Ultra-stable graphene electrodes dopedwith macromolecular acid

Sung-Joo Kwon [1], Tae-Hee Han [2], Taeg Yeong Ko [3], Nannan Li [4], Youngsoo Kim [5], Dong Jin Kim [6], Sang-Hoon Bae [2], Yang Yang [2], Byung Hee Hong [6], Sunmin Ryu [3], Kwang S. Kim [4], and Tae-Woo Lee [7]

[1]Department of Materials Science and Engineering, Pohang University of Science and Technology, Korea, Republic of

[2]Department of Materials Science and Engineering, California NanoSystems Institute, University of California, Los Angeles, CA 90095, U.S.A.

[3]Department of Chemistry and Division of Advanced Materials Science, Pohang University of Science and Technology, Korea, Republic of

[4]Center for Superfunctional Materials, Department of Chemistry, Ulsan National Institute of Science and Technology, Ulsan 44919, Korea, Republic of

[5]Graphene Square Inc., Inter-University Semiconductor Research Centre, Seoul National University, Seoul 08826, Korea, Republic of

[6]Program in Nano Science and Technology, Graduate School of Convergence Science and Technology, Seoul National University, 1 Gwanak-ro Gwanak-gu, Seoul 08826, Korea, Republic of

[7]Department of Materials Science and Engineering, Research Institute of Advanced Materials, Pohang University of Science and Technology , Korea, Republic of

Although conventional p-type doping on grapheneusing small molecule decreases the sheet resistance (R_{sh}) of graphene, the doped graphene has suffered fromsevere increase of R_{sh} inambient conditions, which has been considered as a biggest bottleneck forpractical application of graphene electrodes. Here, we report an extremelyenvironmentally-stable graphene electrode doped with macromolecular acid(perfluorinated polymeric sulfonic acid: PFSA) as a chemical p-type dopant. ThePFSA doping on graphene provided not only ultra-high ambient stability for avery long time (> 64 d) but also high chemical and thermal stability evenafter exposure to various solvents and high temperature (300 °C), which havebeen unattainable by doping with conventional small-molecule acids.Furthermore, PFSA doping induced a great increase of the surface potential(~0.8 eV) of graphene (i.e., graphene WF),reduced its R_{sh} by ~56%and achieved a smooth surface and high optical transmittance that are veryimportant for practical applications. A hole-only device using the PFSA-dopedgraphene demonstrates improved hole injection capability by reducing the energybarrier. High-efficiency green phosphorescent organic light-emitting diodeswere fabricated with the PFSA-doped graphene anode (~98.5 cd/A, ~95.6 lm/Wwithout out-coupling structures). This work lays a solid platform for practicalapplication of air-/chemically-/thermally-stable graphene electrodes with high WF in various optoelectronics.

This work was supportedby the National Research Foundation of Korea (NRF) grant funded by the Koreagovernment (Ministry of Science, ICT & Future Planning)(NRF-2016R1A3B1908431), by the Nano Material Technology Development Programthrough the National Research Foundation of Korea (NRF) funded by the Ministryof Science, ICT & Future Planning (MSIP, Korea) (NRF-2014M3A7B4051747) andby National Honor Scientist Program (2010-0020414). This work was alsosupported by 10079974 Development of core technologies on materials, devices,and processes for TFT backplane and light emitting frontplane with enhancedstretchability above 20% with application to stretchable display, and LGDisplay under LGD-SNU Incubation Program.