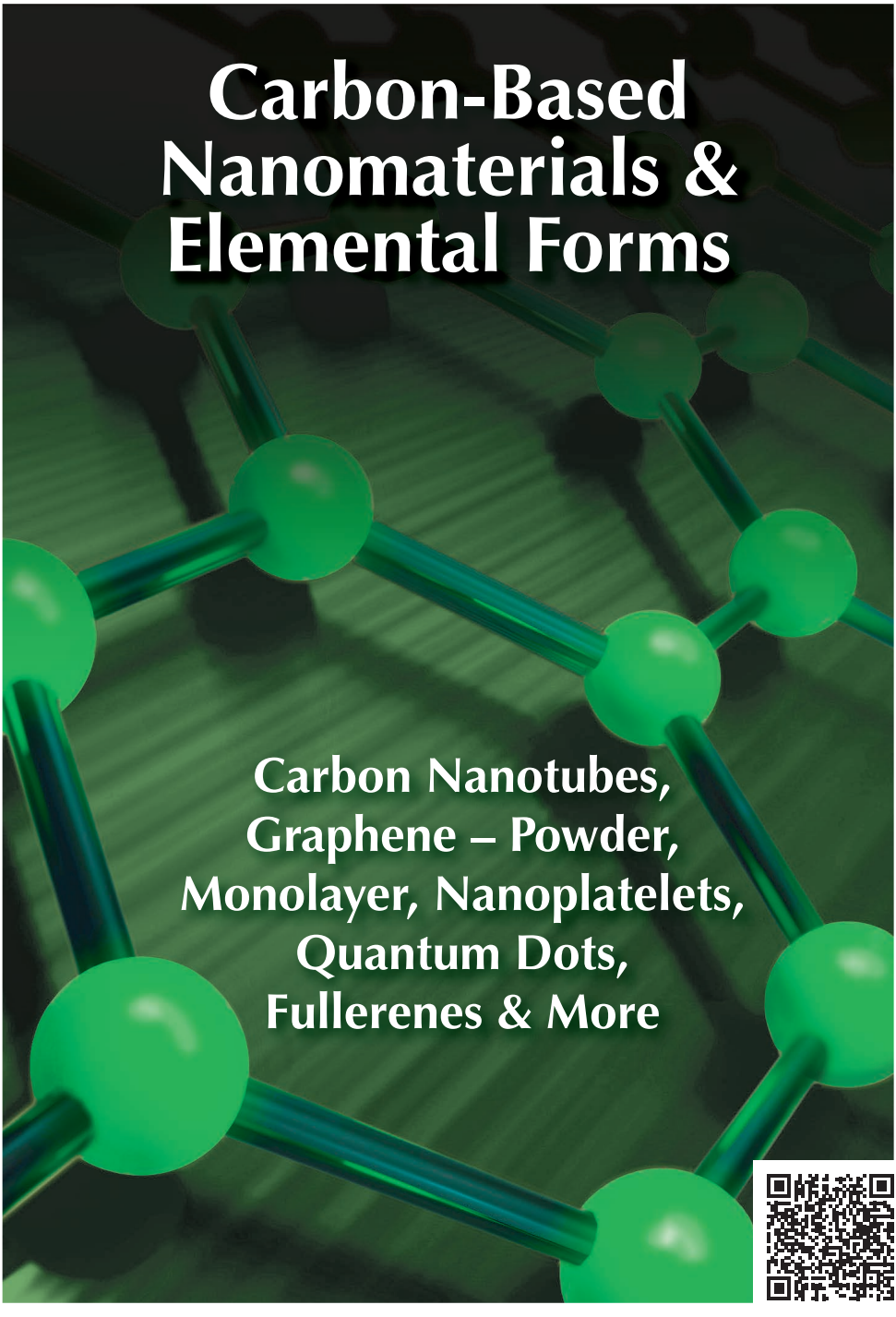
Carbon-Based
Nanomaterials &
Elemental Forms
Carbon Nanotubes,
Graphene – Powder,
Monolayer, Nanoplatelets,
Quantum Dots,
Fullerenes & More

STREM

Carbon-Based Nanomaterials & Elemental Forms

Strem Chemicals, Inc., established in 1964, is an employee-owned company that manufactures and markets specialty chemicals of high purity. In 2004 we began offering a variety of nanomaterials to our customers. As interest in this field increased, so did our product line which includes a number of carbon-based products. We also offer many carbon materials in elemental form which have use in multiple applications. This booklet focuses specifically on these carbon-based products for customers interested in this particular product line. Carbon items in elemental forms are listed first, followed by our carbon nanomaterials and finally any carbon-related kits.

At Strem, we also offer a wide variety of catalysts, ligands and CVD/ALD precursors. Most of our products are of high purity, typically at 99%, while some are as high as 99.9999% metals purity. We continually seek to provide new technologies from around the globe and add to our product line. We have licensing agreements with industry and academia, which allow easier access to these patent-protected products for our customers. We look forward to continued growth in order to best serve our customers' needs with the quality and service they can trust from Strem.

As part of our ongoing commitment to quality, we have achieved ISO 9001 certification for the Quality Management System (QMS) at our corporate headquarters in Newburyport, Massachusetts.

In addition, custom synthesis services are provided on a contract basis. For pharmaceutical applications, manufacturing is conducted under current Good Manufacturing Practices (cGMP) in FDA inspected kilo-lab suites. Complete documentation is available, including validation and stability studies. Active Drug Master Files (DMF's) are maintained in North America and Europe.

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Our other booklets, which focus on applications and product classes, are available in print per request and also on our website. Below is a list of current booklet titles that are available. Please also check our Product Resources section online to find additional literature offerings, such as the Strem Chemiker, our technical publication, and product literature sheets.

- Biocatalysts
- Buchwald Ligands and Precatalysts
- Carbon-Base Nanomaterials & Elemental Forms
- Catalysts & LIgands Sold in Collaboration with Takasago
- Chiral Phosphoric Acids
- Gold Elements & Compounds
- Heterogeneous Catalysts
- High Purity Chiral Reagents
- Kits
- Materials for Energy Applications
- Metal Catalysts for Organic Synthesis
- Metathesis Catalysts
- MOCVD, CVD & ALD Precursors
- MOFs and Ligands for MOF Synthesis
- Nanomaterials
- New Products
- Other Ligands
- Phosphorous Ligands and Compounds
- Photocatalysts
- PURATREM: High Purity Inorganics

Ephraim S. Honig, Ph.D., M.B.A
Chief Executive Officer

ISO 9001 CERTIFIED

CARBON 10/18

Glossary of Terms

$[\alpha]_D$	.....	Specific rotation
AAS	.....	Atomic Absorption Standard
ACS	.....	Conforms to American Chemical Society specifications
air sensitive	.....	Product may chemically react with atmospheric oxygen or carbon dioxide at ambient conditions. Handle and store under an inert atmosphere of nitrogen or argon.
amp	.....	Ampouled
b.p.	.....	Boiling point in °C at 760mm, unless otherwise noted
d.	.....	Density
dec.	.....	Decomposes
elec. gr.	.....	Electronic Grade, suitable for electronic applications
f.p.	.....	Flash point in °F
gran.	.....	Granular
heat sensitive	.....	Product may chemically degrade if stored for prolonged periods of time at ambient temperatures or higher. Store at 5°C or lower.
hydrate	.....	Unspecified water content which may vary slightly from lot to lot
hygroscopic	.....	Product may absorb water if exposed to the atmosphere for prolonged periods of time (dependent on humidity and temperature). Handle and store under an inert atmosphere of nitrogen or argon.
light sensitive	.....	Product may chemically degrade if exposed to light
liq.	.....	Liquid
m.p.	.....	Melting point in °C
moisture sensitive	.....	Product may chemically react with water. Handle and store under an inert atmosphere of nitrogen or argon.
NMR grade		Suitable as a Nuclear Magnetic Resonance reference standard
optical grade	.....	For optical applications
pwdr.	.....	Powder
primary standard	.....	Used to prepare reference standards and standardize volumetric solutions
PURATREM	.....	Product has a minimum purity of 99.99% (metals basis)
purified	.....	A grade higher than technical, often used where there are no official standards
P. Vol.	.....	Pore volume
pyrophoric	.....	Product may spontaneously ignite if exposed to air at ambient conditions
reagent	.....	High purity material, generally used in the laboratory for detecting, measuring, examining or analyzing other substances
REO	.....	Rare Earth Oxides. Purity of a specific rare-earth metal expressed as a percentage of total rare-earths oxides.
SA	.....	Surface area
store cold	.....	Product should be stored at -18°C or 4°C, unless otherwise noted (see product details)
subl.	.....	Sublimes
superconductor grade	.....	A high purity, analyzed grade, suitable for preparing superconductors
tech. gr.	.....	Technical grade for general industrial use
TLC	.....	Suitable for Thin Layer Chromotography
v.p.	.....	Vapor pressure mm of Hg
xtl.	.....	Crystalline

About Purity

Chemical purity	.....	is reported after the chemical name, e.g. Ruthenium carbonyl, 99%
Metals purity	.....	is reported in parentheses with the respective element, e.g. Gallium (III) bromide, anhydrous, granular (99.999%-Ga) PURATREM where 100% minus the metal purity is equal to the maximum allowable percentage of trace metal impurity

CARBON (Elemental Forms)

06-0025	**Acetylene carbon black (100% compressed)** *(1333-86-4)* C; FW: 12.011; black pwdr. (avg. particle size 0.042 microns); SA: 80m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. bulk 0.21g/cm³	250g 1kg
06-0026	**Acetylene carbon black (50% compressed)** *(1333-86-4)* C; FW: 12.011; black pwdr. (avg. particle size 0.042 microns); SA: 80m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. bulk 0.10/g/cm³	250g 1kg
06-0100	**Activated carbon** *(7440-44-0)* C; FW: 12.011; black pwdr.; SA: 1300-1400 m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	300g 1kg
06-0050	**Activated carbon** *(7440-44-0)* C; FW: 12.011; 4 x 10 mesh black gran.; SA: 1000 m²/g; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	500g 2kg
93-0601	**Carbon powder (99+%)** *(7440-44-0)* C; FW: 12.011; -325 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	250g 1kg
93-0602	**Carbon powder (99.999%)** *(7440-44-0)* C; FW: 12.011; -200 mesh pwdr.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	5g 25g
93-0605	**Carbon rods (99.999%)** *(7440-44-0)* C; FW: 12.011; 3mm dia. x 30cm; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	1rod 5rods
93-0608	**Carbon sheet (99.8%)** *(7440-44-0)* C; FW: 12.011; 0.25 mm thick x 15 cm wide; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	30 x 15cm 150 x 15cm
93-0607	**Carbon sheet (99.8%)** *(7440-44-0)* C; FW: 12.011; 0.127 mm thick x 15 cm wide; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	30 x 15cm 150 x 15cm
93-0609	**Carbon yarn (99.9%)** *(7440-44-0)* C; FW: 12.011; ~0.6mm dia.; m.p. 3652-3697° (subl.); b.p. 4200°; d. 1.8-2.1 (amorphous)	5m 25m
06-0502	**Fullerene - C_{60}, min. 99.9% (Buckminsterfullerene)** *(99685-96-8)* C_{60}; FW: 720.66; black pwdr.	25mg 100mg 500mg
06-0602	**Fullerene - C_{60}, 99.9+% (Buckminsterfullerene)** *(99685-96-8)* C_{60}; FW: 720.66; black pwdr.	25mg 100mg 500mg
06-0500	**Fullerenes - C_{60}/C_{70} mixture (contains ~20% C_{70} and ~1% higher fullerenes)** *(131159-39-2)* C_{60}, C_{70}; FW: 720.66, 840.77; black pwdr.; d. 1.6	50mg 250mg 1g
06-0503	**Fullerene - C_{70}, min. 98%** *(115383-22-7)* C_{70}; FW: 840.77; black pwdr.	10mg 50mg 250mg
06-0603	**Fullerene - C_{70}, min. 99%** *(115383-22-7)* C_{70}; FW: 840.77; black pwdr.	10mg 50mg 250mg
06-0525	**Fullerene - C_{76}, min. 95%** *(135113-15-4)* C_{76}; FW: 912.84; black pwdr.	5mg
06-0526	**Fullerene - C_{76}, min. 98%** *(135113-15-4)* C_{76}; FW: 912.84; black pwdr.	5mg
06-0527	**Fullerene - C_{76}, 99.9%** *(135113-15-4)* C_{76}; FW: 912.84; black pwdr.	5mg
06-0530	**Fullerene - C_{78}, min. 95%** *(136316-32-0)* C_{78}; FW: 936.86; black pwdr.	5mg
06-0507	**Fullerene - C_{84}, min. 95%** *(135113-16-5)* C_{84}; FW: 1008.93; black pwdr.	5mg

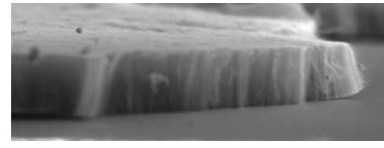
CARBON (Elemental Forms)

06-0607	**Fullerene - C_{84}, min. 99%** *(135113-16-5)* C_{84}; FW: 1008.92; black pwdr.	5mg
06-0512	**Fullerene carbon soot (contains 5-8wt% C_{60}/C_{70} and higher fullerenes)** *(131159-39-2)* C_{60}/C_{70}; black pwdr.	5g 25g

CARBON (Nanomaterials)

Carbon Nanotubes

06-0440 **Carbon nanotube array, multi-walled, on quartz (diameter= 100nm, length=30 microns)** *(308068-56-6)*
black microfibers — 1pc



Technical Note:
1. Arrays grown on 10x10x1mm quartz substrate using a single source CVD process that yields vertically aligned MWNTs (< 1% catalyst impurity). Arrays are 30µm tall (± 3µm) and are composed of MWNTs 100nm in diameter (± 10nm). Arrays up to 150µm an be provided on request.

06-0470	**Carbon nanotubes, multi-walled (diameter = ~140nm, length = ~7 microns) (>90% nanotubes)** *(308068-56-6)* black pwdr.	1g 5g

Technical Note:
1. Produced by chemical vapor deposition. Typical metal content is <0.1%.

06-0475	**Carbon nanotubes, multi-walled (diameter = ~20-25nm, length = ~1-5 microns) (85% nanotubes)** *(308068-56-6)* black pwdr.	250mg 1g

Technical Note:
1. Produced by chemical vapor deposition. Typical metal content is 4-5 wt %.

06-0720	**Carbon nanotubes, multi-walled, arc-produced (diameter = 2-50nm, length = >2 microns) (55-65wt% nanotubes)** *(308068-56-6)* black pwdr.	250mg 1g

Technical Note:
1. Arc-produced, multi-walled carbon nanotubes contain 55-65 wt% nanotubes and 35-45wt% graphite nanoparticles. The tubes have a diameter distribution of 2-50 nm, and a typical length of >2 microns (straight tubes). The chemical composition is 100% carbon, with no metal impurities. Because the nanotubes are grown at very high temperatures (3000-4000°C), the product contain far less defects than nanotubes produced by other methods. The nanotubes are stable in air up to 700°C.

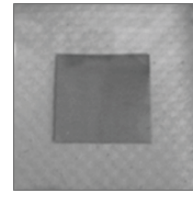
06-0504	**Carbon nanotubes, multi-walled, as produced cathode deposit** *(308068-56-6)* pieces	1g 5g
06-0505	**Carbon nanotubes, multi-walled, core material** *(308068-56-6)* pieces (20-40% nanotubes)	1g 5g
06-0506	**Carbon nanotubes, multi-walled, ground core material** *(308068-56-6)* -270 mesh pwdr. (20-40%nanotubes)	250mg 1g 5g
06-0508	**Carbon nanotubes, single-walled/double-walled, 90%** *(308068-56-6)* pwdr.	250mg 1g

Technical Note:
1. This product is nanotubes, single-walled/double-walled, 90%. The tubes are 1-2nm in diameter with lengths of 5-30 microns. Ash is <1.5wt%.

CARBON (Nanomaterials)

Graphene

06-0274 **Graphene film, monolayer, on copper foil (1cm x 1cm)** 2pcs
(1034343-98-0)
C; foil



100% coverage, >95% single atomic layer
Average grain (crystal/domain) size: >~100 micron
Average sheet resistance (on non-conductive substrate): 400 OPS (+/- 200 OPS)
Average transmission: T >96% (on transparent substrate,
i.e. ~4% lower than substrate T)

06-0310 **Graphene film, monolayer, on Si/SiO_2 wafer (1cm x1cm), by CVD** 1pc
(1034343-98-0)
C; FW: 12.011; wafer

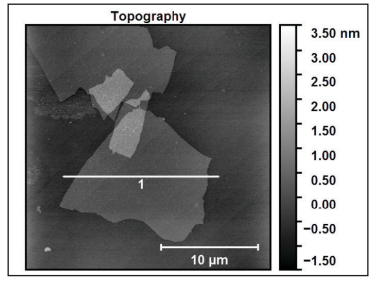
06-0323 **Graphene oxide (0.8-1.2nm thick x 1-15 microns wide,** 250mg
made by the Staudenmaier Method) *(1034343-98-0)* 1g
black pwdr.; SA: 5-10 m^2/g

06-2545 **Graphene oxide (4mg/ml water dispersion)** *(1034343-98-0)* 50ml
yellow-brown liq. dispersion 250ml

Physical Properties:
Form: Dispersion of graphene oxide sheets; *Sheet dimension*: Variable; *Color*: yellow-brown; *Dispersibility*: Polar solvents; *Solvent*: Water; *pH*: 2.2-2.5; *Concentration*: 4 mg/mL; *Monolayer content (measured in 0.5 mg/mL)*: >95%*
*Note: 4 mg/mL tends to agglomerate the GO flakes and dilution followed by slight sonication is required in order to obtain a higher percentage of monolayer flakes
Elemental Analysis: (sample preparation: 2g of 4 wt% GO in water were dried under vacuum at 60°C overnight)
Carbon: 49-56%; *Hydrogen*: 0-1%; *Nitrogen*: 0-1%; *Oxygen*: 41-50%; *Sulfur*: 0-2%
Quality Control:
Amount of residue on evaporation
pH control
Elemental analysis
Applications: Graphene/polymer composite materials, batteries, biomedical, solar cells, supercapacitors, support for metallic catalysts, low permeability materials, biosensors, multifunctional materials, graphene research
References:

1. *J. Mater. Chem.*, **2011**, *21*, 9762.
2. *Environ. Sci. Technol.*, **2013**, *47*, 3715.
3. *Phys. Chem. Chem. Phys.*, **2013**, *15*, 2321.

06-2530 **Graphene oxide (4mg/ml water dispersion) - low Mn.** *(1034343-98-0)* 100ml
NEW C; brown liq. 500ml
Note: Diameter: 5-30 micron flakes.



Properties:
Form: Extra-large graphene oxide flakes
Production method: Modified Hummer's method
Odor: Odorless
Solvent: Water
pH: neutral
Thickness of a single layer: 0.8-12nm
Manganese content: 0.0006%
One of the highlights of 06-2530 is the products' low manganese contamination. A high purity of graphene oxide dispersion is attained through a careful washing process. Electron paramagnetic resonance (EPR) is used to confirm the high purity of the material and low Mn content. Manganese contamination is a common issue within typical graphene oxide due to the production process. Since this product has low levels of Mn and high product purity, it does not show toxicity in living cells and allows for additional product applications.

CARBON (Nanomaterials)

Graphene *(continued)*

06-2550 **Graphene oxide, reduced** *(1034343-98-0)* 250mg
black pwdr. 1g

Physical Properties:
Form: powder; *Reduction method*: chemically reduced; *Sheet dimension*: variable; *Color*: black; *Solubility*: insoluble; *Dispersability*: <0.1 mg/mL in NMP, DMF, DMSO; *Humidity (Karl Fisher, TGA)*: 3.7-4.2%; *Electrical conductivity*: 666,7 S/m (measured in a 20 nm film thickness); *BET surface area*: 422.69 - 499.85 m^2/g; *Density*: 1.91 g/cm^3
Elemental Analysis: (sample preparation: 2g of 4 wt% GO in water were dried under vacuum at 60°C overnight) *Carbon*: 77-87%; *Hydrogen*: 0-1%; *Nitrogen*: 0-1%; *Oxygen*: 13-22%; *Sulfur*: 0%
Quality Control: Elemental analysis
Applications: Batteries, biomedical, solar cells, supercapacitors, printable graphene electronics, graphene research
References:
1. *Nano Letters*, **2010**, *10*, 92.
2. *J. Phys. Chem. Lett.*, **2013**, *4*, 1347.

06-0318 **Graphene powder (1-5 layers thick x 0.5-5 microns wide, surface area 650-750 m^2/g)** *(1034343-98-0)* 250mg 1g
C; FW: 12.011; black pwdr.

06-0313 **Graphene powder (single layer, surface area 400-1000 m^2/g)** *(1034343-98-0)* 50mg
C; FW: 12.011; black pwdr.

06-2510 **Monolayer Graphene on Cu (10 mm x 10 mm)** *(1034343-98-0)* 4pcs
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 98%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on* Al_2O_3: 2000 cm^2/Vs; *FET Electron Mobility on* SiO_2: 4000 cm^2/Vs; *Sheet Resistance on* SiO_2/Si: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 µm
Substrate Cu foil:
Thickness: 18 µm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality Control: Raman Spectroscopy and Optical Microscopy
References:
1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

06-2518 **Monolayer Graphene on Cu (60 mm x 40 mm)** *(1034343-98-0)* 1pc
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on* Al_2O_3: 2000 cm^2/Vs; *FET Electron Mobility on* SiO_2: 4000 cm^2/Vs; *Sheet Resistance on* SiO_2/Si: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 µm
Substrate Cu foil:
Thickness: 18 µm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:
1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

CARBON (Nanomaterials)

Graphene *(continued)*

06-2523 **Monolayer Graphene on Cu with PMMA coating (60mm x 40mm)** 1pc
(1034343-98-0)
C; FW: 12.011; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on* Al_2O_3: 2000 cm^2/Vs; *FET Electron Mobility on* SiO_2: 4000 cm^2/Vs; *Sheet Resistance on* SiO_2/*Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 µm
Substrate Cu foil:
Thickness: 18 µm
Pretreated for easier bottom layer removal: Monolayer graphene on the back side of Copper is partially removed, but not completely, so an additional treatment like RIE is needed before transfer to eliminate the bottom layer totally
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:
1. *J. Electrochem. Soc.*, **2012**, *159*, A752.
2. *J. Mater. Chem. A.*, **2013**, *1*, 3177.

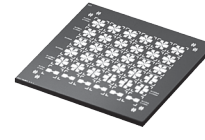
06-2534 **Monolayer Graphene on** SiO_2**/Si (10mm x 10mm)** *(1034343-98-0)* 4pc
C; wafer

Physical Properties:
Growth Method: Chemical Vapor Deposition (CVD synthesis); *Appearance*: Transparent; *Transparency*: >97%; *Coverage*: 95%; *Layers*: 1; *Thickness (theoretical)*: 0.345 nm; *FET Electron Mobility on* Al_2O_3: 2000 cm^2/Vs; *FET Electron Mobility on* SiO_2: 4000 cm^2/Vs; *Sheet Resistance on* SiO_2/*Si*: 410-490 Ω/sq (1 cm x 1 cm); *Grain size*: Up to 10 µm
Substrate Cu foil:
Dry Oxide Thickness: 285-315 nm; *Type/Dopant*: P/Bor; *Orientation*: <100>; *Resistivity*: <0.005 Ohm·cm; *Thickness*: 505-545 µm; *Front surface*: single side polished; *Back surface*: etched; *Particles*: <10@0.3 µm
Applications: Flexible batteries, electronics, aerospace, MEMS and NEMS, Microactuators, Conductive coatings
Quality control: Raman Spectroscopy and Optical Microscopy
References:
1. *J. Electrochem. Soc.,* **2012**, *159*, A752
2. *J. Mater. Chem. A.,* **2013**, *1*, 3177

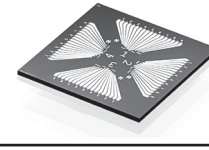
CARBON (Nanomaterials)

Graphene Field-Effect Transistor (GFET) Chip

06-2555 NEW **Graphene Field-Effect Transistor (GFET) Chip - Grid pattern** *(1034343-98-0)* 1pc
Chip
Note: Storage of the chips in a low humidity environment (N2 cabinet, desiccator, or vacuum) is highly recommended.



06-2560 NEW **Graphene Field-Effect Transistor (GFET) Chip - Quadrant pattern** *(1034343-98-0)* 1pc
Chip
Note: Storage of the chips in a low humidity environment (N2 cabinet, desiccator, or vacuum) is highly recommended.

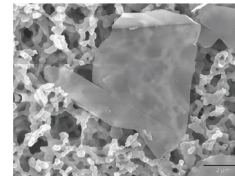


CARBON (Nanomaterials)

Graphene Nanoplatelets

06-0222 **Graphene nanoplatelets, (2-10nm thick x ~5 microns wide)** 5g
(1034343-98-0) 25g
C; black solid

06-0210 **Graphene nanoplatelets** 25g
(6-8 nm thick x 5 microns wide) *(1034343-98-0)* 100g
C; black platelet
Note: Graphene nanoplatelets are unique nanoparticles consisting of short stacks of graphene sheets having a platelet shape. They have an average thickness of approximately 6 - 8 nanometers and a typical surface area of 120 to 150 m^2/g.



The unique size and platelet morphology of the graphene nanoplatelets makes these particles especially effective at providing barrier properties and improving mechanical properties, while their pure graphitic composition makes them excellent electrical and thermal conductors.

06-0215 **Graphene nanoplatelets (6-8 nm thick x 15 microns wide)** *(1034343-98-0)* 25g
C; black platelet 100g

Technical Note:
1. See 06-0210 (page 6)

06-0220 **Graphene nanoplatelets (6-8 nm thick x 25 microns wide)** *(1034343-98-0)* 25g
C; black platelet 100g

Technical Note:
1. See 06-0210 (page 6)

06-0225 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 300m^2/g)** 25g
(1034343-98-0) 100g
black platelet
Note: Graphene nanoplatelet aggregates are unique nanoparticles consisting of short stacks of graphene sheets having a platelet shape. They typically consist of aggregates of sub-micron platelets that have a particle diameter of less than 2 microns and a typical particle thickness of a few nanometers, depending on the surface area.

The unique size and platelet morphology of the graphene nanoplatelets makes these particles especially effective at providing barrier properties and improving mechanical properties, while their pure graphitic composition makes them excellent electrical and thermal conductors.

06-0230 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 500m^2/g)** 25g
(1034343-98-0) 100g
black platelet

Technical Note:
1. See 06-0225 (page 6)

06-0235 **Graphene nanoplatelets aggregates (sub-micron particles, surface area 750m^2/g)** 25g
(1034343-98-0) 100g
black platelet

Technical Note:
1. See 06-0225 (page 6)

CARBON (Nanomaterials)

Graphene Quantum Dots *(1034343-98-0)*
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

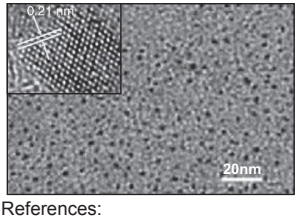
06-0330	**Graphene Quantum Dots (GQDs), Aqua-Green Luminescent** *(1034343-98-0)* C; dark red-brown pwdr. *light sensitive, (store cold)*	100mg

Suggested Applications:
Graphene quantum dots (GQDs), sheets of few-layered graphene and lateral dimensions smaller than 100nm possess strong quantum confinement and edge effects. Thus, they possess unique physical properties such as strong photoluminescence, which can be tailored for specific applications by controlling their size, shape, defects and functionality.

In contrast to classic QDs, such as metal or silicon quantum dots, GQDs are biocompatible, photostable and inherit superior thermal, electrical and mechanical properties from the graphene. These features can greatly contribute to various state-of-the-art applications: optical brighteners, taggants for security applications[1], bioimaging markers[2], fluorescent polymers[3], antibacterial[4], antibiofouling[5], and disinfection systems[6], heavy metals[7], humidity and pressure[8] sensors, batteries[9], flash memory devices[10], photovoltaic devices[11] and light-emitting diodes[12].

Item #	Photoluminescence			
	QY⁺ *	λ_{max} *	Max emission	FWHM *
06-0330 / 06-0332	>17%	485 nm	525 nm	70 nm
06-0334 / 06-0336	>65%	350 nm	445 nm	65 nm
06-0340	>25%	420 nm	490 nm	80 nm

Abbreviations	
QY⁺	Quantum Yield
λ_{max}	Maximum excitation wavelength
FWHM	Full width at half maximum



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11. *Angew. Chem. Int. Ed.*, **2010**, *49*, 3014
12. *J. Mater. Sci.* **2013**, *48*, 2352

CARBON (Nanomaterials)

Graphene Quantum Dots *(continued)* *(1034343-98-0)*
light sensitive, (store cold)
Note: Particle diameter: <5 nm. Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.

06-0332 **Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent** 100ml
(1034343-98-0)
C; cloudy orange liq.
light sensitive, (store cold)
Technical Note:
1. See 06-0330 (page 7)

06-0334 **Graphene Quantum Dots (GQDs), Blue Luminescent** *(1034343-98-0)* 100mg
C; dark brown pwdr.
light sensitive, (store cold)
Technical Note:
1. See 06-0330 (page 7)

06-0336 **Graphene Quantum Dots (GQDs) in water, Blue Luminescent** *(1034343-98-0)* 100ml
C; cloudy colorless liq.
light sensitive, (store cold)
Technical Note:
1. See 06-0330 (page 7)

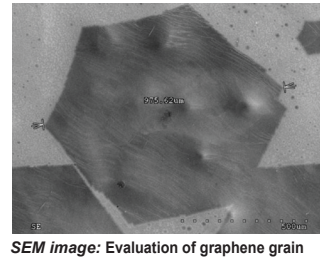
06-0340 **Graphene Quantum Dots (GQDs) in water, Cyan Luminescent** *(1034343-98-0)* 100ml
C; cloudy brown liq.
light sensitive, (store cold)
Technical Note:
1. See 06-0330 (page 7)

CARBON (Nanomaterials)

Monolayer High Strength Metallurgical Graphene

06-0365 **Monolayer High Strength Metallurgical Graphene, HSMG®, on GLASS (10x10mm)** 1pc
NEW
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

PRODUCT DATA	
GROWTH METHOD	Metallurgical graphene growth on liquid metal
STANDARD SUBSTRATES	PMMA, Si/SiO_2, quartz
TRANSFER AVAILABILITY	Transfer on custom substrates available upon request
QUALITY CONTROL	Raman spectroscopy Optical microscopy SEM microscopy
FORM	Graphene film
GRAIN SIZE	Up to 1mm
COVERAGE*	>95%
OPTICAL TRANSMITTANCE*	>97% *(measured on quartz with UV-Vis method)*
THICKNESS (THEORETICAL)	0.345 nm
AVERAGE SHEET RESISTANCE*	<250 Ω/cm² *(measured on Si/SiO_2 with van der Pauw method)*
*values confirmed by EIT+ Wroclaw Research Centre independent product evaluation study	



SEM image: **Evaluation of graphene grain size during growth process**

Absorption and incorporation of carbon atoms into the crystal structure of the copper matrix occurs during the carburization process. Maximum carbon content is significantly lower for liquid copper matrix than for solid state matrix, therefore, after heating above the melting point, the metal matrix becomes supersaturated with carbon atoms. **HSMG® growth is based on the controlled carbon precipitation from the liquid metal matrix.**

The growth process originates with nucleation of single hexagonal flakes on the metallic substrate. Liquid matrix enables grain rotation and rearrangement during nucleation process which results in larger grain sizes and improved graphene properties. This process is fully controlled and enables the production of graphene sheets with specified number of layers.

CARBON (Nanomaterials)

Monolayer High Strength Metallurgical Graphene *(continued)*

06-0345 NEW — **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (10x10 mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

Technical Note:
1. See 06-0365 (page 8)

06-0355 NEW — **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (25x25mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

Technical Note:
1. See 06-0365 (page 8)

06-0360 NEW — **Monolayer High Strength Metallurgical Graphene, HSMG®, on PMMA (50x50mm)** 1pc
(1034343-98-0)
C; FW: 12.011; Colorless solid
Note: HSMG® Sold under license for research purposes only.
U.S. Patent no. 9,284,640 B2.

Technical Note:
1. See 06-0365 (page 8)

CARBON KITS - Graphene Quantum Dots (GQDs) Master Kit

96-7410 **Graphene Quantum Dots (GQDs) Master Kit**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale.
Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 7
06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 8
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 8
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 8
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 8

Item #	Photoluminescence			
	QY⁺ *	λ max *	Max emission	FWHM *
06-0330 / 06-0332	>17%	485 nm	525 nm	70 nm
06-0334 / 06-0336	>65%	350 nm	445 nm	65 nm
06-0340	>25%	420 nm	490 nm	80 nm
Particle diameter: <5 nm **Topographic height:** 1.0 - 2.0 nm **Concentration:** 1mg/ml (for liquid items)				
Abbreviations: QY⁺ = *Quantum Yield*; λ max = *Maximum excitation wavelength*; FWHM = *Full width at half maximum*				

CARBON KITS - Graphene Quantum Dots (GQDs) Mini Kit (Powders)

96-7425 **Graphene Quantum Dots (GQDs) Mini Kit (Powders)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale.
Contains the following:

06-0330	Graphene Quantum Dots (GQDs), Aqua-Green Luminescent *(1034343-98-0)*	100mg	See page 7
06-0334	Graphene Quantum Dots (GQDs), Blue Luminescent *(1034343-98-0)*	100mg	See page 8

Item #	Color & Form	Photoluminescence			
		QY⁺ *	λ max *	Max emission	FWHM *
06-0330	dark red-brown pwdr.	>17%	485 nm	525 nm	70 nm
06-0334	dark brown pwdr.	>65%	350 nm	445 nm	65 nm
Particle diameter: <5 nm **Topographic height:** 1.0 - 2.0 nm					
Abbreviations: QY⁺ = *Quantum Yield*; λ max = *Maximum excitation wavelength*; FWHM = *Full width at half maximum*					

CARBON KITS - Graphene Quantum Dots (GQDs) Mini Kit (Liquids)

96-7420 **Graphene Quantum Dots in water (GQDs) Mini Kit (Liquids)**
Sold in collaboration with Dotz Nano Ltd. for research purposes only.
Suggested use within 6 months of purchase. Do not freeze. Store in DARK.
Components also available for individual sale.
Contains the following:

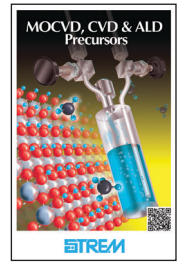
06-0332	Graphene Quantum Dots (GQDs) in water, Aqua-Green Luminescent *(1034343-98-0)*	100ml	See page 8
06-0336	Graphene Quantum Dots (GQDs) in water, Blue Luminescent *(1034343-98-0)*	100ml	See page 8
06-0340	Graphene Quantum Dots (GQDs) in water, Cyan Luminescent *(1034343-98-0)*	100ml	See page 8

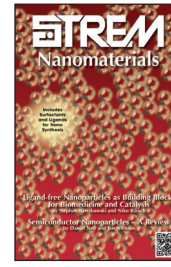
Item #	Color & Form	Photoluminescence			
		QY+ *	λ max *	Max emission	FWHM *
06-0332	cloudy orange liq.	>17%	485 nm	525 nm	70 nm
06-0336	cloudy colorless liq.	>65%	350 nm	445 nm	65 nm
06-0340	cloudy brown liq.	>25%	420 nm	490 nm	80 nm

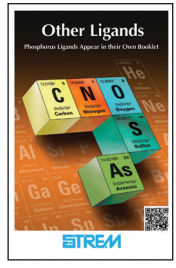
Particle diameter: <5 nm
Topographic height: 1.0 - 2.0 nm
Concentration: 1mg/ml

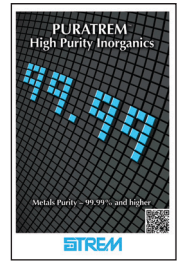
Abbreviations: QY+ = *Quantum Yield*; λ max = *Maximum excitation wavelength*; FWHM = *Full width at half maximum*

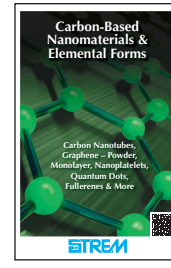
Available Booklets

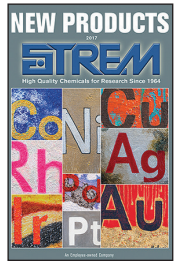


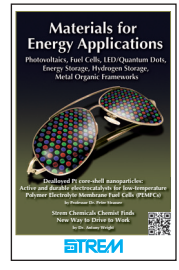


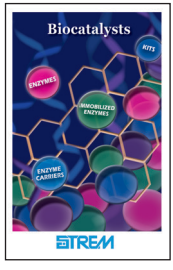


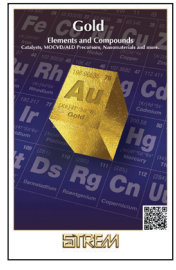


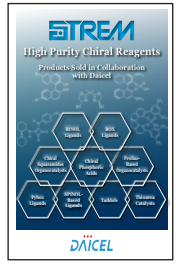


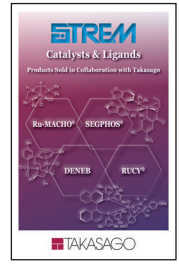


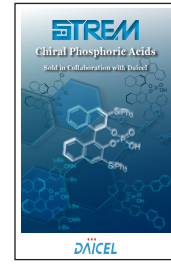












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