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Effect of Plasma Treatment on CVD-grown Graphene/Metal Contact

Taesoo Kwon[1], Hyosub An[1] and Jongwan Jung[1*]

[1] Institute of Nano and Advanced Materials Engineering, Graphene Research Institute, Sejong Univ.
98, Gunja-dong, Gwangjin-Gu, Seoul 143-747, South Korea
Phone: +82-3408-3688 E-mail: *jwjung@sejong.ac.kr

1. Introduction

Graphene, a flat mono atomic layer of carbon atoms has a high electron mobility that could lead to exceptionally fast transistors. However, for electron device application of graphene [1], the control of contact properties will be more important than the intrinsic channel mobility. Whereas considerable work has focused on the electronic properties of bulk graphene, relatively less experiments have addressed the properties of metal/graphene interfaces. Furthermore, most of them focus on pristine graphene/metal contact properties [2-3] or epitaxial graphene (on SiC) to metal contact properties [4]. In reality, graphene is more likely contaminated during process steps using UV sensitive polymer photoresist, which makes real graphene/contact resistance could be much higher than the pristine case. For CVD-grown graphene, the transfer process which detaches graphene from metal foil could also deteriorate graphene/metal contact due to possible remains of PMMA on the transferred graphene. In this report, we show that contact properties of CVD-grown graphene/metal is much improved with O_2 and Ar plasma treatment just prior to metal deposition.

2. Fabrication

Graphene synthesis was accomplished via rapid thermal CVD system with a 2-inch horizontal quartz tube and halogen lamp heaters. A Copper foil was loaded into the system, and the chamber was vacuumed under 1 mTorr by a mechanical pump, and purged at Argon (Ar), Hydrogen (H_2) ambient (99.999% purity). Graphene growth was performed at 950℃ with methane gas. After synthesis, PMMA was spin coated onto the graphene/Cu foil, and Cu was removed in $FeCl_3$-based etchant (Transcene Co. Type I). Then, the PMMA/graphene film was transferred to SiO_2/Si substrate, and PMMA was removed in acetone. Active area of graphene channel was formed via standard UV litography system, and O_2 plasma etcher. Then, metal pad area for source and drain was patterned by UV lithography. The effect of contact properties of CVD-graphene/metal is evaluated using 10 nm Ti/ 50 nm Au metal contacts. Before the metal deposition, plasma pre-treatments were performed as summarized in Fig.1. Oxygen plasma treatment is accomplished using 20 W rf (13.56Mhz) power, with a 10 SCCM O_2 at 300 mTorr pressure. Ar plasma treatment is done using 50 W rf power, with a 10 SCCM Ar at 400 mTorr pressure. Subsequent metal, Ti (10 nm)/Au (50 nm) was deposited by thermal evaporator at low 10^{-7} Torr pressure. Electrical measurements were accomplished using transfer length method (TLM) test structures, with metal pad spacing ranging from 2 to 15 μm. The properties and the layer number of graphene were characterized by Raman spectroscopy. I-V measurements of TLM patterns were performed by semiconductor analyzer (Agilent B1500A).

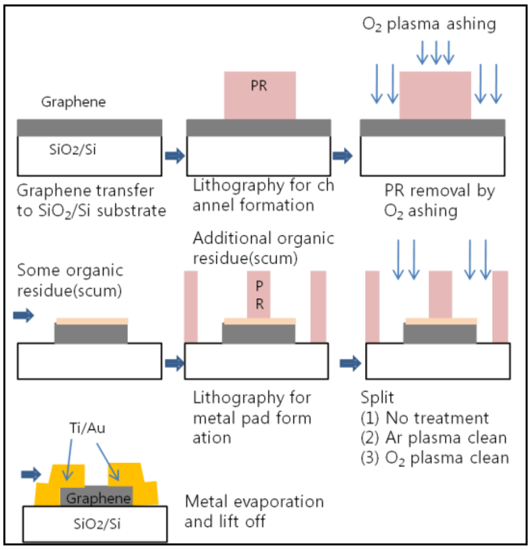

Fig.1 Overall process flow for this work.

3. Results and Analysis

Throughout many experiment, we found that polymer process including lithography step using photoresist and graphene transfer process using PMMA could remain polymer residue on the surface of graphene. Raman spectra in Fig.2 belong to the graphene samples with PMMA residue (a) and PR residue (b) on graphene. The locally remained residue in contact area could deteriorate CVD-graphene/metal contact.

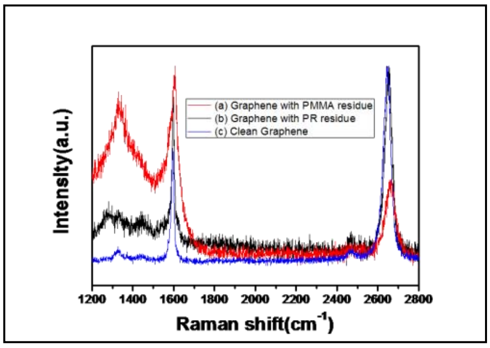

Fig.2 Raman spectra of (a) Graphene with PMMA residue, (b) graphene with PR residue, and (c) clean Graphene.

The Raman spectra of graphene samples used in this experiment before and after O_2 or Ar plasma clean are shown in Fig.3. It is clear that background signal reduces after both Ar and O_2 plasma clean. All the measured 6 sites of Ar plasma samples (15 sec) and 6 sites among the measured 8 sites for O_2 plasma samples (1 sec) exhibited the reduced background signal compared to the sample before treatment.

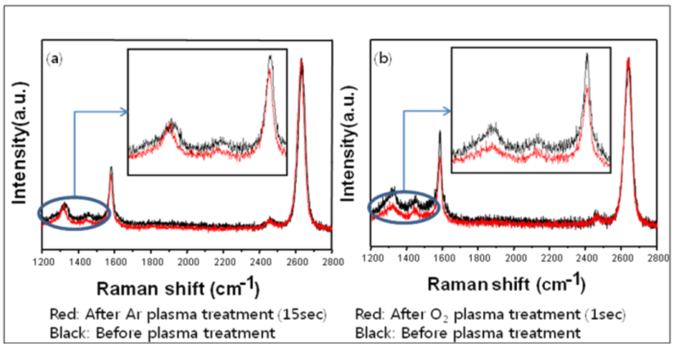

Fig.3 Comparison of Raman spectra before and after plasma clean ((a): Ar plasma and right, (b) O_2 plasma treatment)

Fig. 4 shows I-V curves of TLM patterns for various samples with different plasma treatment conditions. The black, red, blue and green line correspond to no treatment, Ar plasma (5 sec), Ar plasma (15 sec), and O_2 plasma (1 sec) sample, respectively.
Please note that for no treatment sample, contact resistance exhibits very high at low bias, and decrease with increasing bias. Most of the no treateatment samples also showed very noisy I-V curve, suggesting a poor, non uniform interface between graphene and metal. On the contrary, the most of plasma treated samples showed much neat and linear I-V curves.

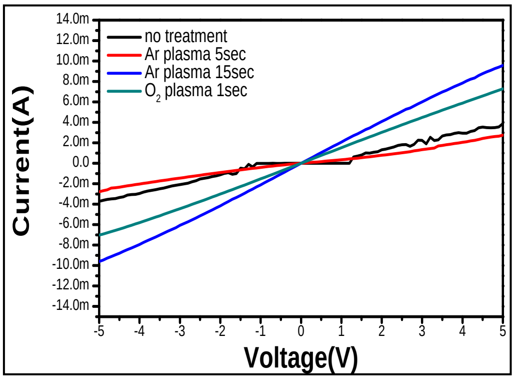

Fig.4 I-V curves of TLM patterns (with L=12 μm, W=20 μm) for different plasma treatment conditions.

Please note that the data of reference sample (no treatment sample) was not included in the figure since most of the measured samples show highly nonlinear contact properties.

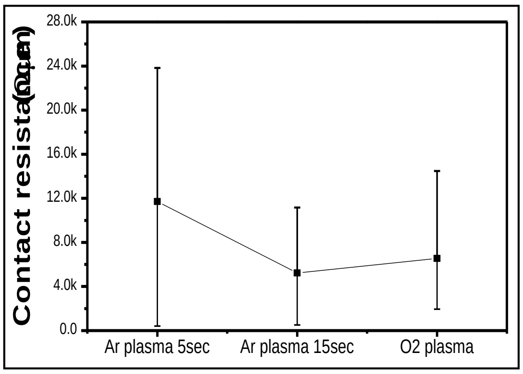

Fig.5 Comparison of contact resistances for various samples. The Ar plasma- treated sampls (15sec) shows the lowest value of ~5×10^3 Ωμm.

4. Conclusions

In this report, we showed that contact properties of CVD-grown graphene/metal is highly improved with O_2 and Ar plasma treatment just prior to metal deposition.

Most of the reference samples without plasma treatment showed non linear I-V curves, with high contact resistance at low bias. They also showed very noisy I-V curve, suggesting a poor, non uniform interface between graphene and metal. On the contrary, the plasma treated samples showed much neat and linear I-V curves.

Acknowledgements

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