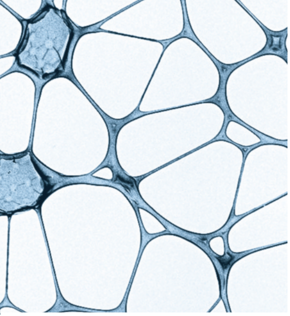
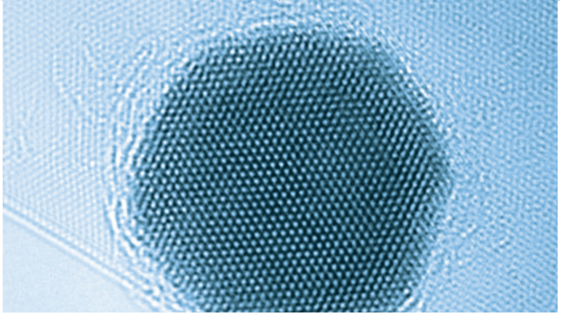
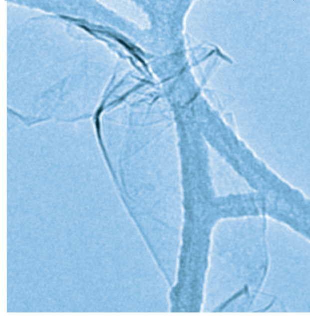
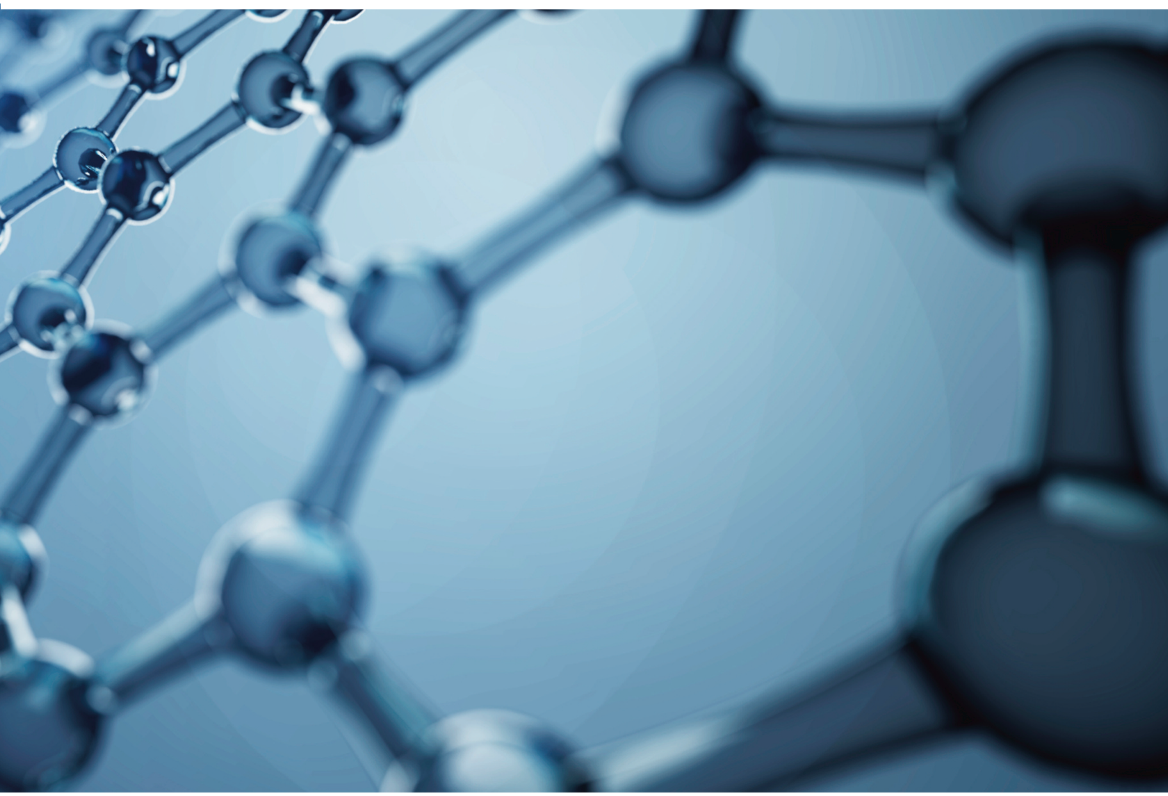




Graphene & Graphene Oxide Support Films for TEM



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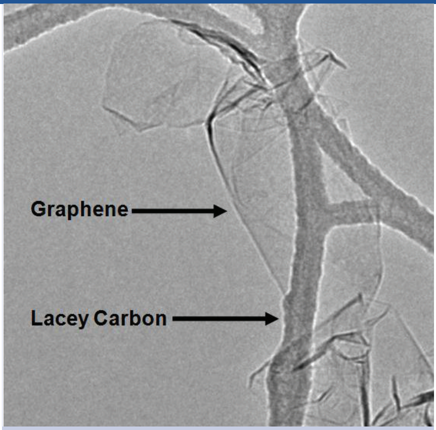
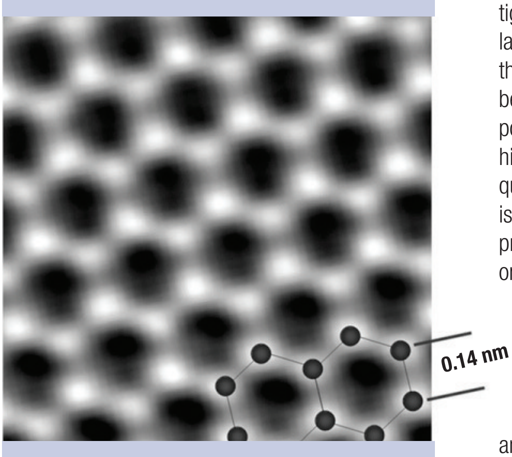


A typical TEM image of graphene sheets freely suspended on a lacey carbon TEM grid.



An atomic-resolution image of a clean and structurally perfect graphene sheet synthesized by the substrate-free gas-phase method. Individual carbon atoms appear white in the image.

Potential Applications:

Biodevices

Single molecule gas detection

Graphene nanoribbons

Integrated circuits

Transparent conducting electrodes

Ultracapacitors

Graphene is a single atomic layer of carbon atoms tightly packed in a two-dimensional honeycomb lattice. This novel material is atomically thin, chemically inert, consists of light atoms, and possesses a highly ordered structure. Graphene is electrically and thermally conductive, and is the strongest material ever measured. These remarkable properties make graphene the ideal support film for electron microscopy.

Synthesis

The substrate-free gas-phase method

Graphene is a single atomic layer of carbon atoms tightly packed in a two-dimensional honeycomb lattice. The novel material has generated great interest throughout the scientific and technological community because of its remarkable properties and numerous potential applications. However, obtaining pure and highly ordered graphene has been a challenge. Small quantities of ultrahigh-quality graphene have been isolated through an unwieldy and time-consuming process involving the mechanical exfoliation of highly oriented pyrolytic graphite. Alternative methods require substrates or graphite to create atomically-thin sheets, and these techniques involve multiple steps, expensive substrates, or non-ambient conditions. Furthermore, the sheets produced by these alternative methods exhibit defects, disorder, and oxygen functionalities that have a detrimental effect on the properties of graphene.

The substrate-free gas-phase method is the first and only process that can synthesize ultrahigh-quality graphene in a single step, without the use of substrates or graphite [1]. Graphene sheets are created through the delivery of liquid alcohol droplets directly into atmospheric-pressure microwave-generated plasmas. Extensive characterization of the synthesized graphene has proven that the sheets are oxygen-free and exhibit a highly ordered structure [2]. The graphene produced by this unique method can immediately be utilized for graphene applications.

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Application

Direct imaging of soft and hard nanomaterials

The interfaces between soft and hard nanomaterials have been the subject of extensive research.

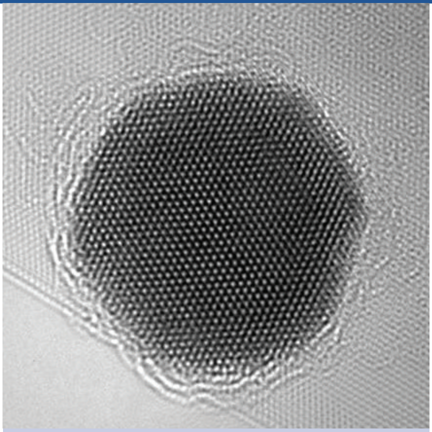
Nanoparticles coated with molecular layers have been shown to self-assemble into novel structures that could potentially be used in electronics, sensors, and photonics. Self-assembly is influenced by the nature of molecular coatings and thus more detailed characterization of these soft materials is needed.

However, imaging surface molecules and their interfaces with nanoparticles at the atomic scale is a significant challenge. The transmission electron microscope (TEM) imaging of functionalized nanoparticles has been attempted.

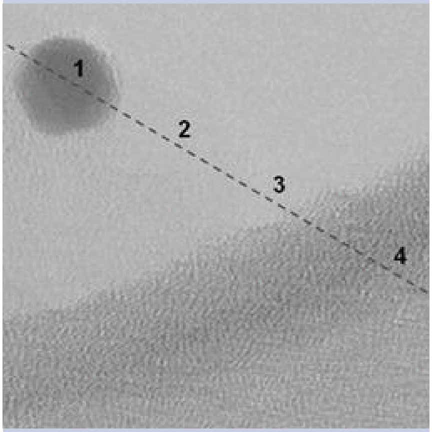
However, it has not been possible to observe molecular surface layers and their interfaces with nanoparticles at the atomic level. Modern aberration-corrected TEMs can produce atomic-resolution images of soft and hard nanomaterials. However, conventional TEM support films (e.g. ultrathin amorphous carbon) limit the capabilities of these advanced microscopes because they contribute to overall electron scattering and diminish the contrast of low-atomic number specimens. The TEM imaging of the interfaces between soft and hard nanomaterials therefore requires better support films that have a lower dynamical interference with an imaging object [3].

Graphene is the ideal TEM support film. The material possesses a highly ordered structure and is atomically thin, chemically inert, structurally stable, and electrically and thermally conductive. The ultrahigh-quality graphene produced by the substrate-free gas-phase method [1, 2] has enabled the unsurpassed TEM imaging of organic molecules and the interfaces between soft and hard nanomaterials. The pure and highly-ordered sheets were used as a near-invisible support film to directly image the atoms in a gold nanoparticle and its surrounding citrate coating [3]. The results showed that the synthesized graphene can be used to directly observe nanoparticles functionalized with a diverse range of molecular coatings, such as proteins and DNA.

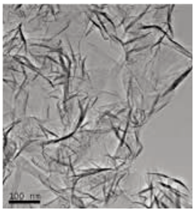
We offer ultrahigh-quality graphene that is produced through the substrate-free gas-phase method[1]. The



An atomic-resolution image of a 10 nm gold nanoparticle and its surrounding citrate capping agent on a synthesized graphene support film.



A low-magnification image of a (1) gold nanoparticle 10 nm in diameter on a (2) transparent synthesized graphene support film, (3) the vacuum, and (4) a lacey carbon support.

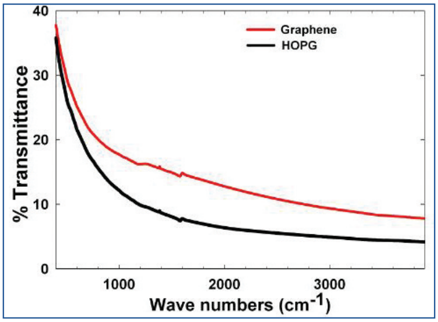


A typical low-magnification TEM image of crumpled and randomly oriented large-area graphene sheets suspended on a lacey carbon TEM grid.

Application (continued)

graphene created by this technique possesses a highly ordered structure that is composed of 99% carbon by mass (1% hydrogen)[2]. This graphene was used to directly image gold nanoparticles and their organic surface molecules in both conventional and atomic-resolution TEMs at a level that greatly surpasses any current TEM support film[3].

Our graphene provides an invisible, crystalline background that enables the unrivaled TEM characterization of organic and inorganic nanomaterials.



Elemental analysis by FT-IR reveals that the synthesized graphene sheets are free of detrimental oxygen functionalities. The FT-IR spectrum of synthesized graphene is similar to that of highly oriented pyrolytic graphite (HOPG).

References:

[1] Dato et al., “Substrate-Free Gas-Phase Synthesis of Graphene Sheets”, Nano Letters 8, 2012–2016 (2008).

[2] Dato et al., “Clean and highly ordered graphene synthesized in the gas phase”, Chemical Communications, 6095–6097, (2009).

[3] Lee et al., “Direct Imaging of Soft-Hard Interfaces

Additional References:

Galatzer-Levy, J. Graphene "sandwich" improves imaging of biomolecules. University of Illinois at Chicago News Center Web Site. February 4, 2014. Available at: http://news.uic.edu/graphene-sandwich-improves-imaging-of-biomolecules. Accessed February 12, 2014.

Wang, C., Qiao, Q., Shokuhfar, T. and Klie, R. F. (2014), High-Resolution Electron Microscopy and Spectroscopy of Ferritin in Biocompatible Graphene Liquid Cells and Graphene Sandwiches. Adv. Mater.. doi: 10.1002/adma.201306069

Dato, A. and Frenklach, M., "Substrate-free microwave synthesis of graphene: experimental conditions and hydrocarbon precursors", New Journal of Physics, 12, 1367-2630 (2010).

Ordering Information

Graphene products come available in five different ways, allowing you to choose which is best for you

a) As a solution of 0.1 mg Graphene in 1 ml of Ethanol. A homogeneous solution will take less than 30 seconds to create by sonicating the Graphene-solvent mixture. One is able to coat their own grids using this solution.

b) As Graphene-enhanced lacey carbon TEM grids. 200 and 300 mesh. These grids are created by coating our existing lacey carbon grids with graphene. Through a unique drop method, solution is dispersed onto the Lacey Carbon Grid.

c) As dry, synthesized Graphene powder, 1 mg.

Cat. No.	Description	Qty.
GF1200	0.1 mg Graphene in 1 ml of Ethanol	each
GF1201	Graphene-Enhanced Lacey Carbon TEM Grid 200 # Cu	each
GF1202	Graphene-Enhanced Lacey Carbon TEM Grid 200 # Ni	each
GF1203	Graphene-Enhanced Lacey Carbon TEM Grid 300 # Cu	each
GF1204	Graphene-Enhanced Lacey Carbon TEM Grid 300 # Ni	each
GF1205	Synthesized Graphene Powder, 1 mg	each

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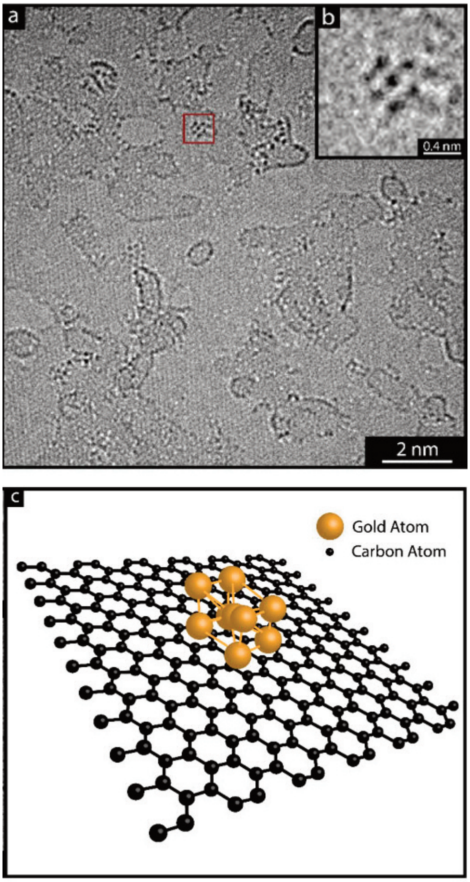
Graphene Oxide Membranes

A Scalable and Efficient Application of 2D Materials

Since the first report on producing the two-dimensional (2D) material graphene in 2004, there has been considerable time and money invested into developing new graphene-based technologies. These aim to exploit the remarkable properties of graphene including its strength and electrical- and thermal-conductivity. At a basic level, transmission electron microscopy (TEM) image contrast is caused by the scattering of electrons and is dependent on the thickness and composition of the sample material. The ultimate thinness of graphene, combined with the low atomic number of carbon, provides the ideal blueprint for a low-contrast TEM support. Producing graphene and transferring onto a TEM support grid is difficult to carry out at large scale and high yield. A simpler, cheaper, and higher yield production method uses graphene oxide, a 2D material similar to graphene. Graphite is reduced using a strong oxidising agent, and the oxygen functionalities introduced render it hydrophilic, allowing it to be easily dispersed in water, as well as other organic solvents. Controlled sonication of the water-dispersed material allows finely-tuned exfoliation of the graphene oxide, which in turn allows samples, including TEM supports, to be coated in single or few-layer graphene oxide. These flakes possess the low contrast benefits of graphene, which, combined with the efficient production of graphene oxide, make it ideal as a cheap, high-yield TEM support.

see Graphene Oxide TEM Support Films on page 11...



a) A high-resolution TEM image showing gold nanoparticles dispersed across modified graphene-oxide. b) Magnified image of red-box area in image a, showing single gold-nanoparticles with atomic rsolution. c) Schematic depicting of image b in 3D. Adapted from Bosch-Navarro.

Graphene on Lacey Carbon 300 Mesh Copper TEM Grids

Graphene TEM support films are supported by a lacey carbon film on a 300 mesh copper TEM grid.

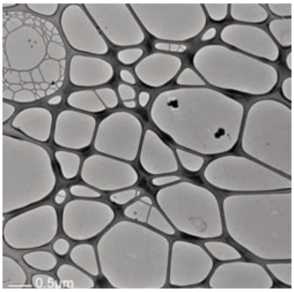
CAS No. 7782-42-5

Characteristics

1. Four thicknesses of CVD graphene
   Available in either 1, 2, 3-5 or 6-8 layers
2. TEM Substrate
   Lacey carbon support film on 300 mesh copper TEM grid
3. Graphene coverage of the TEM grid is better than 75%

Appearance

The graphene film appears as a near-transparent to light-grey film on the surface of the Lacey Carbon mesh on a red-brown colored copper TEM grid.



Low magnification TEM image of single-layer graphene on lacey carbon film. Typical grain size is in the region of 2-3 μm

Specifications

Type	Thickness of the Graphene	Transparency	TEM Grid/ AFM Substrate	Support Film
1 Layer	~0.35 nm	~96.4%	300 Mesh Copper Grid	N/A
2 Layers	~0.7 nm	~92.7%	300 Mesh Copper Grid	N/A
3-5 Layers	1.0-1.7 nm	~85.8-90.4%	300 Mesh Copper Grid	N/A
6-8 Layers	2.1-2.8 nm	~78.5-83.2%	300 Mesh Copper Grid	N/A

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GLC300Cu-5	Graphene on Lacey Carbon, 300 Cu	5/pk
1GLC300Cu-10	Graphene on Lacey Carbon, 300 Cu	10/pk
1GLC300Cu-25	Graphene on Lacey Carbon, 300 Cu	25/pk
2 Layers		
2GLC300Cu-5	Graphene on Lacey Carbon, 300 Cu	5/pk
2GLC300Cu-10	Graphene on Lacey Carbon, 300 Cu	10/pk
2GLC300Cu-25	Graphene on Lacey Carbon, 300 Cu	25/pk
3-5 Layers		
3GLC300Cu-5	Graphene on Lacey Carbon, 300 Cu	5/pk
3GLC300Cu-10	Graphene on Lacey Carbon, 300 Cu	10/pk
3GLC300Cu-25	Graphene on Lacey Carbon, 300 Cu	25/pk
6-8 Layers		
6GLC300Cu-5	Graphene on Lacey Carbon, 300 Cu	5/pk
6GLC300Cu-10	Graphene on Lacey Carbon, 300 Cu	10/pk
6GLC300Cu-25	Graphene on Lacey Carbon, 300 Cu	25/pk

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■ Graphene on Ultra-Fine 2000 Mesh Copper TEM Grids

CAS No. 7782-42-5

Characteristics

1. Four thicknesses of CVD graphene
   Available in either 1, 2, 3-5 or 6-8 layers
2. TEM Substrate
   Microporous Copper TEM Grids with Beryllium-Copper Support Aperture
3. Graphene coverage of the TEM grid is better than 75%

Appearance

The graphene film appears as a near-transparent to light-grey film on the surface of the red-brown microporous copper TEM grid. For support, the TEM grid is attached using epoxy to a gold-colored beryllium-copper disk with a 2 x 1 mm aperture.

Specifications

Type	Thickness of the Graphene	Transparency	TEM Grid/ AFM Substrate	Support Film
1 Layer	~0.35 nm	~96.4%	2000 Mesh Copper Grid	N/A
2 Layers	~0.7 nm	~92.7%	2000 Mesh Copper Grid	N/A
3-5 Layers	1.0-1.7 nm	~85.8-90.4%	2000 Mesh Copper Grid	N/A
6-8 Layers	2.1-2.8 nm	~78.5-83.2%	2000 Mesh Copper Grid	N/A

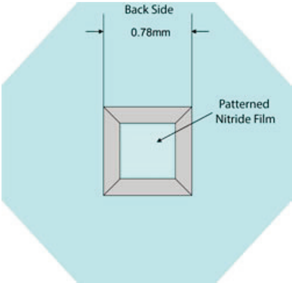
Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GUF2000Cu-5	Graphene on Ultra-Fine, 2000 Cu	5/pk
1GUF2000Cu-10	Graphene on Ultra-Fine, 2000 Cu	10/pk
1GUF2000Cu-25	Graphene on Ultra-Fine, 2000 Cu	25/pk
2 Layers		
2GUF2000Cu-5	Graphene on Ultra-Fine, 2000 Cu	5/pk
2GUF2000Cu-10	Graphene on Ultra-Fine, 2000 Cu	10/pk
2GUF2000Cu-25	Graphene on Ultra-Fine, 2000 Cu	25/pk
3-5 Layers		
3GUF2000Cu-5	Graphene on Ultra-Fine, 2000 Cu	5/pk
3GUF2000Cu-10	Graphene on Ultra-Fine, 2000 Cu	10/pk
3GUF2000Cu-25	Graphene on Ultra-Fine, 2000 Cu	25/pk
6-8 Layers		
6GUF2000Cu-5	Graphene on Ultra-Fine, 2000 Cu	5/pk
6GUF2000Cu-10	Graphene on Ultra-Fine, 2000 Cu	10/pk
6GUF2000Cu-25	Graphene on Ultra-Fine, 2000 Cu	25/pk

■ Graphene on Silicon Nitride TEM Grids (2.5 µm holes)

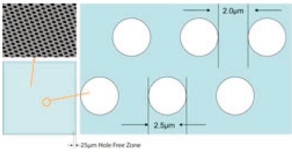
Characteristics

1. Four thicknesses of CVD graphene
   Available in either 1, 2, 3-5 or 6-8 layers
2. TEM Substrate
   200 µm thick 3.0mm hexagonal silicon substrate with a 0.5 x 0.5 mm aperture and 200 nm thick silicon nitride membrane with approximately 6,400 2.5 µm holes
3. Graphene coverage of the TEM grid is better than 75%



Appearance

Solid hexagonal disk with a greenish hue. The graphene film appears as a near-transparent to light-grey film on the surface of the microporous Silicon Nitride membrane.



Specifications

Type	Thickness of the Graphene	Transparency	TEM Grid/ AFM Substrate	Support Film
1 Layer	~0.35 nm	~96.4%	2.5 µm Hole Silicon Nitride	Silicon Nitride
2 Layers	~0.7 nm	~92.7%	2.5 µm Hole Silicon Nitride	Silicon Nitride
3-5 Layers	1.0-1.7 nm	~85.8-90.4%	2.5 µm Hole Silicon Nitride	Silicon Nitride
6-8 Layers	2.1-2.8 nm	~78.5-83.2%	2.5 µm Hole Silicon Nitride	Silicon Nitride

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GSiN2.5um-5	Graphene on Silicon Nitride, 2.5 µm	5/pk
1GSiN2.5um-10	Graphene on Silicon Nitride, 2.5 µm	10/pk
1GSiN2.5um-25	Graphene on Silicon Nitride, 2.5 µm	25/pk
2 Layers		
2GSiN2.5um-5	Graphene on Silicon Nitride, 2.5 µm	5/pk
2GSiN2.5um-10	Graphene on Silicon Nitride, 2.5 µm	10/pk
2GSiN2.5um-25	Graphene on Silicon Nitride, 2.5 µm	25/pk
3-5 Layers		
3GSiN2.5um-5	Graphene on Silicon Nitride, 2.5 µm	5/pk
3GSiN2.5um-10	Graphene on Silicon Nitride, 2.5 µm	10/pk
3GSiN2.5um-25	Graphene on Silicon Nitride, 2.5 µm	25/pk
6-8 Layers		
6GSiN2.5um-5	Graphene on Silicon Nitride, 2.5 µm	5/pk
6GSiN2.5um-10	Graphene on Silicon Nitride, 2.5 µm	10/pk
6GSiN2.5um-25	Graphene on Silicon Nitride, 2.5 µm	25/pk

Graphene on Ultra-Flat Thermal SiO2 Substrate

Characteristics

1. Four thicknesses of CVD graphene
   Available in either 1, 2, 3-5 or 6-8 layers
2. TEM Substrate
   The Ultra-flat Thermal SiO2 Substrate consists of a 200 nm thermally grown SiO2 film on an ultra-flat silicon wafer with a normal thickness of 675 µm. The size is 5 mm x 5 mm.
3. Graphene coverage of the TEM grid is better than 75%

Appearance

The graphene film appears as a near-transparent to light-grey film on the surface of the red-brown microporous copper TEM grid. For support, the TEM grid is attached using epoxy to a gold-colored beryllium-copper disk with a 2 x 1 mm aperture.

Specifications

Type	Thickness of the Graphene	Transparency	TEM Grid/ AFM Substrate	Support Film
1 Layer	~0.35 nm	~96.4%	N/A	Ultra-Flat Silicon
2 Layers	~0.7 nm	~92.7%	N/A	Ultra-Flat Silicon
3-5 Layers	1.0-1.7 nm	~85.8-90.4%	N/A	Ultra-Flat Silicon
6-8 Layers	2.1-2.8 nm	~78.5-83.2%	N/A	Ultra-Flat Silicon

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GUFSiO2-5	Graphene on Ultra-Flat Thermal SiO_2	5/pk
1GUFSiO2-10	Graphene on Ultra-Flat Thermal SiO_2	10/pk
1GUFSiO2-25	Graphene on Ultra-Flat Thermal SiO_2	25/pk
2 Layers		
2GUFSiO2-5	Graphene on Ultra-Flat Thermal SiO_2	5/pk
2GUFSiO2-10	Graphene on Ultra-Flat Thermal SiO_2	10/pk
2GUFSiO2-25	Graphene on Ultra-Flat Thermal SiO_2	25/pk
3-5 Layers		
3GUFSiO2-5	Graphene on Ultra-Flat Thermal SiO_2	5/pk
3GUFSiO2-10	Graphene on Ultra-Flat Thermal SiO_2	10/pk
3GUFSiO2-25	Graphene on Ultra-Flat Thermal SiO_2	25/pk
6-8 Layers		
6GUFSiO2-5	Graphene on Ultra-Flat Thermal SiO_2	5/pk
6GUFSiO2-10	Graphene on Ultra-Flat Thermal SiO_2	10/pk
6GUFSiO2-25	Graphene on Ultra-Flat Thermal SiO_2	25/pk

■ Graphene Oxide on Lacey Carbon 300 Mesh Copper TEM Grids

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GOLC300Cu-5	Graphene Oxide on Lacey Carbon, 300 Cu	5/pk
1GOLC300Cu-10	Graphene Oxide on Lacey Carbon, 300 Cu	10/pk
1GOLC300Cu-25	Graphene Oxide on Lacey Carbon, 300 Cu	25/pk
2 Layers		
2GOLC300Cu-5	Graphene Oxide on Lacey Carbon, 300 Cu	5/pk
2GOLC300Cu-10	Graphene Oxide on Lacey Carbon, 300 Cu	10/pk
2GOLC300Cu-25	Graphene Oxide on Lacey Carbon, 300 Cu	25/pk

■ Graphene Oxide on Silicon Nitride, 2.5 µm

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GOSiN2.5um-5	Graphene Oxide on Silicon Nitride, 2.5 µm	5/pk
1GOSiN2.5um-10	Graphene Oxide on Silicon Nitride, 2.5 µm	10/pk
1GOSiN2.5um-25	Graphene Oxide on Silicon Nitride, 2.5 µm	25/pk
2 Layers		
2GOSiN2.5um-5	Graphene Oxide on Silicon Nitride, 2.5 µm	5/pk
2GOSiN2.5um-10	Graphene Oxide on Silicon Nitride, 2.5 µm	10/pk
2GOSiN2.5um-25	Graphene Oxide on Silicon Nitride, 2.5 µm	25/pk

■ Graphene Oxide on Ultra-Flat Thermal SiO_2

Ordering Information

Cat. No.	Description	Qty.
1 Layer		
1GOUFSiO2-5	Graphene Oxide on Ultra-Flat Thermal SiO_2	5/pk
1GOUFSiO2-10	Graphene Oxide on Ultra-Flat Thermal SiO_2	10/pk
1GOUFSiO2-25	Graphene Oxide on Ultra-Flat Thermal SiO_2	25/pk
2 Layers		
2GOUFSiO2-5	Graphene Oxide on Ultra-Flat Thermal SiO_2	5/pk
2GOUFSiO2-10	Graphene Oxide on Ultra-Flat Thermal SiO_2	10/pk
2GOUFSiO2-25	Graphene Oxide on Ultra-Flat Thermal SiO_2	25/pk

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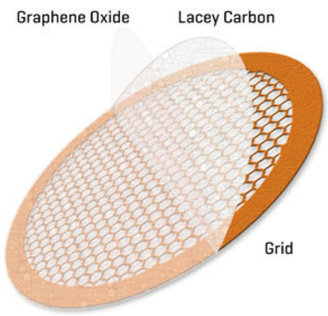
Graphene Oxide TEM Support Films



Graphene Oxide (GO) support film is a super thin (<1nm), naturally hydrophilic layer placed over the Holey, Lacey or Quantifoil support film on copper or gold grids. Pre-treatment of GO Support Films is unnecessary - by default, the hydrophilic surface spreads particles evenly across the grid. A hydrophobic surface can be achieved by heating in the air. Note: plasma cleaning or glow discharge will damage the support film.

- **Works well with Holey Carbon, Lacey Carbon and Quantifoil grid types, effectively spanning the gaps**
- **Less expensive to produce due to complexity of graphene manufacturing**
- **Better background contrast than graphene, results in higher resolution**
- **Nearly transparent in electron beam**
- **Barely visible under optical microscopes**
- **Regular batch checking ensures correct coverage of monolayers**

Ordering Information

Graphene Oxide on Holey Carbon Copper Mesh Grids

Cat. No.	Film	Grid	Mesh	Qty
GOHC300Cu10	GO on Holey Carbon	Cu	300	10/pk
GOHC300Cu25	GO on Holey Carbon	Cu	300	25/pk
GOHC300Cu50	GO on Holey Carbon	Cu	300	50/pk

Graphene Oxide on Lacey Carbon Copper Mesh Grids

Cat. No.	Film	Grid	Mesh	Qty
GOLC300Cu10	GO on Lacey Carbon	Cu	300	10/pk
GOLC300Cu25	GO on Lacey Carbon	Cu	300	25/pk
GOLC300Cu50	GO on Lacey Carbon	Cu	300	50/pk
GOLC300Cu100	GO on Lacey Carbon	Cu	300	100/pk

Graphene Oxide on Quantifoil Grids

Copper and Gold versions available

Cat. No.	Film	Grid	Mesh	Qty
GOQ200R24Cu10	GO on Quantifoils R2/4	Cu	200	10/pk
GOQ200R24Cu25	GO on Quantifoils R2/4	Cu	200	25/pk
GOQ200R24Cu50	GO on Quantifoils R2/4	Cu	200	50/pk
GOQ300R22Cu10	GO on Quantifoils R2/2	Cu	300	10/pk
GOQ300R22Cu25	GO on Quantifoils R2/2	Cu	300	25/pk
GOQ300R24Cu10	GO on Quantifoils R2/4	Cu	300	10/pk
GOQ300R24Cu25	GO on Quantifoils R2/4	Cu	300	25/pk
GOQ300R24Cu50	GO on Quantifoils R2/4	Cu	300	50/pk
GOQ400R1213Au10	GO on Quantifoils R1.2/1.3	Au	400	10/pk
GOQ400R1213Au25	GO on Quantifoils R1.2/1.3	Au	400	25/pk
GOQ400R1213Au50	GO on Quantifoils R1.2/1.3	Au	400	50/pk
GOQ400R1213Cu10	GO on Quantifoils R1.2/1.3	Cu	400	10/pk
GOQ400R1213Cu25	GO on Quantifoils R1.2/1.3	Cu	400	25/pk
GOQ400R1213Cu50	GO on Quantifoils R1.2/1.3	Cu	400	50/pk
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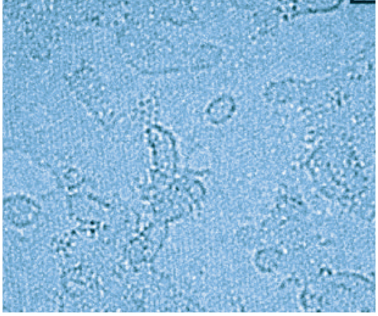

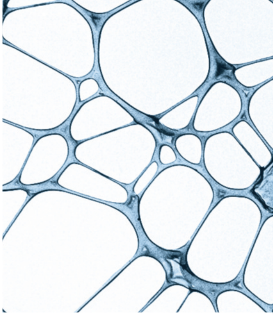

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