Synthesis of graphene via two-step reduction of graphene oxide

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Graphene is one of the most promising materials that have the potential to be employed in many research areas due to its outstanding properties. Synthesis of graphene by the reduction of graphene oxide (GO) is becoming popular in the graphene comunity in terms of large-scale synthesis in an economical manner and synthesis of graphene with tunable properties. However, when applying reduced graphene oxide (RGO) for applications based on electrical conducting properties, the residual oxygen functionalities and lattice vacancies present in RGO hinder its utility [1]. Therefore, much suitable reduction stratergies should be developed. Chemical reduction of GO is known to be a simple, cheap and rapid method, though it cannot reduce all the oxygen functional groups present on GO [2]. Also, the RGO obtained by chemical reduction is difficult to deposit on a substrate as a thin film because of the formation of aggregates of RGO. Thermal annealing at high temperatures, on the other hand, gives RGO with low amount of oxygen groups compared to chemical reduction. Also, it can be done on GO films deposited on thermally stable substrates. However, the high temperature treatments may damage the GO structure due to the carbon loss as CO or CO_2 along with the functional groups. One alterative for these drawbacks is the annealing of GO deposited on a substrate in the presence of a carbon source in order to restore or repair the lattice defects [3]. However, complete recovery of the defects in GO is still a challenge to overcome.

As a step ahead, for the first time we have performed a two-step reduction method of GO deposited on SiO_2/Si substrates at a moderate temperature. Firstly, GO was chemically reduced by placing a drop of ascorbic acid on GO film, which is kept on a hot plate at 65 ^oC. Secondly, the samples were annealed at 800 ^oC in the presence of ethanol. Characterization was done by Raman spectroscopy and atomic force microscopy (AFM). Figure 1 shows the Raman spectra of GO (A) and GO reduced by chemical (B), thermal (C) and two-step method (D). A G'-band can be seen when GO was reduced in the presence of ethanol (Fig.1C and 1D) and it is much prominent in the sample reduced by two-step method. This indicates the restoration of the graphitic structure has been facilitated by ethanol. GO reduced by the two-step method has the lowest I_D/I_G ratio (1.03±0.06) with sharp D- and G-bands and the highest $I_{G'}/I_G$ (0.57±0.02) ratio with the sharpest G'-band (48.9±0.2) among those reduced by individual methods. Additional analyses will be done by atomic force microscopy and X-ray photoelectron spectroscopy. Further improvements of this method would pave the way for the synthesis of graphene in an economical manner.

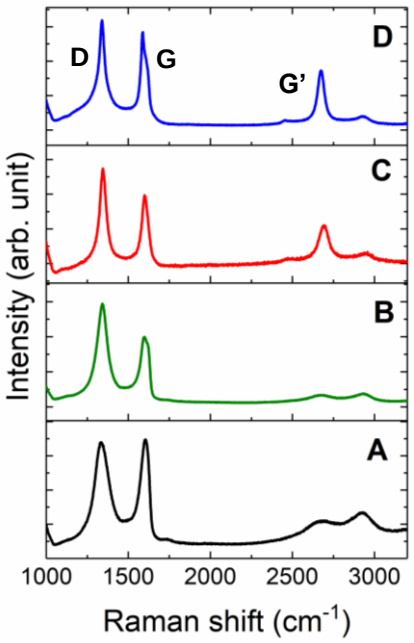

Fig. 1. Raman spectra of GO (A) and GO reduced by ascorbic acid (B), EtOH annealing (C) and two-step method (D).

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