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Supporting Information for

# Effect of degree of reduction on the anode performance of reduced graphene oxide in Li-ion batteries

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**Table S1.** Combustion-based elemental analysis.

| Sample | C At. % | O At. % | H At. % | C/O ratio | C/H ratio |
|---|---|---|---|---|---|
| **Re-G-O-1** | 51.62 | 26.52 | 21.87 | 1.95 | 2.36 |
| **Re-G-O-2** | 56.00 | 26.49 | 17.52 | 2.11 | 3.20 |
| **Re-G-O-3** | 66.41 | 18.92 | 14.67 | 3.51 | 4.53 |
| **Re-G-O-5** | 74.42 | 15.04 | 10.54 | 4.95 | 7.06 |
| **Re-G-O-14** | 76.82 | 14.20 | 8.98 | 5.41 | 8.55 |

**Table S2.** The discharge capacity of Re-G-O-T samples as anode materials at the 1$^{st}$, 2$^{nd}$ and 50$^{th}$ cycle.

| | **1$^{st}$** | **2$^{nd}$** | **50$^{th}$** |
|---|---|---|---|
| **Re-G-O-1-T** | 3,279 | 1,242 | 643 |
| **Re-G-O-2-T** | 2,692 | 1,181 | 481 |
| **Re-G-O-3-T** | 1,845 | 913 | 315 |
| **Re-G-O-5-T** | 2,002 | 950 | 312 |
| **Re-G-O-14-T** | 2,319 | 1,118 | 385 |

**Table S3.** The specific surface area and pore information of Re-G-O samples measured by BET measurements.

| | **Re-G-O-1** | **Re-G-O-3** | **Re-G-O-5** | **Re-G-O-14** |
|---|---|---|---|---|
| **SSA ($m^2/g$)** | 211 | 412 | 403 | 236 |
| **Total pore volume ($cm^3/g$)** | 0.43 | 0.27 | 0.33 | 0.21 |
| **Average pore diameter (nm)** | 8.13 | 2.65 | 3.25 | 3.52 |

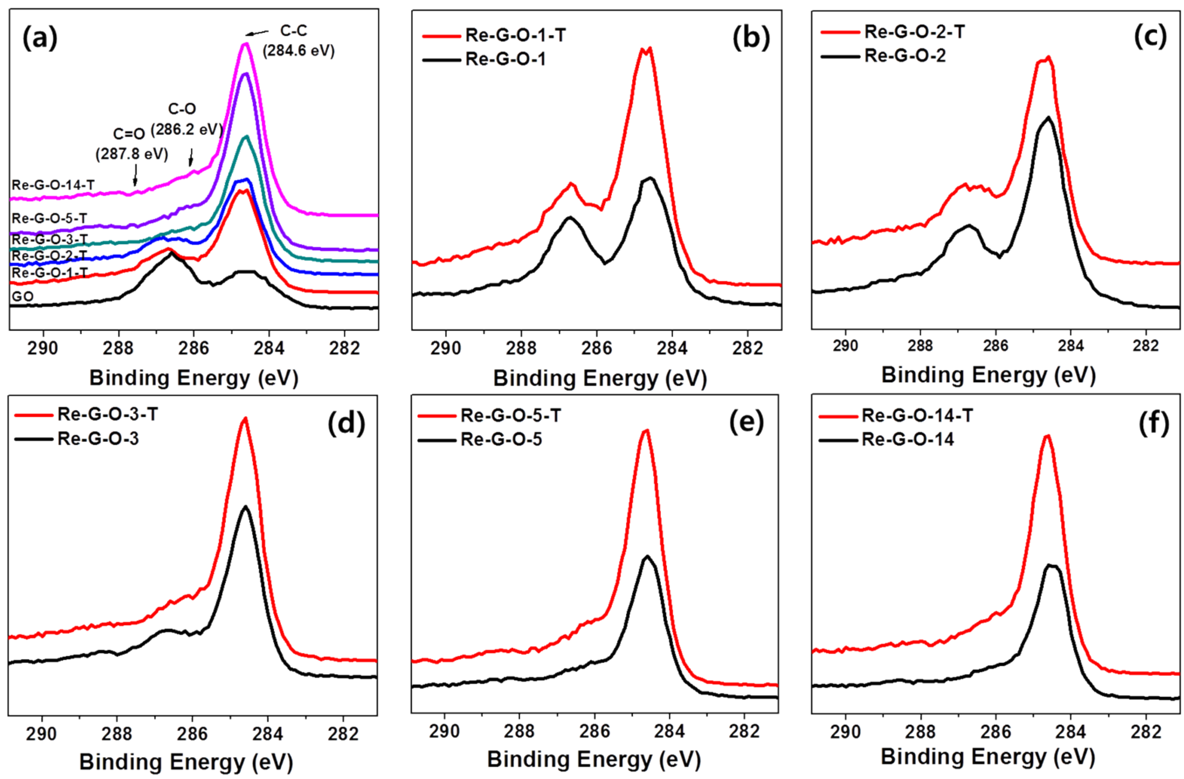


**Figure S1.** (a) XPS C1*s* spectra of GO and Re-G-O-T samples. Comparison between XPS C1*s* spectra of Re-G-O and Re-G-O-T samples at the same reflux time; (b) 1 day, (c) 2 days, (d) 3 days, (e) 5 days, (f) 14 days.

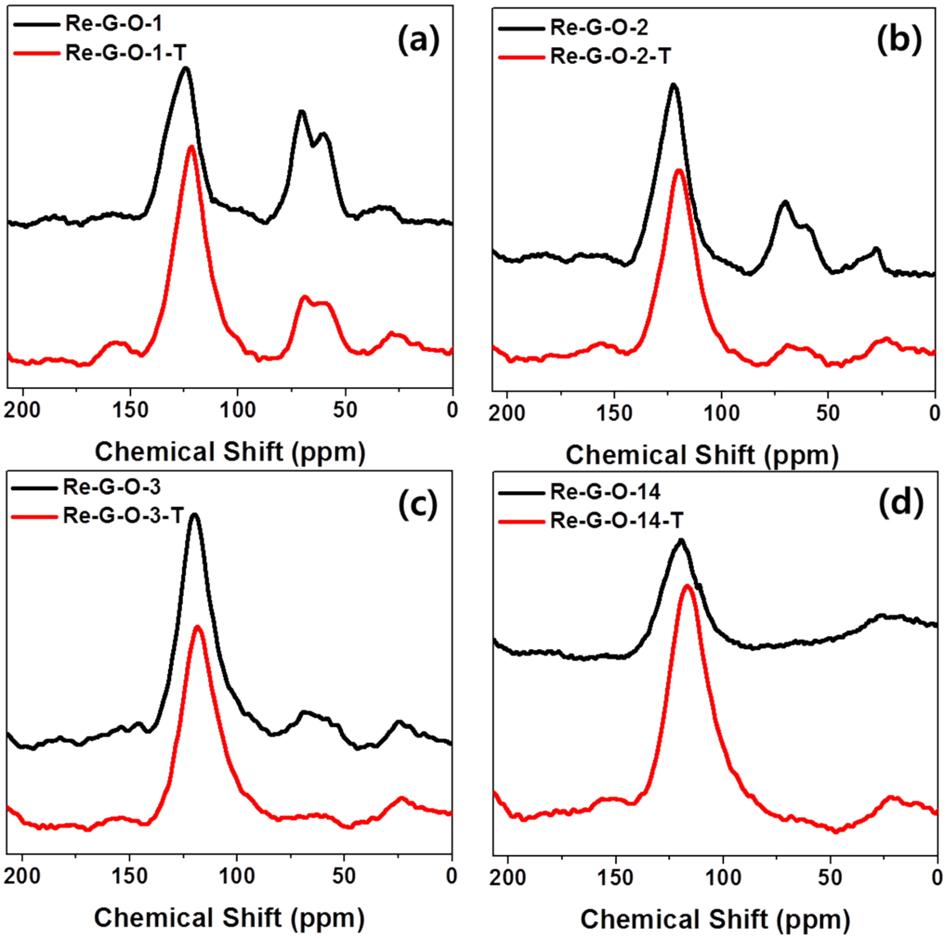


**Figure S2.** Comparison between MAS SSNMR spectra of Re-G-O and Re-G-O-T samples at the same reflux times; (a) 1 day, (b) 2 days, (c) 3 days, (d) 14 days.

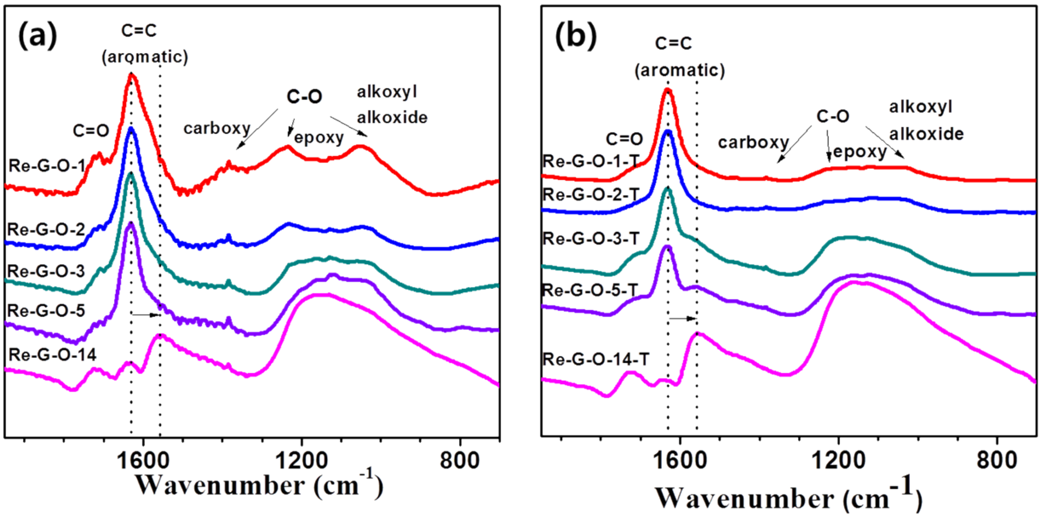


**Figure S3.** FT-IR spectra of (a) Re-G-O and (b) Re-G-O-T samples.

Figure S3 shows the FT-IR spectra of the series of Re-G-O and Re-G-O-T samples at selected region. Components of C–O stretching around 1,410, 1,220, and 1,050 $cm^{-1}$, which were attributed to hydroxyl and epoxy groups, decreased during reflux.[1-3] After 3 days of reflux, the intensities of these peaks decreased significantly, which concurred with NMR and XPS results. The peak around 1,620 $cm^{-1}$, corresponding to C=C stretching , was shifted to ~1,570 $cm^{-1}$ after 2 weeks reflux. This trend is more obvious in the spectra of Re-G-O-T samples. It is generally accepted that $sp^2$ carbon networks are restored during the reduction of the oxidized carbon network of G-O.[3]

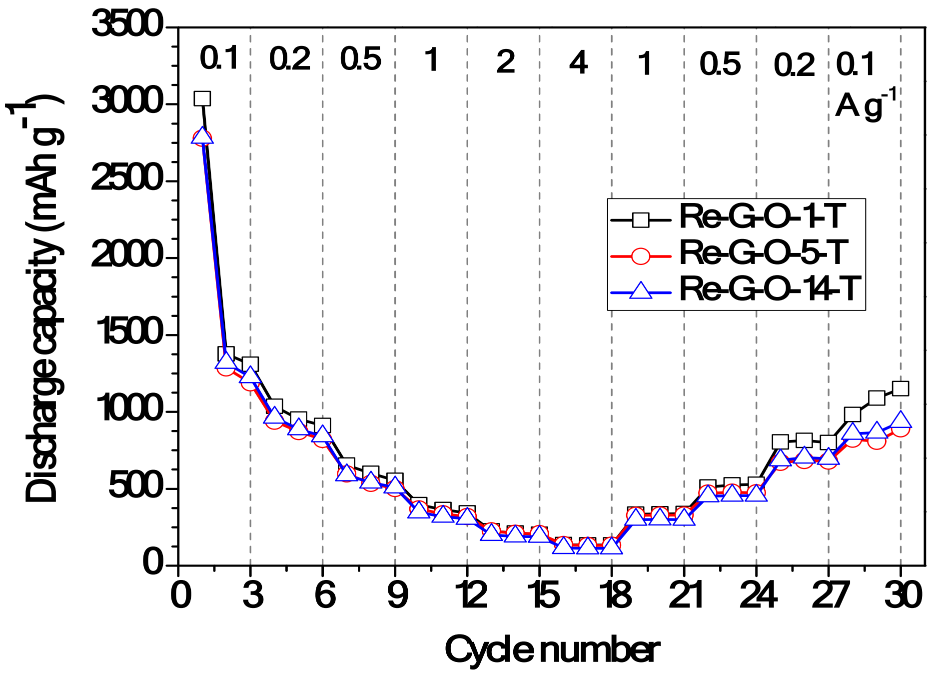


**Figure S4.** Rate performances of **Re-G-O-1-T**, **Re-G-O-5-T**, and **Re-G-O-14-T** electrodes at different current densities ranging from 0.1 to 4 A $g^{-1}$.

The rate capability of **Re-G-O-1-T**, **Re-G-O-5-T**, and **Re-G-O-14-T** electrodes was tested at various current rates ranging from 0.1 to 4 A $g^{-1}$ between 0.005 and 3 V for 3 cycles. After cycles as shown in Figure S4, the **Re-G-O-1-T** electrode still exhibited a high reversible capacity of 1150 mAh $g^{-1}$ at the 30$^{th}$ cycle with a current density of 0.1 A $g^{-1}$. Whereas, the **Re-G-O-5-T** and **Re-G-O-14-T** delivered a reversible capacity of about 889 and 935 mAh $g^{-1}$ at the 30$^{th}$ cycle, respectively.

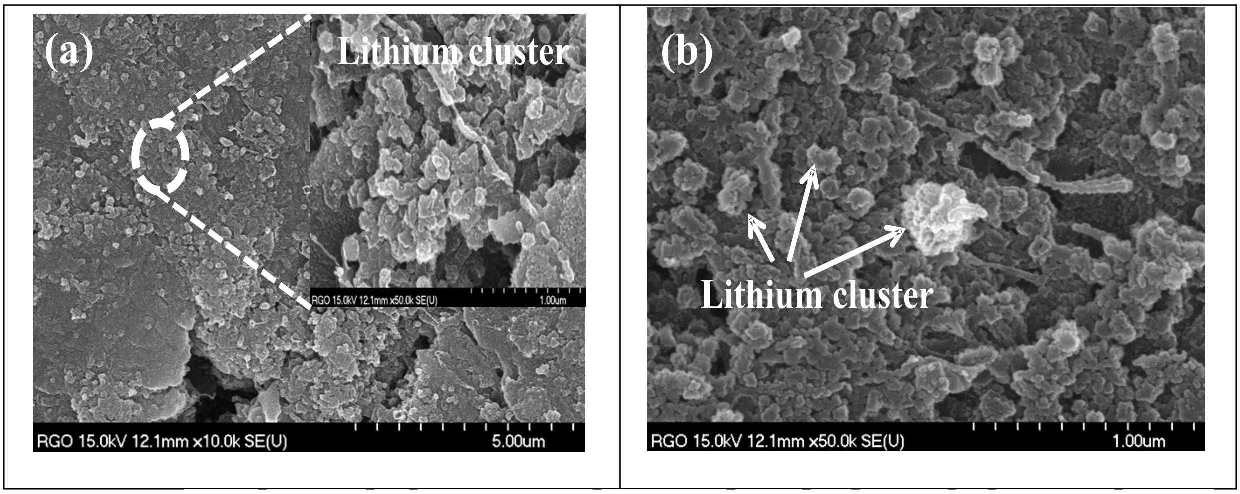


**Figure S5**. SEM images of **Re-G-O-1-T** electrode after 30 cycles at different current densities ranging from 0.1 to 4 A/g, (a) lower magnification and (b) higher magnification of electrode surface.

We measured SEM images of **Re-G-O-1-T** electrode after 30 cycles at different current densities ranging from 0.1 to 4 A/g. Small clusters, which were not found in SEM images of **Re-G-O-1-T** before cycling, were observed. They could be formed as $LiO_2$ by reaction of $Li^+$ with surface oxygen groups of Re-G-O samples.

## Reference

1. C. Hontoria-Lucas, A. Lopez-Peinado, J. d. D. López-González, M. Rojas-Cervantes, R. Martin-Aranda, *Carbon* 1995*,* **33**, 1585-1592.

2. S. Park, K. Lee, G. Bozoklu, W. Cai, S. T. Nguyen, R. S. Ruoff, *ACS Nano* 2008*,* **2**, 572-578.

3. G. Park, S. K. Park, J. Han, T. Y. Ko, S. Lee, J. Oh, S. Ryu, H. S. Park, and S. Park, *RSC Adv.* 2014, **4**, 36377-36384