# Transmissible plasma evolved graphene: a noble approach of graphene production

**Meijo Univ., Nagoya Inst. Technol. °Kamal P. Sharma, Aliza K. Sharma, Daiki Yamamoto, Toru Asaka, Takahiro Maruyama**

**E-mail: kamalprasads@gmail.com**

The chemical vapour deposition (CVD) of carbon feedstock onto a catalyst surface, carbon species that are excited by a plasma, and high-energy laser irradiation of carbon surfaces are important methods for graphene production (1-3). Among them, plasma enhanced CVD (PECVD) utilizing microwave plasma, surface wave plasma, or radio frequency (rf) plasma has been realized as one of the most popular techniques to synthesize graphene at low temperature and with short processing time (4). However, for most CVD and PECVD techniques, time-consuming transfer and chemical treatment processes are essential to produce graphene for subsequent applications. Here, we propose a simple technique to produce suspended graphene with a short processing time and very low temperature by employing a pulsed arc plasma deposition (APD) and termed as transmissible plasma evolved graphene (TPEG).

For TPEG production, commercially available TEM microgrids (Okenshoji Co., Ltd., Japan) with amorphous carbon (a-C) membranes were utilized, onto which Co plasma produced from Co target in a pulsed APD system (APD-2S, Advance Riko, Inc. Japan) was exposed (**Figure 1(a)**). Each arc pulse is triggered by a surface flashover from a trigger electrode to the cathode surface (trigger duration about 10 μS) and the discharge voltage between cathode and anode was varied, which affects mainly the density of metal plasma. As produced TPEG was analyzed by OM, Raman spectroscopy, XPS, AFM, and TEM.

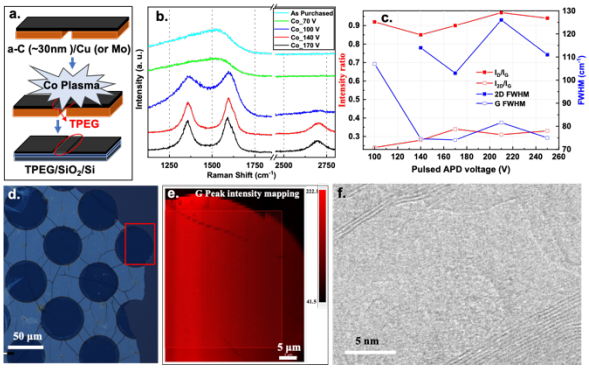


**Figure 1. (a)** Schematics diagram showing transmissible plasma evolved graphene (TPEG) formation, (b) Raman spectra of TPEG at different biased voltage for Co target as a cathode, and (c) shows qualitative Raman analysis. (d) OM image of TPEG/$SiO_2$/Si, and (e) shows Raman map for G-peak intensity around red rectangle. (f) Bright field HRTEM image of as formed TPEG.

**Figure 1(b)** shows the Co plasma utilized with biased voltage of 140V (3 pulses) or more produced the TPEG and high quality TPEG was produced at 170V (**Figure 1(c)**). The uniform G-band map (**Figure 1(e)**) indicates the identical quality of TPEG, corresponding to suspended part of a-C membrane on TEM grid ((**Figure 1(c)**) which is comprised of 3 to 12 layers with interlayer distance of 0.34 nm (**Figure 1(f)**). Thus, by tuning catalytic activity of Co plasma, TPEG could be produced in both time and energy efficient ways at near room temperature.

This work was supported in part by Private University Research Branding Project from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. ACS Appl. Nano Mater. (in press).

**References:** [**1**] Li, X. et al., Science 324, 1312 (2009). [**2**] Jacov, M. V. et al., Nano Lett. 15, 5702 (2015). [**3**] Lin, J. et al. Nat. Commun. 5, 5714 (2014). [**4**] Pharm, V. P. et al., Chem. Soc. Rev. 46, 6276 (2017).