



# GraphMaster

CVD reactors for large format graphene production

## Developed by SECO/WARWICK - one of the world's leading manufacturers of heat processing equipment and a technology leader

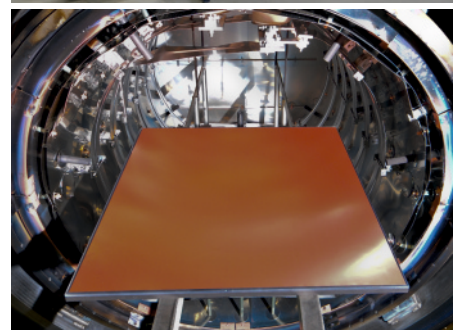
With our fully equipped research and development facility and cooperation with the academic centers in Europe, we are able to provide innovative solutions not offered anywhere else in the world. The Group is made up of companies located in five countries on three continents, and we sell our products worldwide. We supply our equipment to customers involved in steel, titanium and aluminum production as well as aluminum recycling, forging, automotive, aerospace, commercial heat treating, HVAC/R, electronics, wind energy, medical equipment and nuclear industries.

## For wide range of industrial and R&D applications

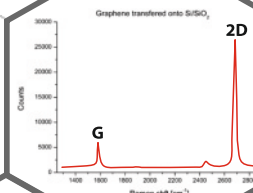
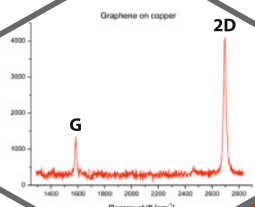
- Working temperature up to 1200°C
- Substrate formats up to 500 x 500 mm (larger reactors on request)
- Ability to load multiple levels of substrate in one batch
- Growth of graphene on 3d objects
- Flexible control system and intuitive HMI

## Flexible equipment

- Large formats and/or small samples can be processed
- Different gasses and mixtures can be used
- Process can be conducted in vacuum / partial pressure and positive pressure (from  $10^{-5}$  Torr to 1,5 bar abs.)
- Variable process temperature and heat-up rate
- Variable cooling rate in vacuum, still atmosphere or accelerated atmosphere

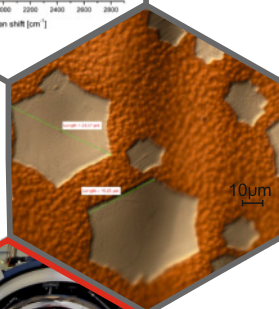


Raman spectrum confirms the high quality of graphene layer grown on copper. D peak is not observed, which indicates low defects level.. Small FWHM of 2D peak indicates a true single layer of graphene.

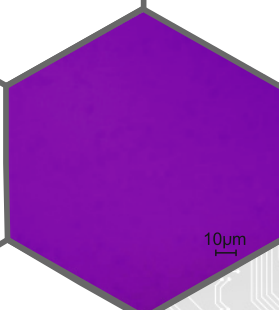


Raman spectrum of graphene grown on Cu foil and transferred onto SiO<sub>2</sub> substrate. Small FWHM of 2D peak indicates a true single layer of graphene; D peak is not observed, which indicates low defects level.

Graphene domain sizes up to 0.1 mm.  
Optical microscope image, after oxidation.



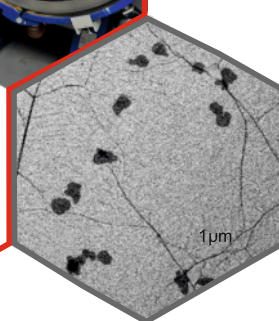
Continuous graphene layer without cracks and holes.  
Optical microscope image of graphene transferred onto SiO<sub>2</sub> substrate.



High quality CVD graphene in formats up to 500 x 500 mm.



No macro-defects in graphene layer, very few seeds of second layer.  
Scanning Electron Microscope image.



Electrical parameters measured based on Hall effect in Van der Pauw configuration at RT over 1cm x 1cm samples of graphene transferred onto Si/SiO<sub>2</sub> substrate.

**high carrier concentration:**  
p= 1,257E13  
μ= 1148  
ρ= 433

**low carrier concentration:**  
p= 2.393E12  
μ= 1771  
ρ= 1476

**where:**  
p- sheet hole concentration [cm<sup>-2</sup>]  
μ- carrier mobility [cm<sup>2</sup>/V-s]  
ρ- resistivity [Ω-cm]



in cooperation with  
research partner



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