KM-7-2
Extended Abstracts of the 2011 International Conference on Solid State Devices and Materials, Nagoya, 2011, pp1331-1332

Touch Pressure Sensor using Metal/PVDF-TrFE/Graphene Device

Eun Jeong Paek[1], Hyeon Jun Hwang[2], Sang Kyung Lee[1], Chang Goo Kang[2], Chun Hum Cho[1], Young Gon Lee[2], Sung Kwan Lim[2], and Byoung Hun Lee[1,2]

[1]Department of Nanobio Materials and Electronics, [2]School of Materials Science and Engineering
Gwangju Institute of Science and Technology, Oryong-dong 1, Buk-gu, Gwangju, Korea
Phone: +82-62-715-2308, E-mail: bhl@gist.ac.kr

1. Introduction

Graphene has been actively studied for transparent electrode applications due to its high carrier mobility and transmittance (>97% for mono layer). Large area graphene process has been demonstrated, but the conductivity of graphene at zero bias condition should be improved further to substitute ITO.[1-3]

In principle, the enhancement of graphene conductivity can be achieved by either increasing the number of graphene layers while sacrificing the transmittance or by increasing the carrier concentration in the graphene. Modulation of carrier concentration in a graphene can be achieved by shifting the Fermi level, even without a carrier injection from outside. Or, an external bias or a doping at the graphene surface can be used. Since the transparent electrode application cannot use an external bias, Ahn et al. reported a graphene doping method using HNO_3, which can be used to obtain ten times lower conductivity than ITO at 90% transmittance.[4]

Another path to control the conductivity of graphene is to use a remnant polarization of ferroelectric capping layer deposited on graphene. [5-7] Several ferroelectric materials such as PVDF and PZT were studied and more than 500% conductivity modulations without an external bias were achieved.

In this paper, based on these existing learning, a new touch pressure sensor with metal/ piezoelectric/ graphene stack that can modulate the conductivity using an external pressure like in a touch sensor panel has been proposed and its functionality has been demonstrated for the first time.[8] The concept of this device can be directly applied to the touch panel to add a vertical touch pressure sensing function, which can be used to extend the functionality of touch sensor panel significantly.

2. Experiments

The fabrication process of PVDF-TrFE/ graphene touch sensor is shown in Fig.1. On a starting graphene sheet on 100nm SiO_2, Au contacts are formed using an e-beam evaporation. Then, the graphene strip with a width ~ 3μm was patterned using an oxygen plasma etch. Then, PVDF-TrFE (75/25 mol%, MSI Sensors) was spin coated at 2500 rpm for 30sec. Weight% of PDVF solution was 20% and final thickness was ~1μm. After the spin coating, PVDF film was baked at 140°C for one hour to eliminate the solvent and improve the crystallinity.

PVDF films were patterned using an oxygen plasma etch (100W, 20min) for open the source and drain electrode. Photo resist mask was removed using diluted PR stripper (1:1 with D.I.water).[9]

Finally back gate electrode (Ni, 100nm) was deposited at the backside substrate for electrical testing. Fig.2 showed the optical and SEM images of device. Optical image shows the region of PVDF-TrFE (dark region covering Au contact) and SEM image taken before PVDF-TrFE deposition shows the graphene channel region between Au contacts.

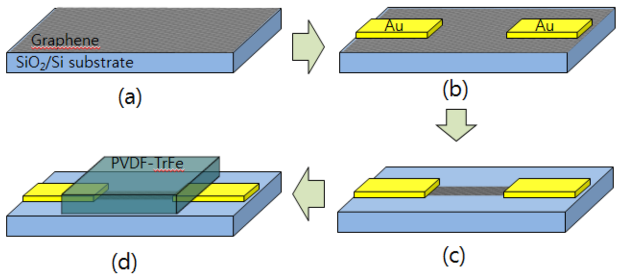

Fig.1 Process flow for PVDF-TrFE/graphene touch sensor

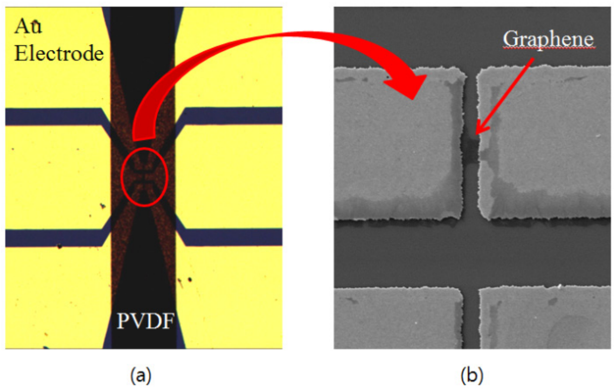

Fig.2 (a) Optical image and (b) SEM image of PVDF-TrFE/ graphene device.

3. Result and discussion

Among the four phases of PVDF-TrFE, β-phase has a permanent polarization due to the arrangement of hydrogen and fluorine atoms as shown in the inset of Fig.3. From XRD analysis, a clear peak around 20° confirming the presence of β-phase was confirmed. AFM was used to analyze the morphology of PVDF-TrFE film (Fig.4). Surface roughness was very high (rms roughness ~26nm). Since the grain of PVD-TrFE is large, even the bottom interface might not contact the graphene in uniform way.

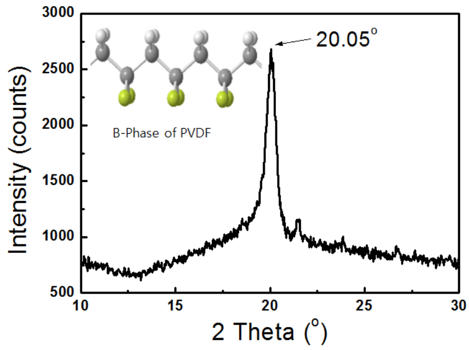

Fig.3 XRD spectrum of PVDF-TrFE. Inset shows a model for β-phase PVDF

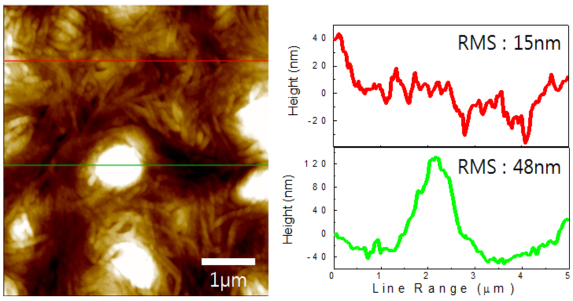

Fig.4 AFM image of PVDF-TrFE film

To study the functionality as a touch sensor, top surface of PVDF-TrFE was pressured with a vertical force using a rounded probe tip. Fig.5 shows that Dirac point of I_d-V_{bg} curve was shifted by -20V after the application of force. In addition to the Dirac point shift, the slope of I_d-V_{bg} curve was reduced, especially at the electron branch like a hole doping behavior.

The mechanism of Dirac point shift and hole doping like behavior is schematically explained in Fig.6. When the vertical force is applied, the polarization of PVDF-TrFE is expected to generate positive dipoles at the graphene/ PVDF-TrFE interface as shown in Fig.6 (a). The direction of I_d-V_{bg} curve shifts actually opposite to the direction of typical hole doping due to negative charges from hydroxyl adsorbates. Unfortunately, positive dipoles cannot explain the hole doping like conductivity reduction at electron branch. Also, the hole doping like behavior disappeared once the force was removed as shown in Fig.5.

Thus, a tentative model to explain the lower conductivity at the electron branch of I_d-V_{bg} curve is shown in Fig.6(b). The first model involves a deformation of rough PVDF at the interface. An enhance electron trapping and carrier scattering at the interface can explain lower conductivity. Another possible explanation is a stronger charge attraction from more positive dipole contacting the graphene due to the vertical force and an enhanced electron scattering from an interface scattering like in a surface channel device. Further study is necessary to finalize this abnormal conductivity modulation upto a few hundred percent

Even though the resistance change at zero bias was not significant at this time, maximum achievable resistance changes were upto 400-600%, which is good enough for practical applications in the touch sensor application. The resistance change can be maximized by shifting the Dirac point using doping or other charged layer if necessary.

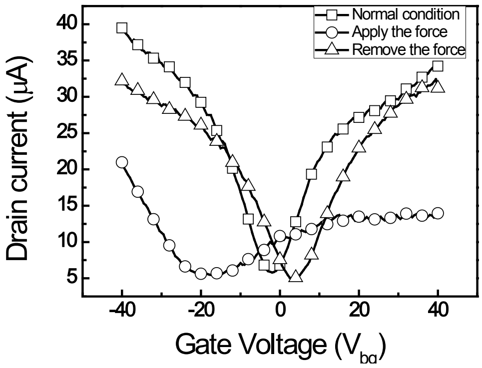

Fig.5 I_d-V_{bg} (back gate) curve of PVDF-TrFE-graphene FET device. Square is normal condition, circle is with a vertical force and triangle is after the removal of the force

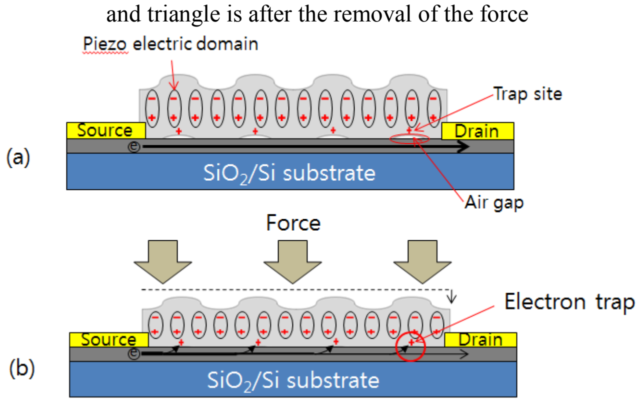

Fig.6 The schematic model to explain the piezoelectric effects of PVDF-TrFE film modulating the graphene conductivity. (a) before and (b) after the application of force

4. Conclusions

In this paper, a novel touch sensor using piezoelectric (PVDF-TrFE)/ graphene stack has been successfully demonstrated and a feasibility to achieve upto 600% conductivity modulation using an external force was shown.

Acknowledgements

This work was supported by WCU program through NRF grant funded by the Korean government(MEST) (No. R31-10026, No. 2011-0000072) and Dasan project funded by GIST.

References

[1] X. Li et al., Nano Lett. 9(12), p.4359 (2009).
[2] S. Bae et al., Nat. Nanotechnol. 5, p.574 (2010).
[3] K. S. Kim et al., Natrue, 457,p.706 (2009).
[4] J.H. Ahn and B.H. Hong, Nature Nanotech., (2010).
[5] R.S. Dahiya et al., Appl. Phys.Lett. 95(3), p. 034105(2009).
[6] Y. Zheng et al., Phy.Rev. Lett. 105, p.166602 (2010).
[7] X. Hong et al., Phy.Rev. Lett. 102, p.136808 (2009).
[8] Y. Zheng et al., EPL, 93, 17002 (2011).
[9] W.Y. Kim, et al., Micro. Eng. 88, p.1576 (2011).