Effects of Plasma Treatment on Interfacial Adhesion between CVD-grown Graphene and Polymeric Substrate

Kwang-Seop Kim, Kyungmin Jo, Dae-Hoon Lee, Woo-Suk Kang, Jae-Hyun Kim, Hak-Joo Lee

Nano-Convergence Mechanical Systems Research Division,
Korea Institute of Machinery & Materials (KIMM),
156 Gajungbukno, Yuseong-gu, Daejeon, 305-343, KOREA

kskim@kimm.re.kr

Abstract

Graphene, one atomic layer of carbon, has drawn much attention due to its exceptional electrical, optical, thermal, and mechanical properties[1]. Graphene based conductive film is regarded as the most promising application for commercialization in the field of transparent electrodes for touch panel, flexible display, and solar cell applications[2-3]. Large-area graphene can be synthesized by a chemical vapor deposition (CVD) process and the graphene is easily transferred onto various substrates, usually on a polymeric film for a flexible conductive film[4-5]. In most applications, graphene should be transferred on a target substrate and the adhesion between graphene and the underlying substrate is critical because the adhesion can significantly affect the reliability and performance of the application devices[6]. When the adhesion between graphene and the underlying substrate is weak, the graphene can be easily delaminated and fractured by external disturbance during production process and operation. In the case of graphene based large area conductive films, one of the bottlenecks in their commercialization is the reliability of graphene conductive films under high humidity and high temperature.

In this study, we investigated the effects of plasma treatments on the adhesion between CVD-grown graphene and a polymeric substrate. Polyethylene terephthalate (PET) substrate with good optical properties was used as polymer substrate and Ar, O_2, and NH_3 plasma was treated on the PET surface. The plasma treatment on PET was carried out in vacuum under low power conditions. After each plasma treatment, the treated surface was analyzed using a contact angle meter, atomic force microscope (AFM), an X-ray photoelectron spectroscopy (XPS). The results show that the plasma treatment did not change the surface morphology of PET but the surface energy drastically increased by introducing reactive group on the surface. CVD-grown graphene was transferred on the plasma-treated PET through a roll-to-roll dry transfer process using a thermal release tape[5]. In order to examine the durability of the graphene electrode, friction test was carried out on the graphene on PET samples using a home-built microtribometer for microscale contact. The friction force was measured under constant normal load during sliding and the wear track was analyzed using an optical microscope and AFM. As a counterpart material in the test, a laser-quality fused silica plano-convex lens was used. In addition, adhesion test was performed to directly investigate the effect of the plasma treatment on the adhesion between the graphene and PET. For the adhesion test, the graphene was transferred on the fused silica lens and the adhesion force between the lens coated with graphene and the plasma treated PET samples were measured. The results show that the plasma treatment can remarkably tune the adhesion properties between graphene and PET substrate, which leads to increase the durability of graphene transferred PET film. The optimization of plasma treatment and transfer conditions could provide the high quality and durable graphene based flexible electrode in the market.

References

[1] Geim, A. K., Graphene: status and prospects. Science 324 (2009), 1530-1534.
[2] Zhu, Y., Murali, S., Cai, W., Li, X., Suk, J. W., Potts, J. R., Ruoff, R. S., Graphene and Graphene Oxide: Synthesis, Properties, and Applications. Adv. Mater. 22 (2010), 3906–3924.
[3] Novoselov, K. S., Fal'ko, V. I., Colombo, L., Gellert, P. R., Schwab, M. G. & Kim, K. A roadmap for graphene. Nature 490 (2012), 192-200.

[4] Li, X., Cai, W., An, J., Kim, S., Nah, J., Yang, D., Piner, R., Velamakanni, A., Jung, I., Tutuc, E. et al. Large-Area Synthesis of High-Quality and Uniform Graphene Films on Copper Foils. Science 324 (2009), 1312–1314.
[5] Bae, S., Kim, H., Lee, Y., Xu, X., Park, J - S., Zheng, Y., Balakrishnan, J., Lei, T., Kim, H. R., Song, Y. I. et al. Roll-to-Roll Production of 30-Inch Graphene Films for Transparent Electrodes. Nat. Nanotechnol. 5 (2010), 574–578.
[6] Yan, C., Kim, K. S., Lee, S. K., Bae, S. H., Hong, B. H., Kim, J. H., Lee, H. J., Ahn, J. H., Mechanical and environmental stability of polymer thin-film-coated graphene, ACS Nano. 6 (2012), 2096-2103.

Figures

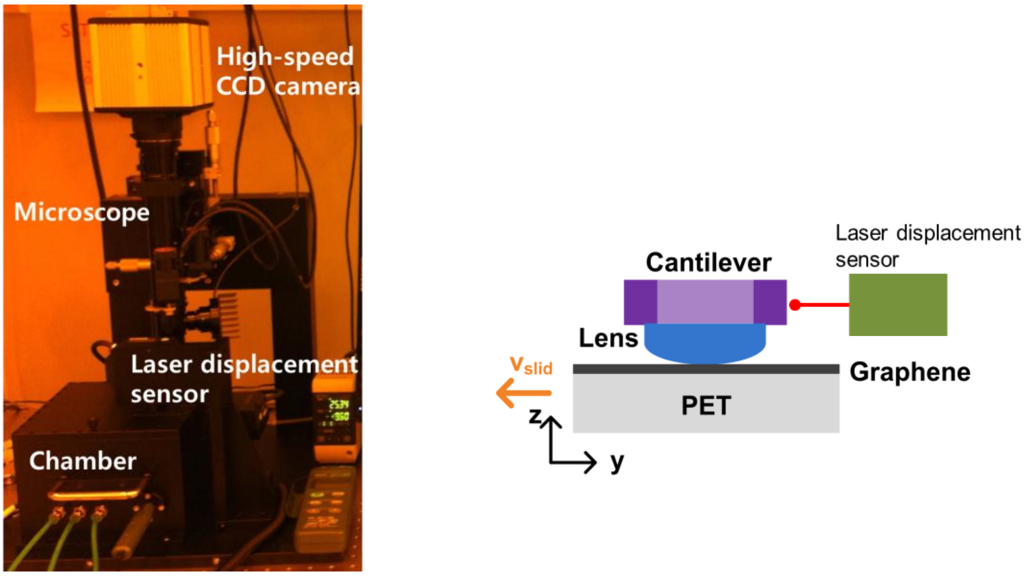

Figure 1. Photograph of home-built microtribometer and schematic of friction test

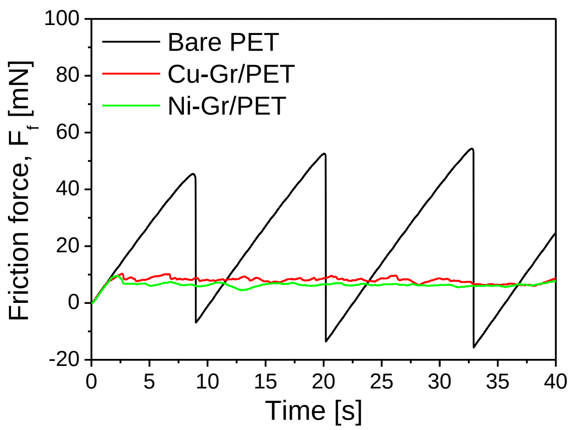

Figure 2. Friction force measured during the friction test