LayerOne
Advanced Materials

Technical Data Sheet
Reduced Graphene Oxide

REGOX™ Graphene P980

REDUCED GRAPHENE OXIDE PREPARATION METHOD

LayerOne Partially Reduced Graphene Oxide (rGO) 80% C
is prepared by thermal reduction (flashing) of GO powder.

PHYSICAL PROPERTIES

Materials property	Analytical method	Value / test result
Appearance (form)	-	Powder
Appearance (color)	-	Black
Reduced Graphene Oxide	Gravimetric	> 99 %
Water	Gravimetric	0-1 %
HCl	Estimated	< 1 %
Bulk density	Weighing	0.007 - 0.013 g/cm^3
pH	pH-meter	About 3 when suspension in water diluted to 0.1 wt %
Smell	-	Faint HCl
rGO-layers in sheet-stacks	SEM and BET	Average 6 layers
Zeta potential in dispersion	Zetapotentiometer	n/a
Dispersibility	Sedimentation test	Cannot be truly dispersed in any medium See instructions on page

COMPOSITION AND CHEMICAL PROPERTIES

Materials property	Analytical method	Value / test result
Primary sheet thickness	XRD - Braggs equation	0.3 - 0.4 nm
Crystallinity	XRD - Peak intensity	Broad peak around 24 deg 2θ
Crystalline phase	XRD - EVA	>99 % Reduced Graphene Oxide
Primary sheet aspect ratio	AFM - visual	n/a
Crystallinity	TEM	n/a
BET surface area	BET measurement	250 m^2 / g
Chemical composition (wt %)* Carbon	XPS	78 - 81 %
Oxygen	XPS	16 - 17 %
Sulfur	XPS	1 - 3 %
Nitrogen	XPS	< 1 %
Chloride	XPS	< 1 %
Metals	XPS	Not detected
C/O ratio (atomic ratio)	XPS	6 - 7

*Chemical analysis refers to weight % on water free basis, obtained by XPS-analysis.

BACKGROUND DATA

LayerOne reduced Graphene Oxide (rGO) is produced by thermal reduction of graphene oxide. The product has been extensive analyzed, comprising SEM, XRD, IR, Raman, XPS, AFM, TEM, TGA, and BET. For most analyses, data can be provided upon request.

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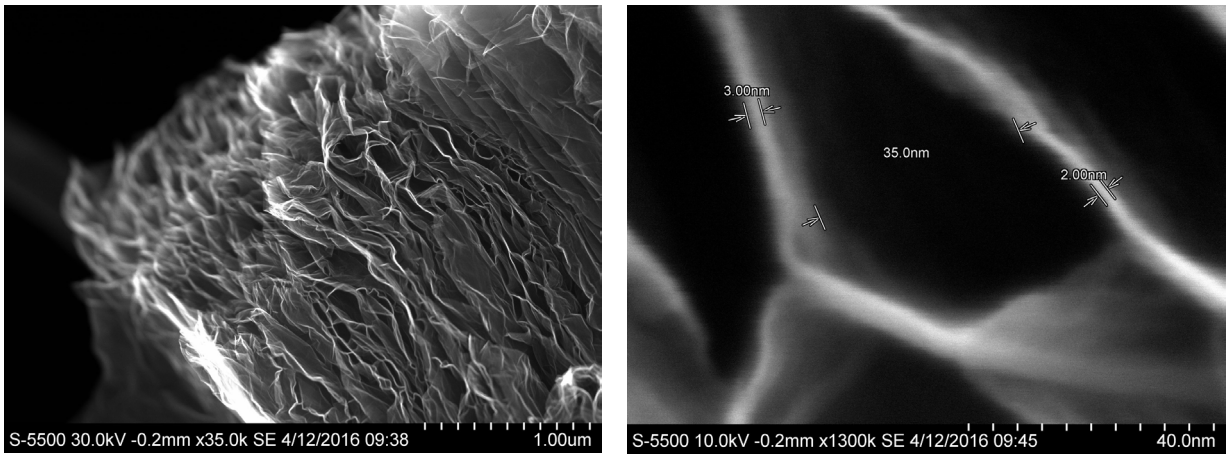
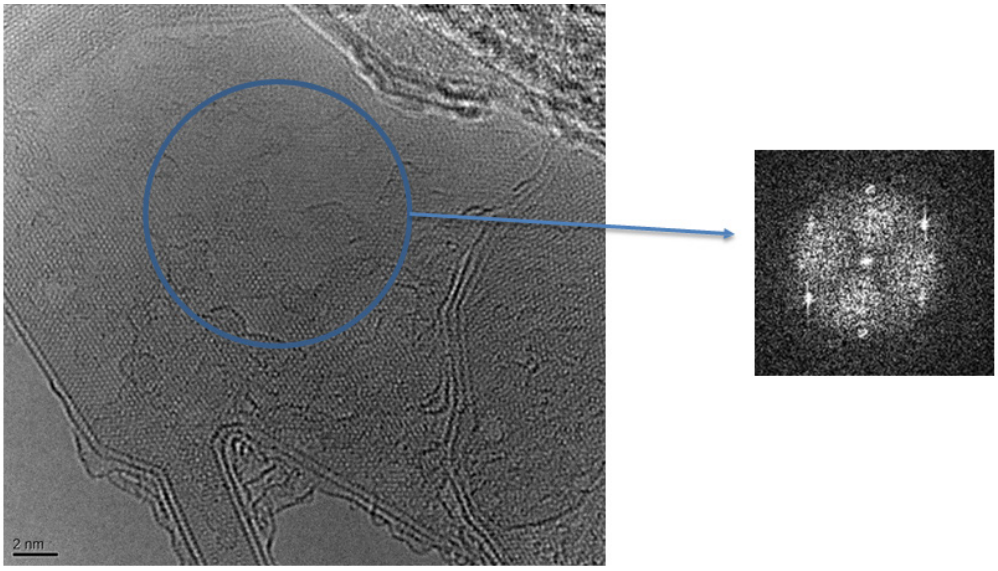
SCANNING ELECTRON MICROSCOPY (SEM)



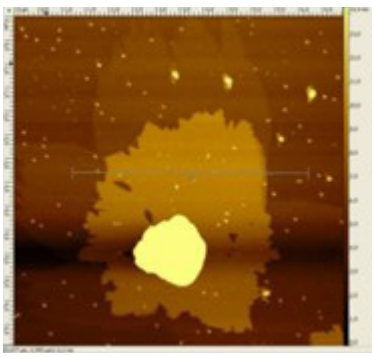
High resolution SEM of rGO powder: Left: The layered structure of rGO is clearly observable for rGO particle. Right: Individual sheets.

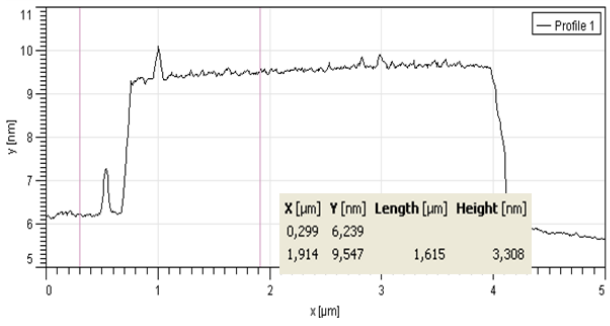
TRANSMISSION ELECTRON MICROSCOPY (TEM) AND ELECTRON DIFFRACTION



High-resolution TEM image of rGO and selected area electron diffraction pattern (SAED)

ATOMIC FORCE MICROSCOPY (AFM)





Dried rGO dispersed on a mica substrate. Shows sheet about 3 nm thick. This image is not necessarily representative, since rGO is not suitable for AFM.

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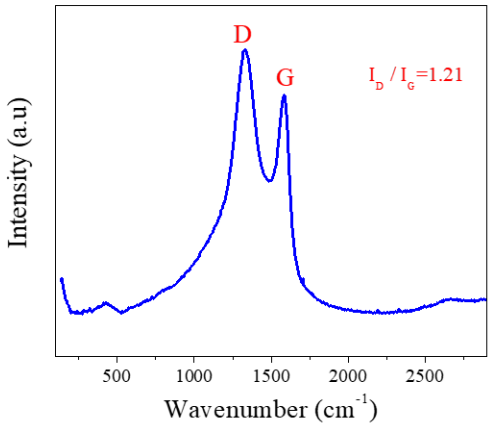
RAMAN SPECTROSCOPY

Raman spectra were obtained with laser wavelengths of 532 nm and 390 nm and a spot size of 2 µm. The Si peak at 520 cm-1 was used as a reference to calibrate the wave number.

The peaks at ~1350 cm-1 (D band) and ~1585 cm-1 (G band) that are commonly seen in the Raman spectra of carbonaceous materials are clearly evident. The ratio of intensity of D/G bands is a measure of the defects present on graphene structure.

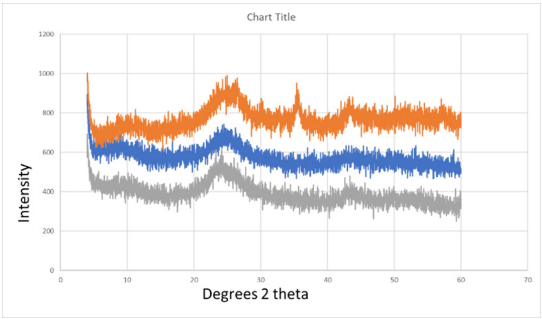
The ratio of the intensity of the D band to the G band (ID/IG) is calculated to be (i.e., ~ 1.21) for our rGO presenting low regime defect density.



X-RAY DIFFRACTOMETRY (XRD)

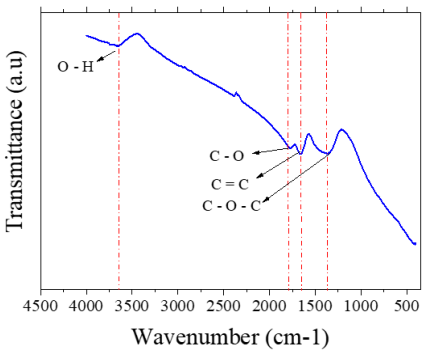
X-ray diffractometry using CuKα radiation (angular interval 4 - 60° 2θ, and count time 4 s per step) was per formed on rGO powder, runs on 3 typical samples shown.

The broad peak at around 26 deg 2 theta corresponds to the typical (001) diffraction peak of rGO. The spacing between the RGO sheets is calculated around 0.35 nm. Occasionally we observe impurities at around 28 and or 35 degrees, assigned to silicates originating from the graphite used to produce the rGO. These impurities can be seen as white spots and amount to less than 0.5 % by weight. For comparison, the intensity of graphite would be in the 50,000 – 100,000 range.



INFRARED SPECTROSCOPY

Fourier transform infrared (FTIR) spectroscopy was recorded with an Agilent 660 FTIR spectrometer. The FTIR samples were prepared by dispersing the materials in KBr. The functional groups detected by FTIR are listed in the Spectrum.



Instructions for safe use

Safety

- **Read MSDS carefully before handling of product.**
- **The product is only for laboratory use by certified personnel.**
- **Use laboratory gloves. Use dust-mask.**
- **The powder is extremely light and will easily blow out of any container if exposed to draft, sneezing or the like.**

Dispersion in liquid

True, stable dispersions cannot be prepared easily unless dispersing agents can be tolerated. Extended use of high shear and / or ultrasound is recommended. Semi-stable dispersions can be obtained in e.g. water/iso-propanol-mixtures. In oils and melted waxes fairly stable dispersions can be prepared by intense stirring.

Dispersion melted polymers

Can be added to melts but if automated feeder is used, we recommend using products 2.2 or 2.3. We recommend storing in cool and dry place.

Further reduction to fully reduced rGO

Thermal: Heat at 1100 deg C in flowing Ar-atmosphere for > 2 h.

Storage

Store in closed container. Shelf life is still not known. To our knowledge, the material does not degrade over time.

LayerOne takes no responsibility for the result of any mixing with or exposure to other substances!