Title: Defect engineering of graphene using e-beam chemistry

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Abstract:

We use a method named e-beam chemistry, where the surface of a material is modified by a reaction with select gaseous species under irradiation by an e-beam using a conventional Scanning Electron Microscope (SEM), to engineer defects in graphene with high precision. To apply e-beam chemistry, graphene is first grown on Cu via low-pressure chemical vapor deposition [1] and then transferred using PMMA on to a Si/SiO_2 substrate. The substrate with graphene is placed inside the SEM and well-defined areas of the substrate are exposed to the e-beam (in a manner similar to e-beam lithography) in the presence of water vapor. The substrate is unloaded and examined using Raman spectroscopy, which reveals the presence of large defect- (D-) band signal at ~ 1350 cm^{-1} with peak widths << 100 cm^{-1} - suggesting negligible amorphous-carbon deposition. The influence of e-beam parameters (e.g. dwell-time, scan-rate, pressure etc.) on the D-band intensity is thoroughly studied. Raman study further reveals negligible D-band intensity near the boundary, showing that we can perform defect engineering with high precision. Atomic Force Microscopy images show higher phase contrast (as observed for oxidized graphene [1]) on the e-beam patterned regions compared to the non-patterned regions. The generated defects can be healed by annealing graphene at ~ 300 ^{o}C in air with a complete removal of the D-band, suggesting that the defects are produced by C-O-C bond formation. E-beam chemistry thus enables us to employ a mask-less, resist-free process to directly engineer defects in graphene.

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[1] Islam et al., RSC Adv., 2016, p. 42545-42553