Diamond as a platform for supporting graphene

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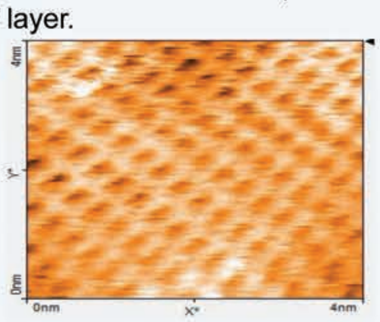
Introduction

Inevitably the substrate that attaches to a material such as graphene will influence the electronic properties of the carbon monolayer. Comparing with the majority substrate SiO_2-Si, we initiated a study on the use of single crystal and thin film nanocrystalline diamond as the substrate material, with a view to investigating the influence of the surface terminating groups on the diamond surface on the subsequent electronic properties of the deposited graphene layer.

(a)



(b)

Figure 1 (a) Single crystal diamoond(100); (b) STM image of chemical vapour deposited (CVD) graphene.

Experimental Methods

CVD produced graphene (Cu-foil) was transferred onto single crystal diamond (100) substrates that had been previously subjected to chemical or plasma treatments to lend them differing surface terminating groups. Diamond with monolayer attachments of H, O, F and N were investigated, in all cases leading to a p-type system once graphene had been deposited. Before transferring, the contact angle goniometer was untilized to measure contact angles and X-ray photoelectron spectroscopy (XPS) provides the binding energy for different substrates.

TABLE 1: The Contact Angle for different substrates

Substrate	Contact Angle
SCD	74.8
Hydrogen terminated SCD	88.9
Oxygen terminated SCD	57.2
Nitrogen terminated SCD	57.6
Sulfur Hexafluoride terminated SCD	93.8

TABLE 2: Surface Composition in Atomic Percent for different substrates

Sample	C	N	O	F	Si
H-terminated SCD	94.8%		3.7%	0.6%	0.9%
O-terminated SCD	89.0%		10.2%	0.8%	
N-terminated SCD	81.2%	5.4%	12.9%	0.5%	
F-terminated SCD	78.8%		11.7%	9.5%	
Graphene on SCD	86.0%		14.0%		

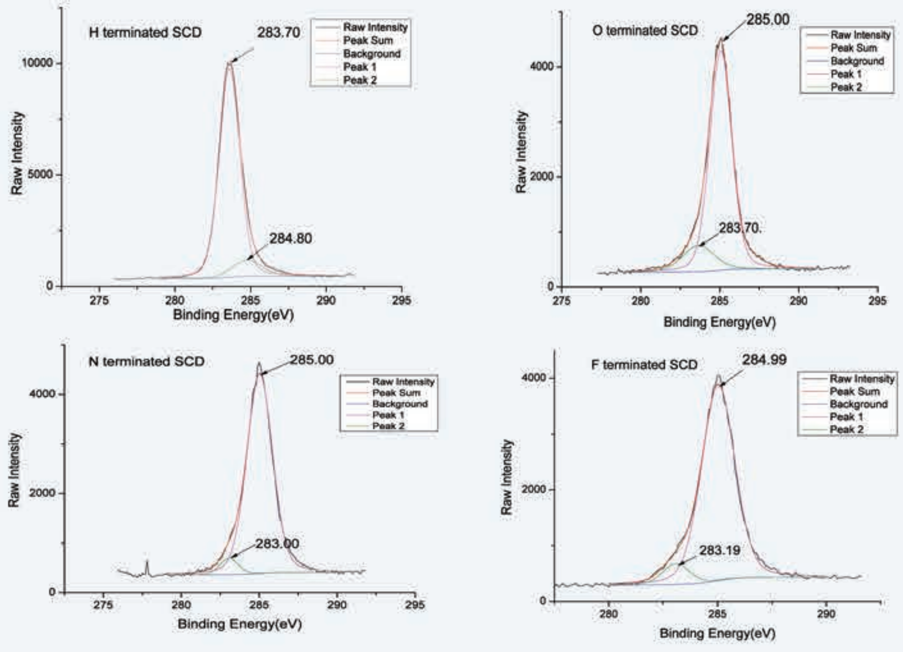


Figure 2. *XPS C1s spectra for different substrates.*

Raman Spectroscopy

Raman spectroscopy is a powerful tool both for identifying the number of graphene layers and for monitoring the doping, defects and chemical functionalization of graphene. Raman analysis was used to investigate CVD graphene on the SiO_2-Si substrate to check the quality of graphene, followed by Raman of graphene on different SCD substrates.

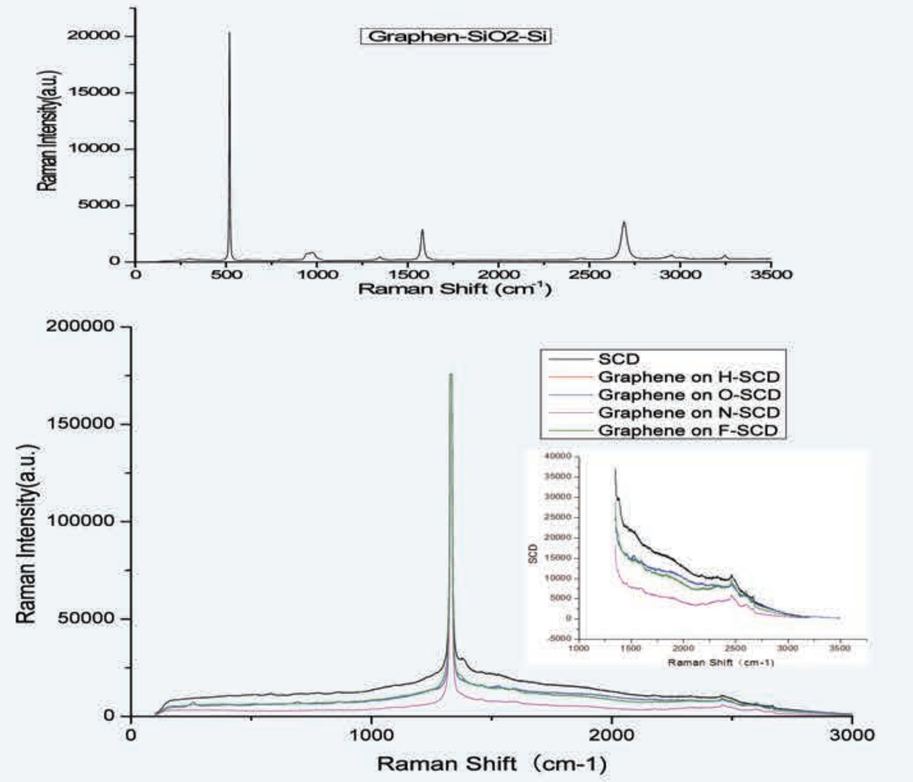


Figure 3. *Raman spectra of graphene on SiO_2-Si and diamond substrates.*

Hall Effect Measurement Results

In graphene films, the charge carrier dynamics appear effectively relativistic with zero effective carrier mass and the transport properties are governed by the Dirac equation. Stark differences in the electrical character of the resultant graphene-diamond heterostructure were observed. In table 3, it can be seen that higher carrier mobility values cannot be simply associated with lower carrier densities (as they are in conventional semiconductor systems).

TABLE 3.

Sample	Temperature (Kelvin)	Sheet resistivity (Ohm/sq)	Carrier concentration (cm^{-3})	Mobility (cm^2/Vs)
Graphene on H-SCD	298	4392	6.44E+12	220.86
Graphene on O-SCD	298	1345	2.79E+13	195.54
Graphene on N-SCD	298	12000	2.37E+13	18.63
Graphene on F-SCD	298	11716	5.12E+14	1.04

In the case of H-terminations, the maximum mobility rose, allied to the lowest carrier concentration, but the carrier concentration rose noticeably for O-terminations, with modest decrease in mobility. In contrast, a similar carrier concentration was observed when N-terminations were charactersied, but a sharp decline in mobility was associated with this heterostructure. In the case of F-terminations, the mobility decreased even further, but the carrier concentration became extremely high. These results are led by the surface-transfer effect within the diamond-terminating group-graphene heterostructures.

References

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