Supplementary information

Direct growth of nanographene film by surface wave plasma chemical vapor deposition and application for photovoltaic device

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Experimental technique of direct growth process:

Microwave assisted surface wave plasma chemical vapor deposition (MW-SWP CVD) technique has special advantage as it can easily produce meter scale uniform plasma, which can be suitable for large area deposition of graphene films. MW-SWP can produce an over-dense plasma even at a low gas pressure, with a density higher than the cut-off density (7.4×1016 m^{-3} for 2.45 GHz), without using a magnetic field, and can be enlarged by employing a large dielectric window and multi-slot antennas. MW-SWP has very low electron temperatures and low plasma space potentials. Carbon radicals are formed with hydrogen detachment within the plasma and graphene growth can be achieved at much lower substrate temperature.[1,2] In the MW-SWP-CVD system a

hollow quartz plate is taken as for plasma generation. Previously, it has been reported that with use of a hollow plate, plasma can be start-up smoothly without any density jump and plasma density is two times higher than that of a flat plate. High density surface wave plasma can be generated in meter size and large area deposition can be achieved at a very fast rate.[3] The schematic representation of the system used for growth of few-layer graphene films directly on SiO_2 and n-Si substrates is shown in figure 1S.

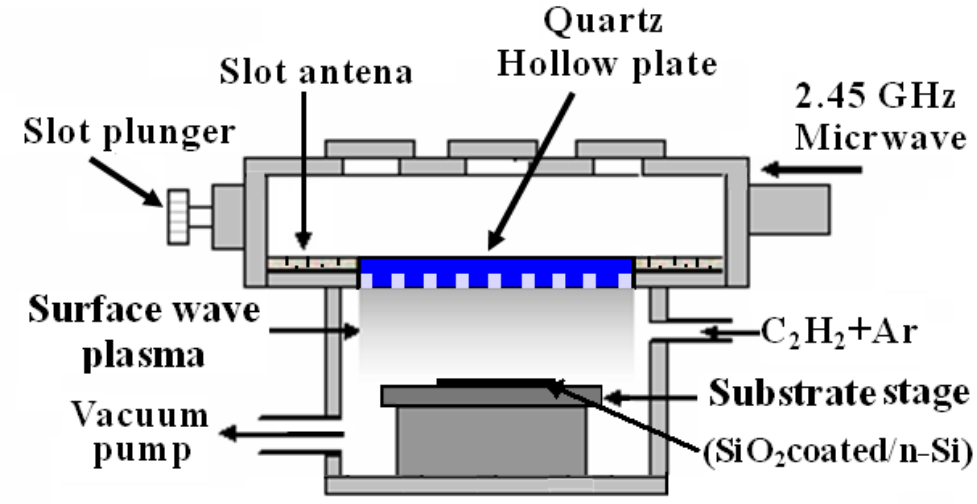

Figure 1S Schematic diagram of Microwave assisted surface wave plasma (MW-SWP) chemical vapor deposition (CVD) system used for deposition of nanographene films.

References

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2. G. Kalita, K. Wakita and M. Umneo, *RSC Adv.*, 2012, DOI:10.1039/C2RA00648K.

3. S. Nakao and H. Sugai, *Jpn. J. Appl. Phys.* **2007**, *46*, 1039-1041.