Synthesis and characterization of graphene thin film with turbostratic stacking from graphene oxide

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Graphene oxide (GO) is promising material for scalable applications of graphene because of their mass-production feature. We have reported [1] that defects in GO formed during its synthesis [2] can be repaired by thermal process in ethanol atmosphere at ultrahigh temperature more than 1000ºC, and the obtained multi-layer graphene does not form the usual Bernal stacking but turbostratic structures [1], and exhibits excellent electric properties such as band-like transport [3]. Electronic structure of the turbostratic graphene similar to that of the single-layer graphene should enable the multi-layer graphene to improve its performance. In this work, we extend our study to synthesis of turbostratic graphene in a larger scale for bulk application and in thin film for property analysis.

Self-standing porous GO sponge in cm scale was fabricated by freeze-dry process for the dispersion of single-layer GO. The GO blocks (inset of Fig.1) processed at 1800 ºC under reactive environment exhibit superior features of D- and 2D-bands in Raman spectra (Fig. 1). This result indicates better crystallinity and single-layer-like properties, which were significantly improved by forming composites with cellulose nanofiber (CNF) as spacer. Chemically stable and flexible features with high surface area and low electric resistivity lead to a variety of practical applications such as electrode and sensor materials.

The turbostratic graphene thin film was prepared from stacked GO film on quartz substrates by thermal process at 1300ºC. Very high conductance and carrier mobility were observed even from thicker film (Fig.2). This behavior was also observed for CVD-grown turbostratic multi-layer graphene [4], and indicates their high performance due to single-layer-like transport properties and screening effect.

These results pave the way to open up novel research using the multilayer graphene with turbostratic stacking as beyond-graphene material.

References

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[2] N. Morimoto et al., Sci. Rep., 6 (2016)
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[4] C. Wei et al., Jpn. J. Appl. Phys., *in press*.

Figures

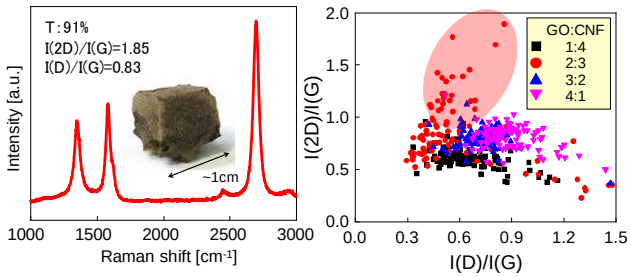

Figure 1: Large 2D bands observed from GO+ CNF composite sponge (inset photo), indicating the single-layer-like properties.

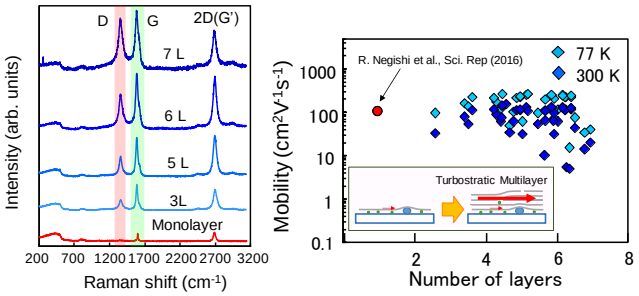

Figure 2: Very sharp 2D band due to turbostratic stacking was observed even from 7L-graphene. High carrier mobility was preserved for thicker graphene owing to screening effect in addition to benefit of the turbostratic stacking.