Ultra-low damage of phosphorous-doped CVD graphene via low energy ion implantation

Shih-Ming He[1]
Wei-Yen Woon[2], Cheng-Chun Huang[1], and Ching-Yuan Su[1,*]

[1] *Graduate Institute of Energy Engineering, National Central University, Taiwan*
[2] *Department of Physics, National Central University, Taiwan*
jackey10102001@hotmail.com,
*cysu@ncu.edu.tw

Development of n-/p-type semiconducting graphene is a crucial route to implement graphene-based nanoelectronics and optronics. Compared to these easily prepared p-type graphene, the n-type graphene, espeicially nitrogen atom doping, are more difficult to be prepared and controlled. Recently, phosphorous atom doping was reported to achieve air-stable and high mobility of n-type CVD graphene. Moreover, the phosphorous-doped graphene by ion implantation was considered as an ideal method due to its IC compatible process; however, it suffers from the limitation of dose controllable and it severally destroy the sp^2 bonding of graphene owing to high acceleration ion energy. The introduced defects degrade the performance of n-type graphene.

Here, for the first time, we report an ultra-low damaged n-type CVD graphene by using low energy ion implantation (20keV, the lowest energy until now), where the additional protection layer (thin Au or Cu film) was covered on as-grown CVD graphene to reduce the ion damage (Figure1). The additional post annealing was processed to healing the crystal defects. Moreover, this method can transfer phosphorous doped graphene onto versatile target substrates without any polymer residue. We characterized the doping configuration, crystallinity, and electrical properties on such n-type doped graphene. In Figure 2, the results indicate the low-damaged graphene with controllable doping concentration (2.3~4.6 at%) was achieved. The carrier mobility could up to ~600 cm^2/v · s, which was superior than previous reports on phosphorous-doped graphene. This work proposed a scalable and IC compatible process to achieve air-stable of n-type doping graphene; particularly, exhibiting an exceptional low defect density owing to our proposed low energy ion implantation, suggesting great potential for unconventional doping technologies for next-generation nanoelectronics.

References

[1] U. Bangert et al., Nano Lett., 13 (2013), 4902–4907

[2] Surajit Some et al., Adv, Mater., 40 (2012) 5481-5486

Figures

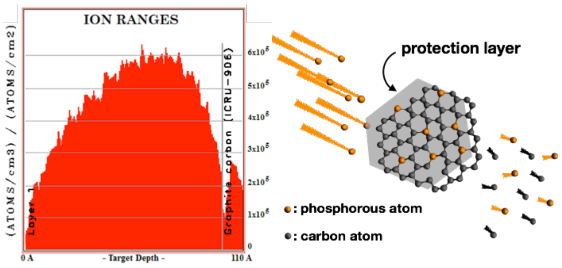

Figure 1: SRIM simulation to modelling the doping profile on CVD graphene with protection layer.

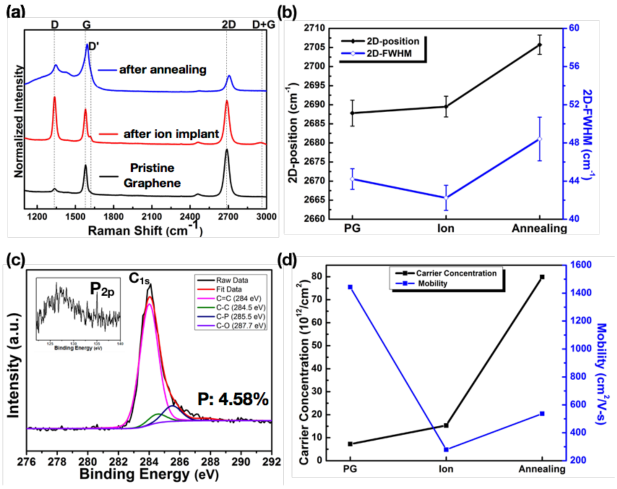

Figure 2: (a)Raman spectra on pristine graphene, after ion implant and post-annealing. (b)2D upshift indicates phosphorous doped graphene. (c) XPS spectrum. (d) Evolution of carrier concentration and mobility.