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Fluorianted Graphene as Passivation Layer of Graphene Field Effect Transistors

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Abstract

Surface roughness and oxygen doping degraded performance of graphene field effect transistors (GFETs). Here we report a method that fluorinated graphene(FG) was employed as passivation layer of graphene channel in GFETs. The similar hexagonal lattice with graphene, superior dielectric properties and stability make FG to be a naturally passivation layer to reduce surface scattering and protect graphene from oxygen doping in GFETs. We found that the low defect FG increase transport performance and n-type doping in GFETs.

1. Introduction

Graphene, the most highest mobility, has attracted attention in electronic applications. However, as a 2 dimensional transport material, graphene was sensitive with situations. Oxygen doping and surface roughness were the two main factors which influence graphene characteristics.

As our previously report, fluorinate graphene was successfully synthesis and used as dielectric layer in graphene electronic applications. In this study, we used fluorinated graphene as passivation layer between graphene channel and top gate dielectric.

Raman spectrum was used as a tool to check fluorinated graphene characters. GFETs was fabricated to measure the transport properties of graphene and the improvement from FG as passivation layer.

2. Device Fabrication

First, we used low pressure CVD (LPCVD) successful growing the high quality monolayer graphene on copper foils. The copper foils were annealed in an H_2/Ar environment, then methane was lead into feeding of H_2/Ar/CH_4 mixture. After the entire system was cooled down to room temperature, the graphene exudates on the surface of copper foils. The foils were covered by poly(methyl methacrylate) (PMMA) to protect the top surface utilizing spin coating. Later, the foils were etched in the copper etching solution for 20 min, and later obtain the monolayer graphene. Then, the graphene was transferred onto the Si/SiO_2 substrates and used acetone to remove PMMA..

Fig. 1 shows the schematic of device and fabrication process. The source-drain electrode region was first patterned by photolithography, and Ni (50nm) metal layer was deposited onto the photoresist pattern by thermal evaporation. Later, the pristine graphene was fluorinated using plasma-enhanced chemical vapor deposition (PECVD). And then, the fluorinated graphene was transferred onto the Si/SiO_2 substrates [pristine: pristine graphene as channel; 1FG: one layer fluorinate graphene onto pristine graphene channel; 3FG: three layers fluorinate graphene onto pristine graphene channel and 5FG: five layers fluorinate grapheme onto pristine graphene channel]. The graphene channels were defined utilizing reactive ion etching (RIE) in an oxygen environment after second patterned by lithography. Afterwards, the 5nm thick Al_2O_3 gate dielectric layer was deposited onto FG passivation layer. Finally, the gate region was third patterned by photolithography, and 150nm thick Al metal layer was deposited by thermal evaporation.

3. Results and Discussion

As shown in Fig. 2, the Raman mapping of four type devices, the type pristine has no Raman D band and 2D band/G band ratio is more than 2, indicating high quality monolayer graphene synthesis by LPCVD system. In 1FG, D band, located 1350cm^{-1} bump up a little and 2D band increase due to the overlay effect. Obviously, D band of 3FG and 5FG, increase but still lower than G band(~1590cm^{-1}), which indicates low defect formation in fluorination process.

To further estimate the character of FG, 121 points of FG were measured through Raman mapping. The high 2D/G intensity ratio of the graphene and FG samples indicate the highly two dimensional property of graphene and FG. the ratio of 5 layers fluorinate graphene is a little higher than 3 layer FG is possibility due to overlay effect. Meanwhile the 2D band is keep stable among the samples.

Fig. 4(a) (b) (c) shows the I_D-V_G curve. The graphene devices exhibit p-type behavior because of the unintentional doping, such as the oxygen and water in air[2]. Due to graphene having relatively large surface area, any atoms and molecules adsorbed on the surface can cause charge movement. Using the fluorinate graphene as passivation layer can isolate graphene reaction with oxygen and water in air. Fig (b) (c) shows Accumulated more layers of fluorinate graphene can effectively isolate pre-existing adsorbents. Fig (b) (c) show the Dirac point along with number of fluorinate graphene layers have gradually left shift behavior. Meanwhile the drain current increase apparently as the fluorinate graphene layers increase, which can be explained by the similar lattice structure between graphene and fluorinate graphene.

4. Conclusion

GFETs was successfully fabricated using FG as passivation layer. FG protect graphene channel from oxygen doping and reduce surface scattering effect. As the FG layers increase, these two phenomenon became more apparently.

Acknowledgements

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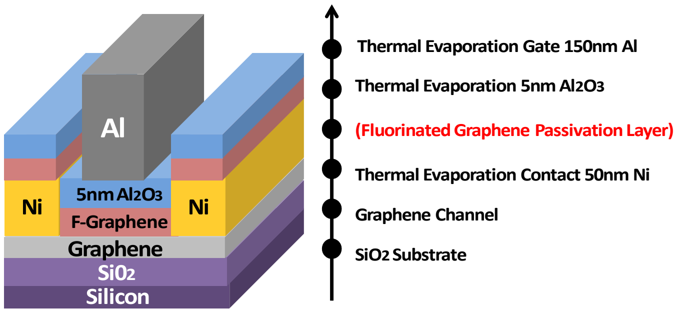

Fig. 1 Schematic of top-gated graphene field effect transistors

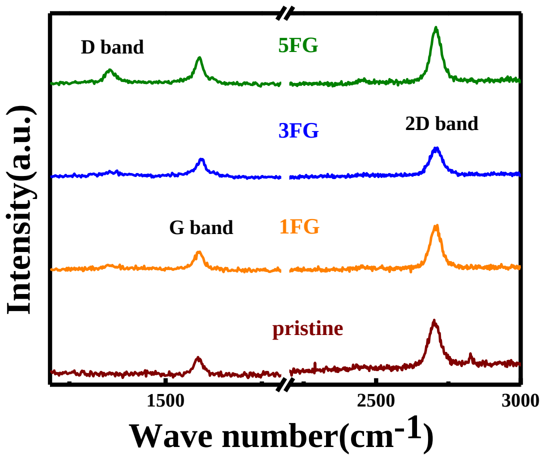

Fig. 2 The evolution of the Ramann spectra onto SiO2. Type pristine is only grapheme channel, type 1FG is one layer fluorographene onto channel, type 3FG is three layera fluorographene onto channel, type 5FG is five layers fluorographene onto channel.

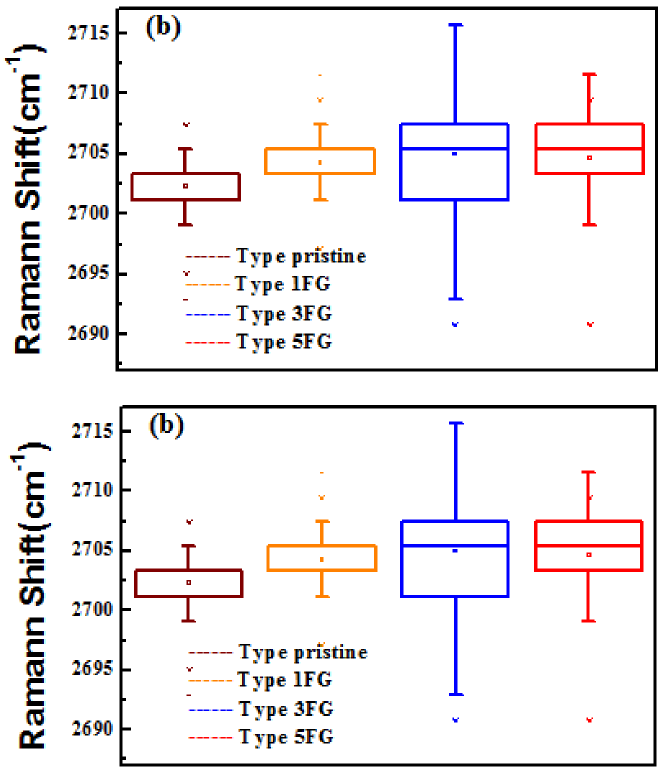

Fig. 3 (a) 2D/G ratio of pristine graphene, 1FG, 3FG and 5FG (b) 2D band raman shift of pristine graphene, 1FG, 3FG and 5FG

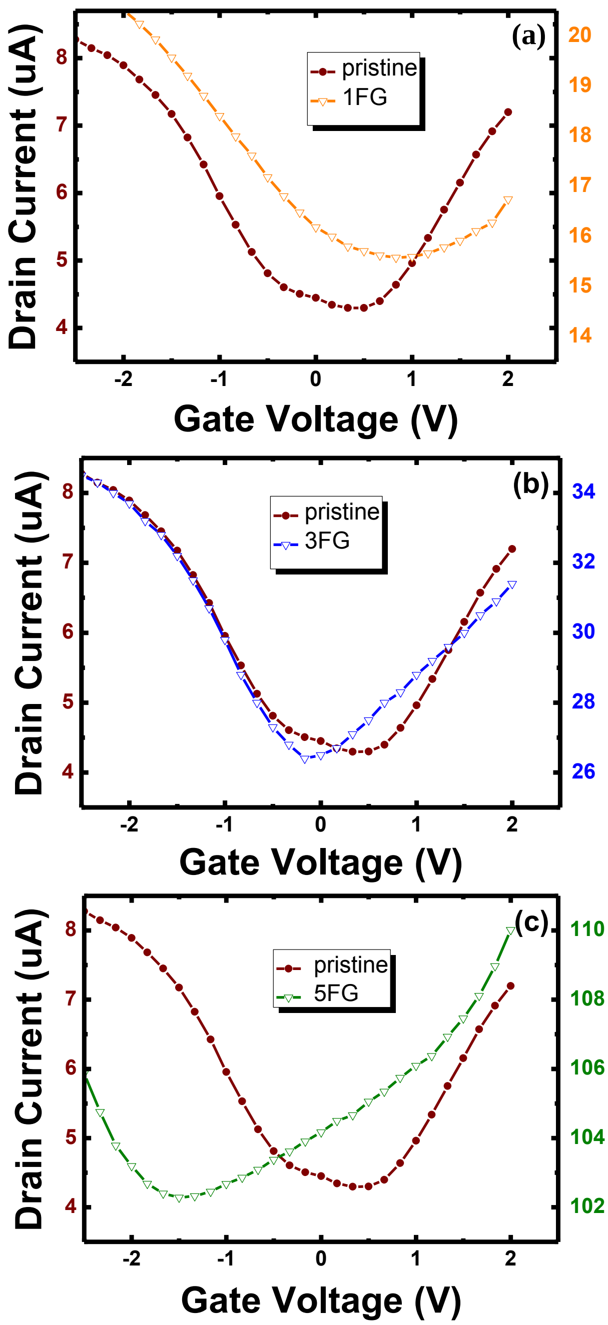

Fig. 4 Transfer characteristics of graphene field effect transistors. (a) pristine graphene channel and 1FG device, (b) pristine graphene channel and 3FG device, (c) pristine graphene channel and 5FG device