



GRAPHENE  
SQUARE  
ELECTRONICS



The Pioneer of  
**CVD Graphene**  
**Commercialization**

[www.graphenesq.com](http://www.graphenesq.com)





Graphene Square, Inc. is a pioneer in the commercialization of graphene material and graphene films for use as a transparent conductor and in other advanced electronics applications. Established in 2012 as a spin-off of the research of Prof. Byung Hee Hong at Seoul National University and with headquarters in Seoul, Korea. Our mission is to be the world's first company commercializing CVD graphene technology and No.1 cost-competitive & best-quality graphene film supplier in emerging markets.

## Main Business Areas

### Providing CVD Graphene Films and Fab Service

Graphene Square offers the highest quality graphene samples currently on the market. In addition to the standard samples available online, Graphene Square also provides fab services and 2D materials tailored to the customer's demand.

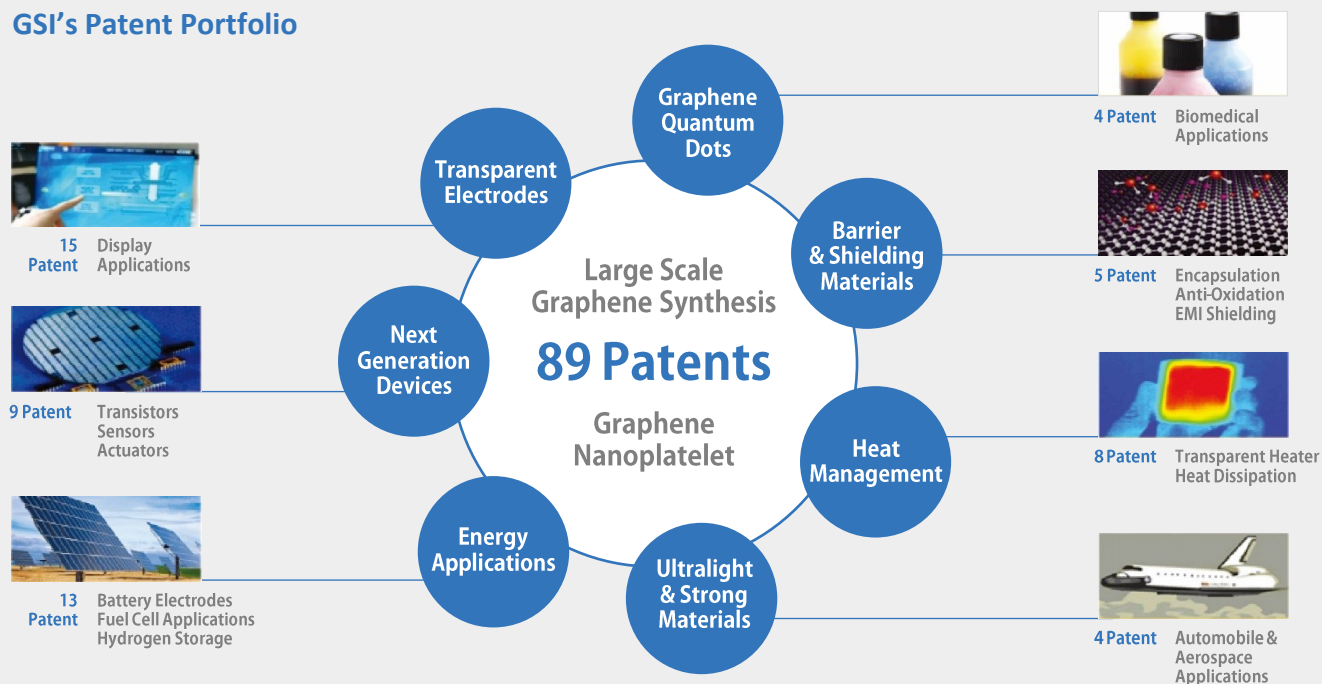
### Manufacturing CVD Systems for R&D and mass-production

Graphene Square markets advanced CVD systems that allow the users to prepare their own large-area, high-quality graphene and 2D materials samples in a lab environment, which have been installed in renowned institutions including Harvard, MIT, Oxford, Cambridge, Manchester, IBM/ETH, Technion, KAUST, etc.

### IP Licensing & B2B

Graphene Square licenses technology from its extensive patent portfolio, and provides B2B services including graphene coating on metal surface, transfer to arbitrary substrates, patterning of graphene to be applied to display, semiconductor, automobile, aerospace, biomedical industries, etc.

## GSI's Patent Portfolio



## GSI's Key Patents Highlighted by Bloomberg & Businessweek

"Hong's patents are key in making cost-efficient, large-scale graphene for touchscreen panels in mass volume."

(Samsung-Apple Smartphone Battleground Is Single Atom Thick May 15, 2014, Bloomberg.com)



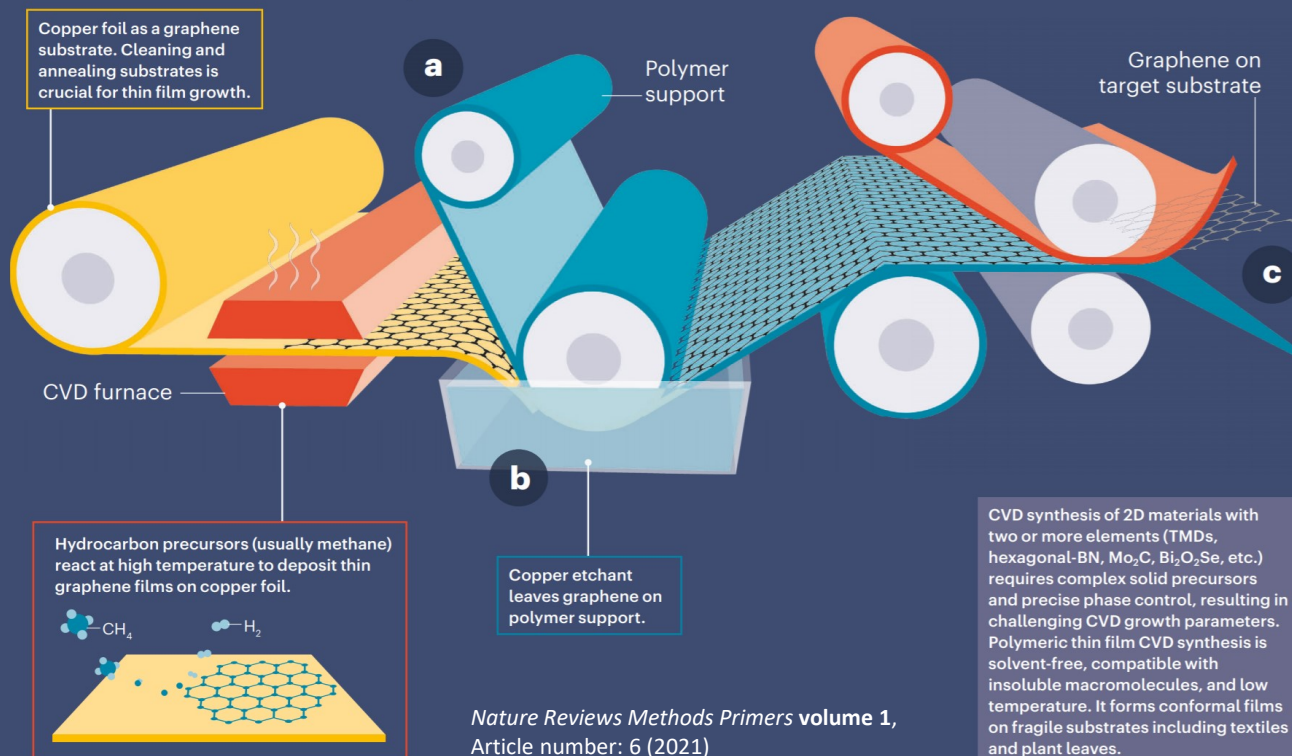
# Key Technology : Continuous Production by Roll-to-Roll CVD



## Applications

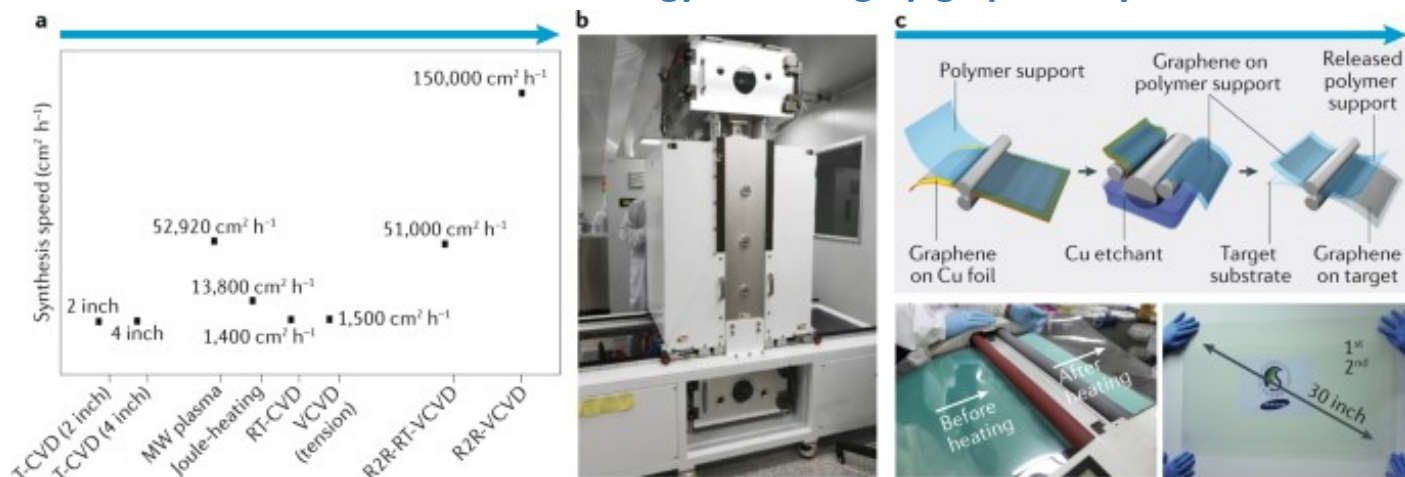
Roll-to-roll synthesis has increased thin film productivity >30-fold and is driving the industrial commercialization of high-quality and large-scale graphene (for example, for flexible touch screens or flexible OLEDs).

Post-CVD processes use a series of rolls to (a) laminate, (b) etch and (c) transfer thin films to target substrates.



Nature Reviews Methods Primers volume 1, Article number: 6 (2021)

## Advances in CVD technology for scaling-up graphene synthesis



Nature Reviews Methods Primers 1, 5 (2021)





# ThermoGraphene™ for Home Appliances

## Transparent and Ultrathin Heater Modules for Cooking Devices and Radiators

The graphene heater module can heat up to  $\sim 400^{\circ}\text{C}$  with longer radiation wavelengths (mid-IR), which is more efficient for the cooking and warming of moisture-rich objects.



## R&D Collaboration

- Size(mm): scalable up to 300 x 300 mm<sup>2</sup>
- Thickness: < 4 mm including substrates
- Temperature: < 400 °C
- # Graphene Layers: 3~4
- Power: ~600W
- Operation Voltage: 110~220V

 **LG Electronics** **SAMSUNG**



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# The Graphene Radiator

with Thermo-Graphene™ Modules



## Graphene Heating Modules

For Electric Vehicles, Home Appliances, Consumer Electronics, Semiconductor Manufacturing Processes

Graphene is capable of generating heats by flowing electrical currents very efficiently, which consumes 30% less energy than conventional coil heaters that produce heats by high resistance. In addition, the graphene heater is transparent and flexible, which is advantages for lamination on glass, wafers, and plastic substrates.

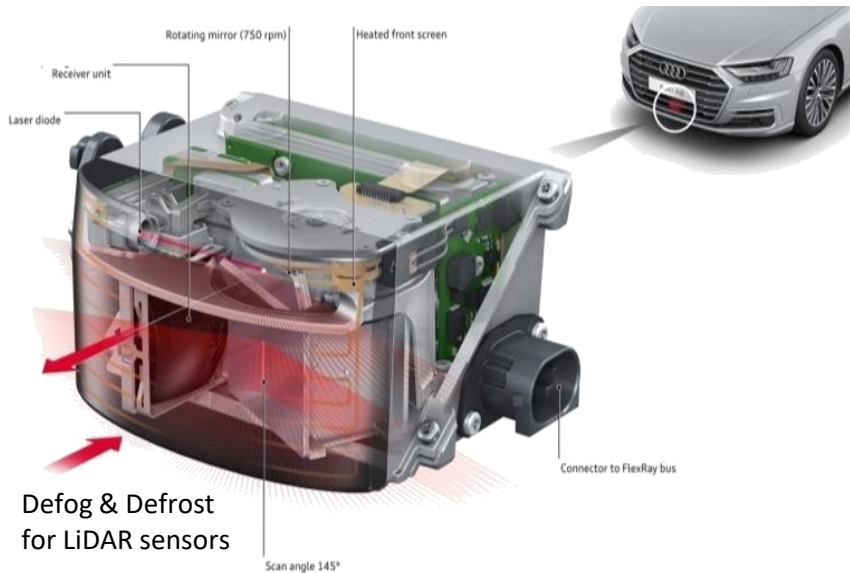


Foldable and Portable IR Radiation Heaters with Hologram Display

# ThermoGraphene™ for Automobile

Graphene Heater Modules can be used as defrost/defogging windows for EV windshields, cameras, and Lidar.

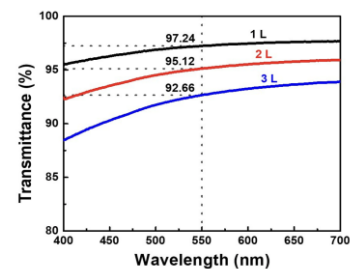
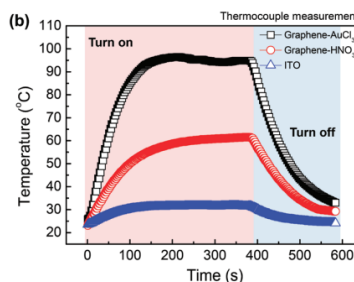
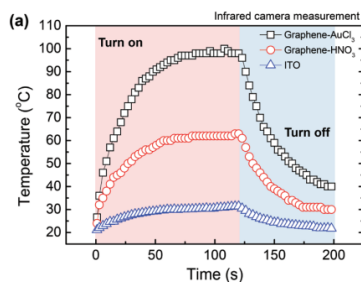
Graphene can generate heats by flowing electrical currents very efficiently, which consumes 30% less energy than conventional coil heaters that produce heats by high resistance. In addition, the graphene heater is transparent and flexible, which is advantages for lamination on glass, wafers, and plastic substrates



Defog & Defrost  
for EV's Windshields & Cameras



Operation Voltage (V)	12			48			220		
Current (I)	0.040	0.067	0.109	0.160	0.267	0.436	0.733	1.222	2.000
No. Graphene Layers	1	2	3	1	2	3	1	2	3
Sheet Resistance (Ohm/sq.)	300	180	110	300	180	110	300	180	110
Power Consumption (W) (for 1:1 aspect ratio)	0.480	0.800	1.309	7.7	12.8	20.9	161	269	440



## Features

- Size(mm): 20 x 20 ~ 1500 x 1000 mm<sup>2</sup>
- Temperature: <100 °C for 12 V, and < 400 °C for 220V
- For windshields: 1~3-Layer Graphene on PET sandwiched between glass panels
- For Lidar: Monolayer Graphene coated on the inner surface of the cover window.

## R&D Collaboration







# CVD Systems for Graphene & 2D Materials

**Sophisticated · Cost Effective · Reliable · Programmable Systems · for Highest Sample Quality  
Fast Heating & Cooling · World's Best Training Service Available**

The development of Graphene Square's CVD systems is based on the researches of Prof. Byung Hee Hong who reported the synthesis of large-area graphene by CVD for the first time in 2009. His continuous efforts toward the industrial synthesis of high-quality graphene enabled the development of most-reliable and cost-effective synthesis systems not only for graphene but also for h-BN and other 2D materials. The performance of our CVD systems for R&D have been proven by more than 100 systems installed across the world. Graphene Square also provides the world's best training service to researchers, including the latest synthesis, transfer, and patterning processes needed for the fabrication of the best-quality devices.

# TCVD-DC100CA

## Premium Custom Design Dual CVD System with Glove Box

Chemical vapor deposition (CVD) system for the syntheses of 2D materials at scales from a chip to a wafer, including the synthesis of **graphene**, **h-BN**, **TMDCs** on various substrates by use of gas-phase or solid precursors and metal-organic (MO) sources



## Features

- Size(mm): 3000(W) x 1800(H) x 750(D)
- Up to 10 gases and 3 MO sources for gas-phase synthesis.
- Motor-controlled movable heater for fast heating and cooling (patented).
- Fully computer-controlled programmable recipes.
- TCVD100 platform: Proven performance for ~100 systems for more than 5 years.
- Invited training for full sample preparation processes from synthesis, etching, and transfer.
- Supply of high-quality source materials.
- 1 year warranty included (2 year extended)
- CVD chambers connected to a Glove Box. Free from air exposure.

## Customers / Demo Sites



Seoul National University  
Graphene Research Center

**ETH** zürich **IBM**

IBM Zürich Nanotech Center



**TECHNION**  
Israel Institute  
of Technology





# TCVD-50B

## 2inch Table-Top Manual Type Thermal CVD

This small size equipment was developed on customers' demand on low-cost but high quality synthesizer. Every research had its potential, but not all researches are funded well. TCVD-50B is the most ideal system for institutes who are limited in budget or those who searches for cost-effective equipment.



### Features

- Size(mm): 1500(W) x 893(H) x 590(D)
- Economic & space-saving model.
- Optimized for graphene, CNT, h-BN and TMDC growth.
- Water-cooled end chambers and doors.
- Process Temperature: ~1,100°C
- Protective design from heat
- Uniformity of Film Thickness:  $\leq \pm 3\%$
- Testing Uniformity:  $\leq \pm 3\%$
- Movable furnace method is our unique knowhow for fast heating and fast cooling of the sample

\* Price is determined after consultation. (Different customization from the standard parts will affect the overall price)

### Customization

#### Furnace

- Single – 2 Heating Zone (Standard)
- Dual – 3 Heating Zone
- Single + RF M/W Module

#### Chamber Size

- 2inch (Standard)
- 4inch

#### Pumping Unit

- Oil Type Rotary Pump (Standard)
- Dry Scroll Pump
- Additional: Mechanical Turbo Pump

#### Gas Control Unit

- 3 MFCs +1 Spare (Standard)
- Up to 5 MFCs

#### Warranty

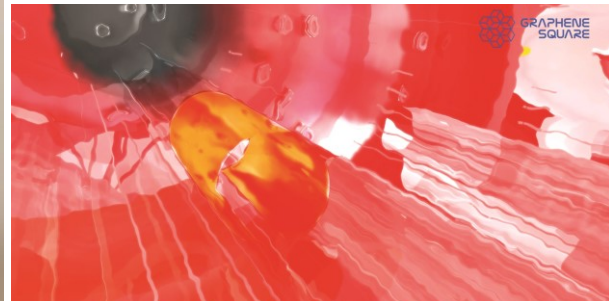
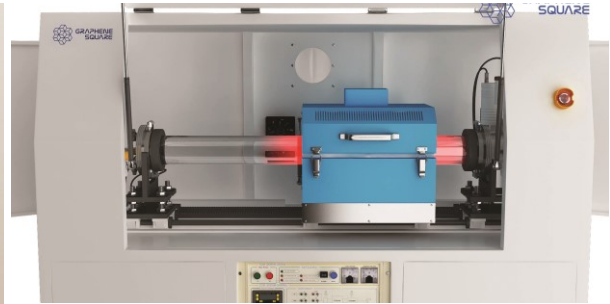
- 1 year – Provided (Standard)
- 2 years – Optional



# TCVD-100A

## 4inch Safety Cabinet Installed Automatic System

TCVD-100A is very sophisticated and cost effective equipment with automatic control system installed. It is the most ideal equipment for high quality graphene research. Safety house that covers whole system protects users from any hazardous event, and the Emergency Stop button will ensure the safety even further.



## Features

- Size(mm): 1750(W) x 1585(H) x 750(D)
- Advanced Semi-Auto System
- Optimized for graphene, CNT, h-BN and TMDC growth
- Water-cooled end chambers and doors
- Process Temperature:  $\sim 1,100^{\circ}\text{C}$
- Uniformity of Film Thickness:  $\leq \pm 3\%$
- Testing Uniformity:  $\leq \pm 3\%$
- Movable furnace method is our unique knowhow for fast heating and fast cooling of the sample
- Standard safety box

\* Price is determined after consultation. (Different customization from the standard parts will affect the overall price)

## Customization

### Furnace

- Single – 2 Heating Zone (Standard)
- Dual – 3 Heating Zone
- Single + RF M/W Module

### Chamber Size

- 2inch
- 4inch (Standard)
- 6inch
- 8inch

### Pumping Unit

- Oil Type Rotary Pump (Standard)
- Dry Scroll Pump
- Additional: Mechanical Turbo Pump

### Gas Control Unit

- 3 MFCs +1 Spare (Standard)
- Up to 8 MFCs

### Warranty

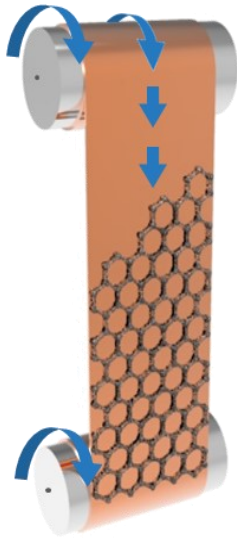
- 1 year – Provided (Standard)
- 2 years – Optional



# TCVD-V200A

## 8-inch Rapid Thermal Vertical Roll-to-Roll System

Graphene Square was the first group to publish paper on Roll-to-Roll(R2R) method for mass production of graphene. TCVD-V200A is vertical tube type equipment that enables the large scale deposition of graphene film.



### Features

- Size(mm): 1500(W) x 2500(H) x 1000(D)
- Advanced Semi-Auto Vertical Tube Roll-to-Roll System
- Optimized for large graphene synthesis
- Rapid heating furnace reaches 1,000°C in 5 min.
- Water-cooled end chambers and doors
- Process Temperature: ~1,100°C
- Uniformity of Film Thickness:  $\leq \pm 3\%$
- Testing Uniformity:  $\leq \pm 3\%$
- Rapid heating and automatic rolling system is ideally the first stage of graphene mass production.
- Standard safety box

\* Price is determined after consultation. (Different customization from the standard parts will affect the overall price)

### Customization

#### Furnace

- Single – 8 Heating Zone (Only Option)

#### Chamber Size

- 8inch (Only Option)

#### Pumping Unit

- Oil Type Rotary Pump (Standard)
- Dry Scroll Pump
- Additional: Mechanical Turbo Pump

#### Gas Control Unit

- 3 MFCs + 1 Spare (Standard)
- Up to 5 MFCs

#### Warranty

- 1 year - Provided (Standard)
- 2 years - Optional





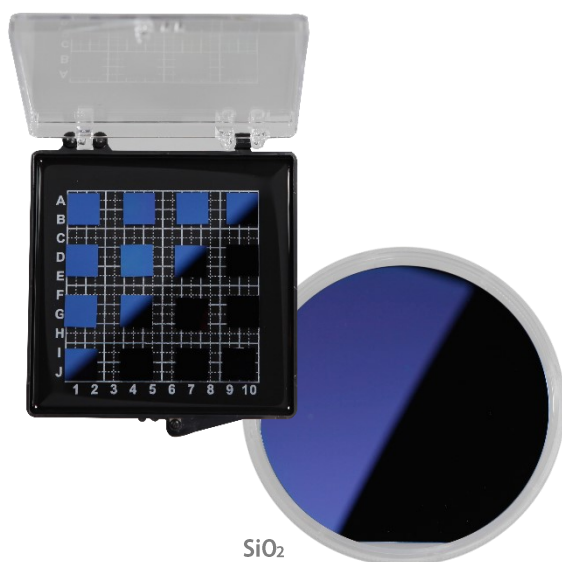


# Graphene Samples

The Highest Quality CVD Graphene Films on Custom Substrates · Graphene Oxides (GOs) · Graphene Quantum Dots (GQDs) · Consumables for Graphene Researches

Using state-of-the-art chemical vapor deposition (CVD) methods developed in-house, Graphene Square offers the highest quality graphene samples currently on the market. In addition to the standard samples available online, Graphene Square can provide various fab. services including the sample transfer on the customers' own substrates as well as end-equipment prototype devices. Graphene Square also supplies graphene oxides (GOs) and graphene quantum dots (GQDs) applicable to various biological, display, and energy researches.

# Graphene on SiO<sub>2</sub> wafer

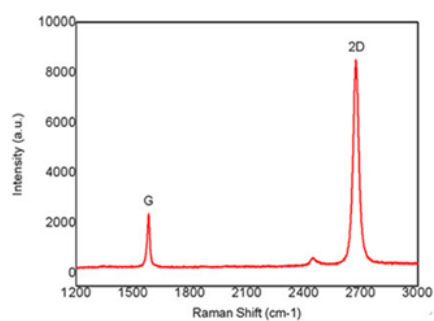


Product Size	Up to 65x65mm <sup>2</sup>
Film morphology	Continuous Monolayer (>95%)
Sheet Resistance	Av. < 250~400Ω/sq
Mobility	>3500cm <sup>2</sup> /Vs
Transmittance	>97%
Substrate	SiO <sub>2</sub> (300nm)/Si wafer
Domain Size	3-12μm

## Applications

- Flexible / Stretchable / Electronics
- Transparent electrode
- Support for m
- MEMS or NEMS
- Catalytic catalysis
- Conduc
- Multi-functional Nanocomposite coating
- Graphene Research
- ETC

## Raman Spectrum



## Reference

- (1) S. Bae\*, H. Kim\* et al. "Roll-to-roll production of 30 inch graphene films for transparent electrodes" Nature Nanotech. 5, 574 (2010)
- (2) K S. Kim et al. "Large-Scale Pattern Growth of Graphene Films for Stretchable Transparent Electrodes." Nature 457, 706 (2009) [pdf].



# Graphene on PET



Product Size	Up to 500x600mm <sup>2</sup>
Film morphology	Continuous Monolayer(>95%)
Sheet Resistance	Av. < 250~400Ω/sq
Mobility	>3500cm <sup>2</sup> /Vs
Transmittance	>97%
Substrate	PET(188μm)
Domain Size	3-12μm

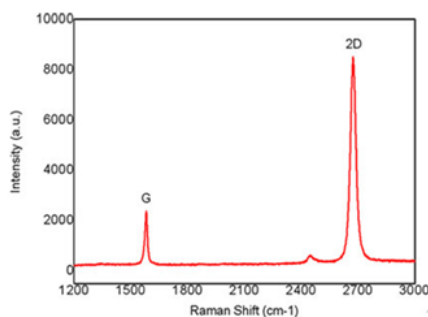
## Properties of Graphene Film on PET

- Thickness and quality of graphene films is controlled by Raman Spectroscopy Graphene coverage is about 80%
- The graphene film is continuous, with occasional holes and cracks.
- The graphene film is polycrystalline, i.e. it consists of grains with different crystallographic orientation.
- Sheet resistance: < 500 Ωa/□

## Applications

- Flexible / Stretchable / Electronics
- Transparent electrode
- Support for metallic catalysis
- MEMS or NEMS
- Conductive coating
- Multi-functional Nanocomposite
- Graphene Research
- ETC

## Raman Spectrum



## Reference

- (1) S. Bae\*, H. Kim\* et al. "Roll-to-roll production of 30 inch graphene films for transparent electrodes" Nature Nanotech. 5, 574 (2010)(Cover Article).
- (2) K S. Kim et al. "Large-Scale Pattern Growth of Graphene Films for Stretchable Transparent Electrodes." Nature 457, 706 (2009) .





# Graphene on Glass



Product Size	Up to 300x400mm <sup>2</sup>
Film morphology	Continuous Monolayer(>95%)
Sheet Resistance	Av. < 250~400Ω/sq
Mobility	>3500cm <sup>2</sup> /Vs
Transmittance	>97%
Substrate	Glass (3T)
Domain Size	3-12μm

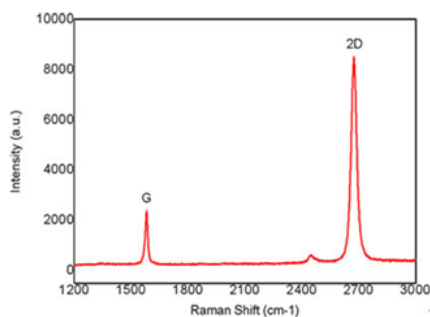
## Properties of Graphene Film on PET

- Thickness and quality of graphene films is controlled by Raman Spectroscopy Graphene coverage is about 80%
- The graphene film is continuous, with occasional holes and cracks.
- The graphene film is polycrystalline, i.e. it consists of grains with different crystallographic orientation.
- Sheet resistance: < 500 Ω/□

## Applications

- Flexible / Stretchable / Electronics
- Transparent electrode
- Support for metallic catalysis
- MEMS or NEMS
- Conductive coating
- Multi-functional Nanocomposite
- Graphene Research
- ETC

## Raman Spectrum



## Reference

- (1) S. Bae\*, H. Kim\* et al. "Roll-to-roll production of 30 inch graphene films for transparent electrodes" Nature Nanotech. 5, 574 (2010) .
- (2) K S. Kim et al. "Large-Scale Pattern Growth of Graphene Films for Stretchable Transparent Electrodes." Nature 457, 706 (2009).





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