Abstract

Graphene oxide (GO) has unique properties including electronic energy band-gap, hydrophilic behavior and numerous anchoring sites required for functionalization. However, the presence of numerous clusters containing oxygen functional groups (called debris). Here, we present a simple method consists of minimal treatments, like sonication and/or water rinsing processes, aimed to reduce the density of oxygen debris. Whereas this simple method removed epoxy and hydroxyl oxygen groups weakly attached to the graphene matrix, the double C=O bonds are almost not affected by the applied treatment, as demonstrated by X-ray photoelectron spectroscopy (XPS) and Fourier-Transform Infrared Spectroscopy (FTIR). A non-uniform distribution of the oxidation sites was observed, some appearing as clusters concentrated preferentially on GO defected regions, which are separated by pristine graphene area as seen by scanning tunneling microscopy and high-resolution transmission electron (STM).

STM measurements of Multilayer GO before sonication and water rinsing treatment

Characterization of the as-purchased GO multilayer samples: (a) A STM image; (b) Fourier transform of image in (a), showing two distinct regions: An inner part at low frequency, corresponding to a distorted region as framed by a green line in (b); An outer ring at a higher frequency, related to the “graphenic” region marked by blue-line in (a). (c) Inverse Fourier transform image considering only the higher frequencies in (b).

Effective Reduction Process

As-purchased → Short bath ultrasonic sonication → Water Rinsing

XPS GO measurements in all steps

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
<th>C-C [%]</th>
<th>C=O [%]</th>
<th>C=O [%]</th>
<th>C/O ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) As purchased</td>
<td>Multilayer GO</td>
<td>47.08</td>
<td>46.19</td>
<td>6.73</td>
<td>0.89</td>
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<td>(ii) Sonicated</td>
<td>Single layer</td>
<td>70.60</td>
<td>20.45</td>
<td>8.95</td>
<td>2.40</td>
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<tr>
<td>(iii) Sonicated</td>
<td>Single layer</td>
<td>87.19</td>
<td>4.95</td>
<td>7.86</td>
<td>6.81</td>
</tr>
</tbody>
</table>

FTIR GO measurements in all steps

GO effective reduction proposed model

STM Measurements after reduction

(a) STM topography image of single layer and (b) STS curve from image (a).

(a) STM topography image of single layer and (b) STS curve from image (a).

(a) STM topography image of single layer and (b) STS curve from image (a).

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(a) STM topography image of single layer and (b) STS curve from image (a).