Reduced graphene oxide films produced from graphene oxide under an oscillating electric field around y-axis on x-z plane

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Abstract

Reduced graphene oxide (rGO) films can be obtained by heating graphene oxide (GO) in a reduction atmosphere [1]. Because the C-O bonds of GO have electric dipole moment, if the starting GO suspension is dried under an electric field in z-direction as shown in Fig. 1, then the more aligned rGO areas along the z-direction will be produced after the reduction process. On the x-y plane, however, the rotation of the GO (and the rGO) around the z-axis is not controlled.

We focus on the difference in the moment of inertia for GO around the x- and y- axes under an electric field in z-direction. If the electric field in the z-direction is shaken around the y-axis on the x-z plane, the GO will align also on the x-y plane with the less inertia momentum around the y-axis. Then, after the reduction process, the direction of all the rGO will be arranged not only in the z- but also in the x-direction.

GO prepared by Hummer method was resolved into DI water, and the suspension was dip-coated on the SiO_2/Si substrates. As shown in Fig. 2, the specimens were dried at room temperature under an oscillating electric field with both a 1 kV/cm of DC electric field in z-direction [2] and 0 – 0.14 kV/cm of AC electric field in x-direction. Then, the specimens were reduced in ethanol (2%) and nitrogen (98%) atmosphere at 950 ℃ for 30 min. The surface morphology was observed by SEM and the rGO films were evaluated by Raman spectroscopy. The D and the G peak separation was done based on the Gaussian profiles at the centers of 1350 cm^{-1} and 1600 cm^{-1}.

Figure 3 shows the surface SEM images of the specimens after the drying and the reduction process. The surface morphology seems to change from homogeneous to some structures as the process proceeded from under (a) no electric field, (b) only a DC electric field, and (c) an oscillating (DC + AC) electric field.

Figure 4 shows Raman spectra of the specimens shown in Fig. 3 (a) through (c). Without electric field, the ratio of G/D in the Raman spectra was 0.49. By using DC electric field the, G/D ratio increased by about 30 %. By using an oscillating electric field, the G/D ratio increased by about 4 % compared with the ones under only a DC electric field.

In conclusion, the DC electric field is effective to align the GO in the drying process and in producing rGO with high G/D ratios in Raman spectroscopy. The oscillating electric fields can improve further the D/G ratios by about 4 %.

References

[1] Ching-Yuan Su et al., ACS Nano **4(9)**, (2010)
[2] K.Abe et.al, Phys Status Solidi, c **10**, 1272 (2013)

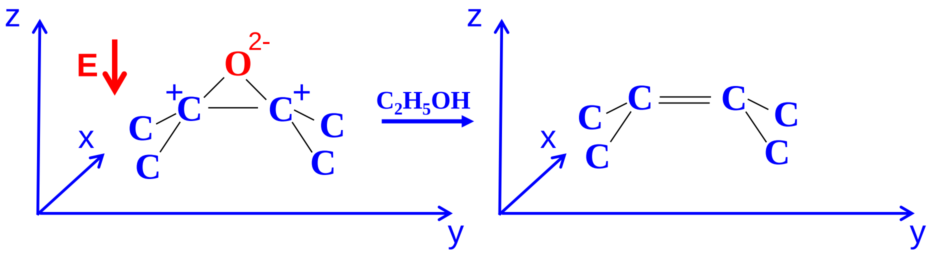


Figure 1 Drying and Reduction model of GO under only a DC electric field in z-direction.

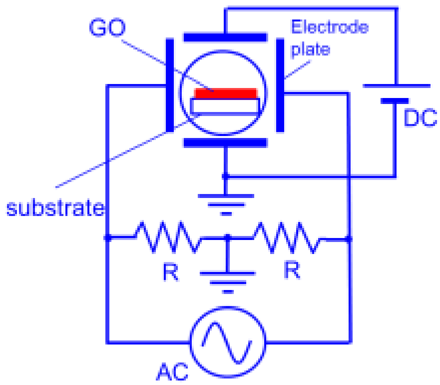
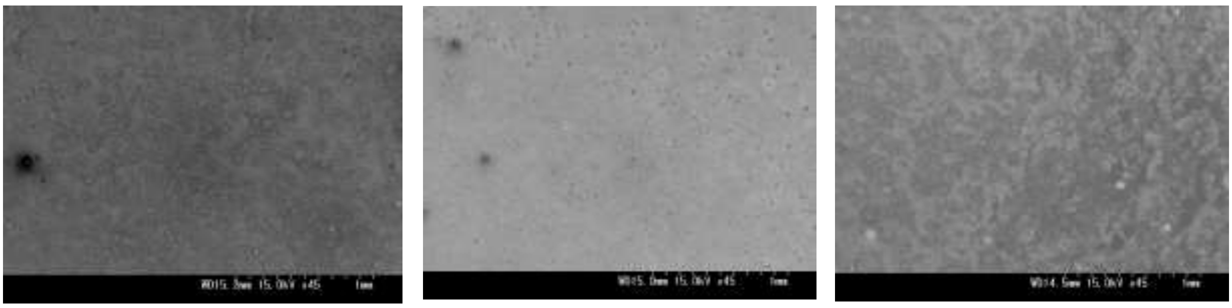
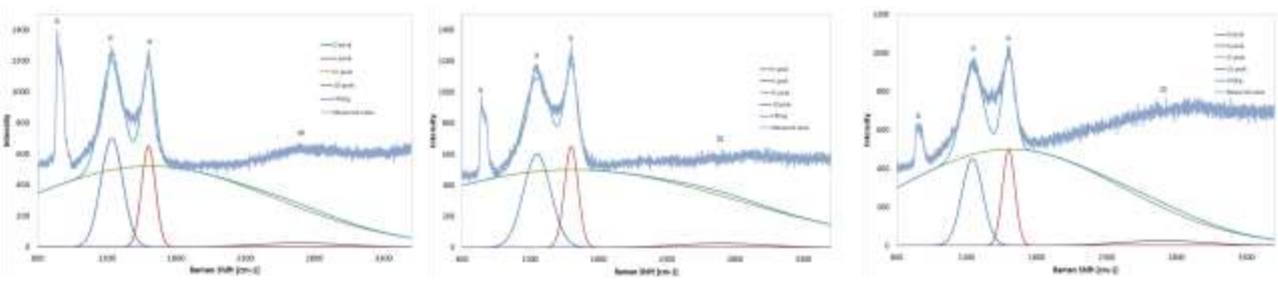


Figure 2 Schematic of drying and reduction experiment of GO under both DC and AC electric fields.



(a) (b) (c)

Figure 3 Surface SEM images of rGO films dried and reduced under (a) no electric field, (b) only 1.0kV/cm of DC electric field, and (c) both 1.0kV/cm of DC in z- direction and 0.14kV/cm of AC in y-direction electric fields.



a) (b) (c)

Figure 4 Raman spectra of rGO films dried and reduced under (a) no electric field, (b) only 1.0kV/cm of DC electric field, and (c) both 1.0kV/cm of DC in z- direction and 0.14kV/cm of AC in y-direction electric fields.