Fabrication of ultrasensitive graphene nano-biosensors

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Summary

The development of miniaturised systems for detection of disease biomarkers, at clinically relevant concentrations in biological samples, is key in the early diagnosis and monitoring of diseases. This poster presents the development of novel antibody functionalized epitaxial graphene devices for bio-sensing applications. Epitaxial graphene has been grown on silicon carbide (SiC) substrates under high vacuum and high temperature conditions (1200 – 1700°C). A generic electrochemical surface functionalisation chemistry, which can be used to attach a variety of "bio-receptors" to graphitic surfaces, has been developed. The attached bio-receptors are capable of specific and selective interaction with disease biomarkers. When a target biomarker molecule interacts with the "bio-receptor" functionalised surface, the charge density at that surface is affected. This change can be detected as an electrical signal from the biosensor, enabling highly sensitive detection of biomarker analytes.

Motivation

"Bio-chip" sensors, developed using semiconductor devices will enable detection of biomarkers at ultra-low concentrations for early diagnosis and monitoring of diseases. This poster presents novel epitaxial graphene-based devices for bio-sensing applications. Silicon Carbide (SiC) has recently been discovered to be a suitable substrate for graphene growth [1, 13, 2]. During annealing at temperatures of between 1100ºC and 1700ºC the SiC surface reconstructs itself, with silicon atoms subliming and leaving behind a layer, or multiple layers, of epitaxial graphene [3]. Epitaxial graphene's superb electronic properties (high carrier mobilities), and reported biocompatibility [4], and substrate-inferred processability make it ideal for fabrication of nano-scale electronics and sensors. The biosensors work on the principle of a target disease biomarker, binding with a "bio-receptor" attached to the graphene surface, yielding a change in the surface charge density. This change can be detected as an electrical signal from the biosensor device. The device itself consists of a conductive graphene channel – functionalised with the "bioreceptor". Graphene nano-channel sensors have the potential for much greater sensitivity to biomarkers than traditional bioassays because of their high signal-to-noise ratios (S:N).

Results

This poster presents the growth of multi-layer epitaxial graphene (MEG) on silicon carbide substrates (Fig. 1) and the electrochemical functionalisation of MEG layers with monoclonal antibody bio-receptors. A novel electrochemical method for attachment of antibodies to epitaxial graphene/SiC surfaces using chemical functionalisation of graphene with nitro groups and subsequent reduction to an amine has been monitored using X-ray Photoelectron Spectroscopy (XPS) (Fig. 2). The amino (NH_2) group has been used to bind a fluorescently labeled antibody, in the first known bio-functionalisation of epitaxial graphene on SiC. Strong fluorescence from the quantum dot labeled antibody, bound to the graphene substrate, was detected, indicating good surface attachment (Fig. 3). A control sample , not functionalised with an amine group, showed no fluorescence and thus no binding. Following epitaxial graphene growth, micro and nanochannel graphene devices have been fabricated (Fig 4 and Fig. 5). The results from a specific sensor, fabricated by functionalising a graphene nanochannel surface with an antibody bioreceptor, indicative of oxidative stress and prostate cancer risk, will be presented.

References

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[2] C. Berger et al., Science 312, p.1191, 2006.

[3] A. Castaing, O.J. Guy, M. Lodzinski, S.P. Wilks, "Investigation of Graphene Growth on 4H-SiC", Mater. Sci. Forum 615-617, 223-226, 2009.

[4] X. Sun, Z. Liu, K. Welsher, J.T. Robinson, A. Goodwin, S. Zaric, H. Dai, Nano Res. 1: 203, p.212, 2008.

Figures

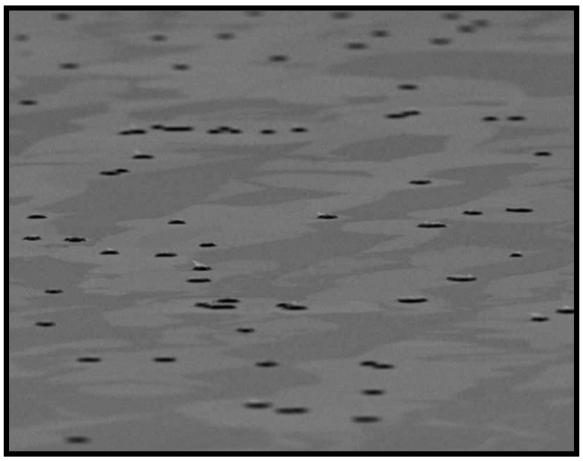


Fig. 1: SEM image of epitaxial graphene grown on a silicon carbide substrate.

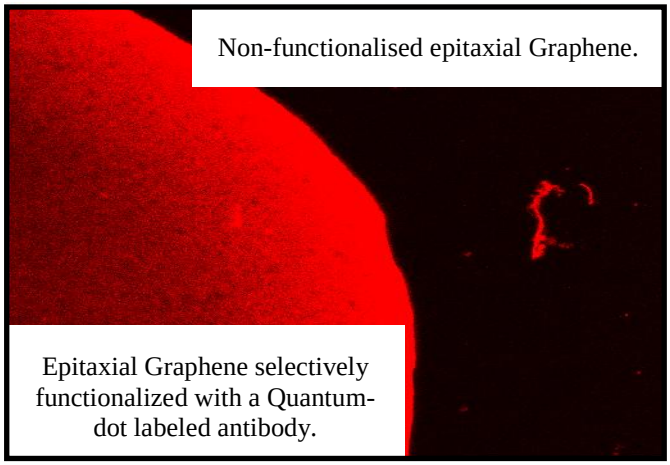


Fig. 2: Laser scanning confocal micrograph of epitaxial Graphene selectively functionalized with a Quantum-dot labeled antibody.

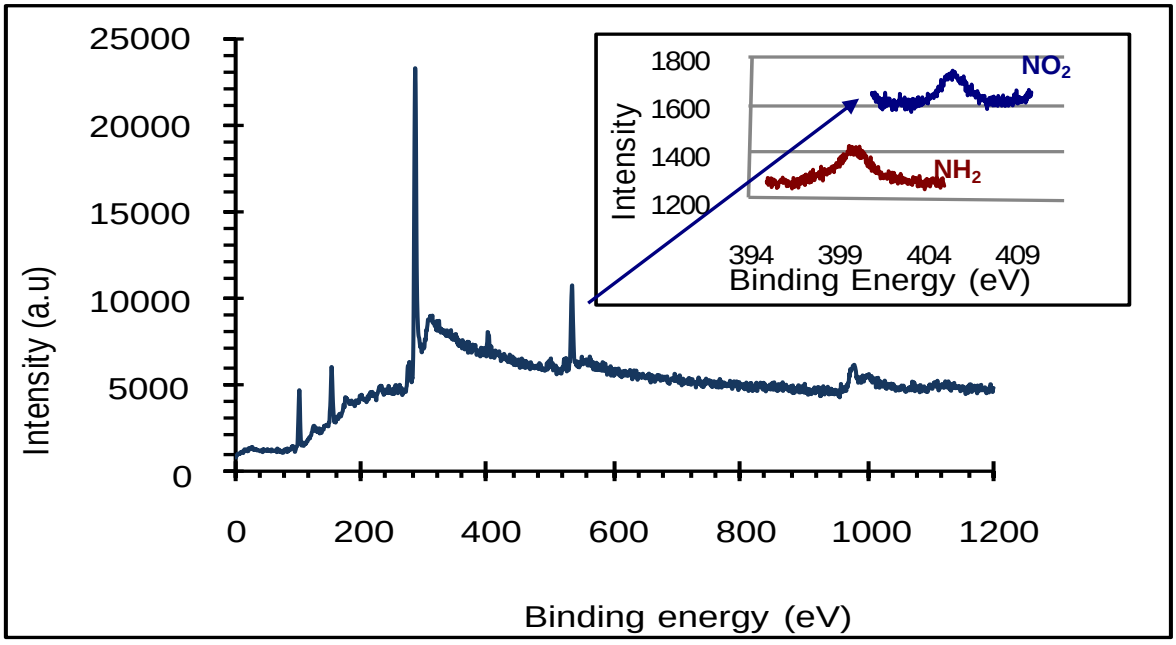
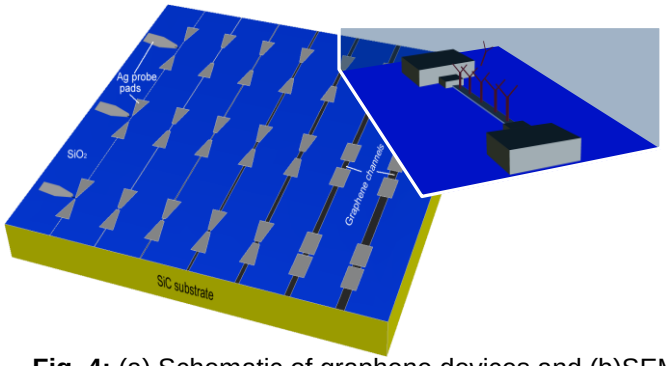


Fig. 3: XPS spectrum of nitrobenzene functionalized graphene surface. Inset: N 1s peak, conversion of nitro to amino group upon subsequent electrochemical reduction to aniline.



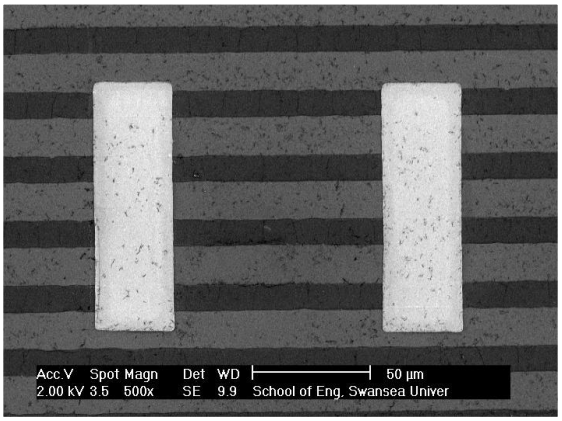


Fig. 4: (a) Schematic of graphene devices and (b)SEM image of epitaxial graphene microchannel device.