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Controllable growth of graphene layer on dielectric substrate in microwave plasma torch at atmospheric pressure

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The initial stage of graphene layer deposition on silicon oxide substrate (Si/SiO_2) by ethanol decomposition in dual-channel microwave plasma torch at atmospheric pressure was studied in dependence on precursor flow rate and delivered microwave power. Prepared layers were analysed by scanning electron microscopy (SEM), Raman spectroscopy and X-ray photoelectron spectroscopy (XPS). The microwave plasma diagnostics was carried out using optical emission spectroscopy (OES). The sample analysis by SEM showed increasing density and lateral dimensions of horizontally aligned carbon nanosheets with increasing ethanol flow rate and their delamination and transition into vertically aligned graphene sheets with increasing substrate temperature. The Raman spectroscopy analysis of layers showed presence of D (1345 cm^{-1}), G (1585 cm^{-1}) and 2D (2685 cm^{-1}) peaks with 2D/G ratio corresponding to few layer graphene structure. At higher microwave power, above 400 W, mixture of amorphous carbon particles and graphene sheets was deposited on the substrate. In this case deposition, the D* peak at 1210 cm^{-1} and D** at 1500 cm^{-1} was observed in Raman spectra and C1s XPS spectra of carbon contained 20.4 at% of sp^3 carbon phase in comparison to 8.3 at% in case of graphene nanosheets layer. The ability to controllably grow wide range of carbon-based layers directly on dielectric substrate using simple precursor at atmospheric pressure plasma system represents unique opportunity for future applications such as transparent conductive layers, sensors and carbon functional coatings.
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