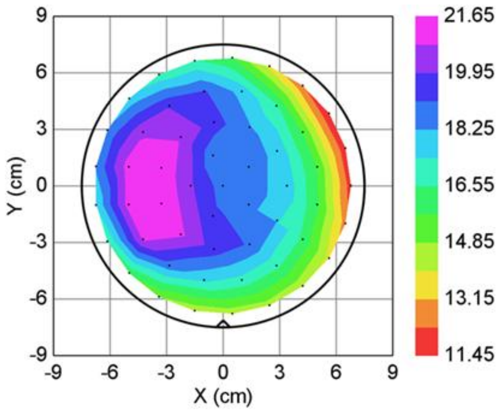

Figure 1. Ellipsometer thickness and uniformity measurement of NCG film on 300 nm SiO_2 on silicon wafer. The NCG film is deposited at 900 °C.

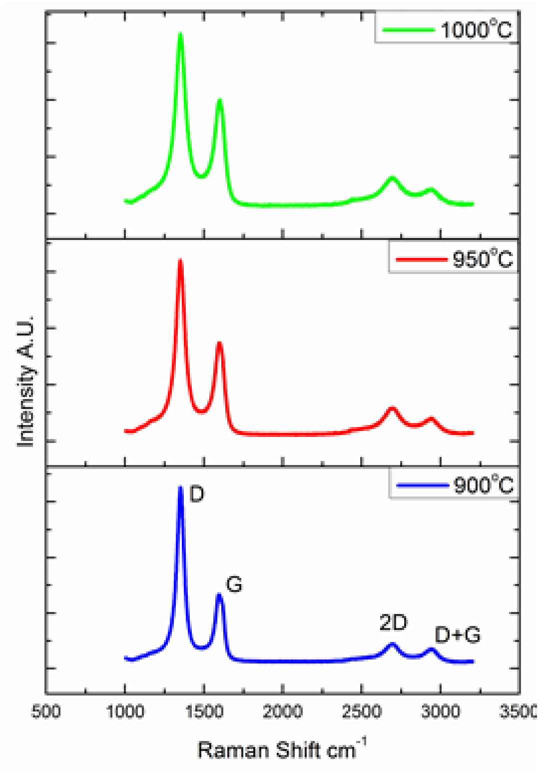

Figure 2. Raman spectra of NCG film deposited at 900 °C (blue), 950 °C (red) and 1000 °C (green). The D peak is 1350 cm^{-1}, G peak is 1594 cm^{-1}, 2D peak is 2694 cm^{-1} and D+G peak is 2946 cm^{-1}.