MOORFIELD
NANOTECHNOLOGY

nanoCVD-8G

Benchtop, turnkey system for rapid synthesis of high-quality graphene

Key Features:

- Ultra-compact, benchtop, CVD system
- Reproducible synthesis of high-quality graphene
- Precise control of conditions
- 1100 °C maximum temperature
- Process times <30 minutes
- 20 × 40 mm^2 maximum substrate size
- Fully-automatic
- User-friendly, touchscreen interface
- Define/save multiple growth recipes
- PC connection for data-logging
- Equipped for easy servicing
- Comprehensive safety features
- Cleanroom compatible
- Proven performance

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nanoCVD-8G

System Description:

Developed in collaboration with academic partners, the nanoCVD-8G is designed for the high-throughput production of high-quality graphene for R&D and pilot-scale applications. Synthesis is via the well-established chemical vapour deposition (CVD) route. This method allows for rapid production, and, in contrast to approaches such as mechanical exfoliation (i.e., the "sticky-tape method"), is also scalable making it promising for future commercialisation of graphene-based technologies.

Technology:

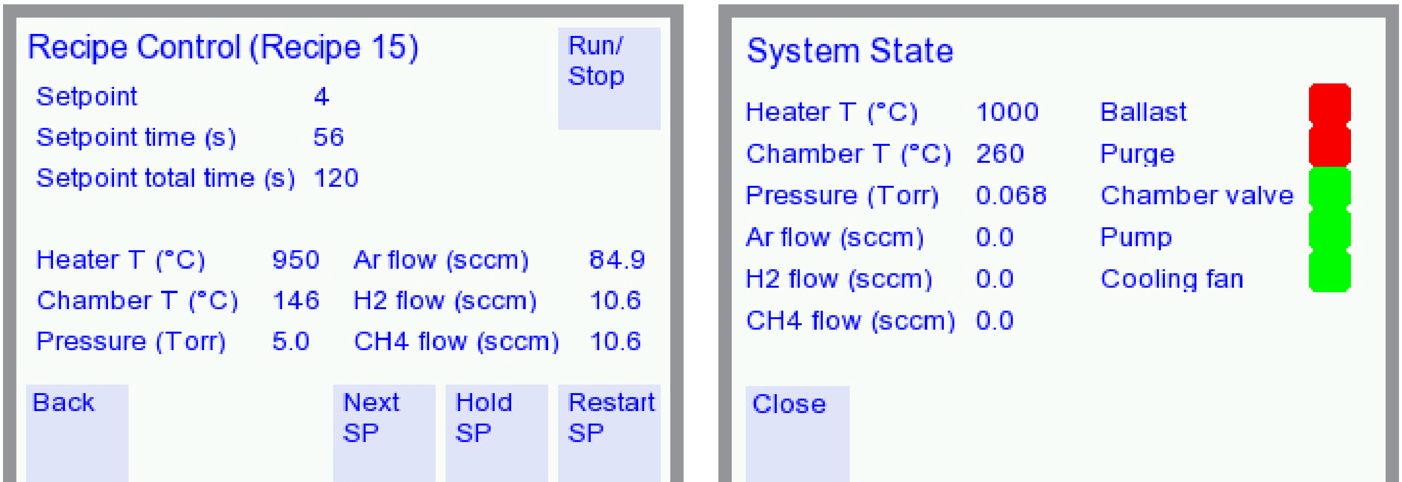
The system contains a low thermal-mass heater stage onto which film or foil substrates can be placed. The stage slides into a small volume, cold-walled reaction chamber, which is sealed during process operation, and is designed for uniform heating over areas up to 20 x 40 mm^2. The maximum setpoint temperature is 1100 °C, and temperatures can be set and controlled with a resolution of 1 °C. The unit is capable of high heating/cooling rates, if required, allowing for complete growth cycles <30 minutes. Such efficient operation also results in minimised resource usage (e.g., in terms of power and process gases).

Process gases are controlled via mass-flow controllers (MFCs). The standard configuration is equipped for 3 process gases: argon, methane and hydrogen. The system is capable of operating in flow-rate or pressure control modes. Automatic pressure control is possible throughout the range 0-20 Torr. Pressure measurement is by capacitance manometer, with pumping by rotary or scroll-type backing pumps.

The nanoCVD-8G allows for graphene synthesis via a wide variety of CVD schemes, including, but not limited to, those based on metal substrates and using methane as feedstock gas that are known to provide high-quality material.

Control System:

The unit is fitted with industrial-grade PLC electronics. User operation is via a 5" touchscreen HMI mounted on the front panel. Users are able to define, store and run multiple 'recipes' via flexible, but easy-to-use, touchscreen software. Online data-logging and recipe upload/download to a PC is possible via the provided *NanoConnect* software.



Screenshots from the touchscreen HMI software through which all user operation of the nanoCVD-8G is carried out.

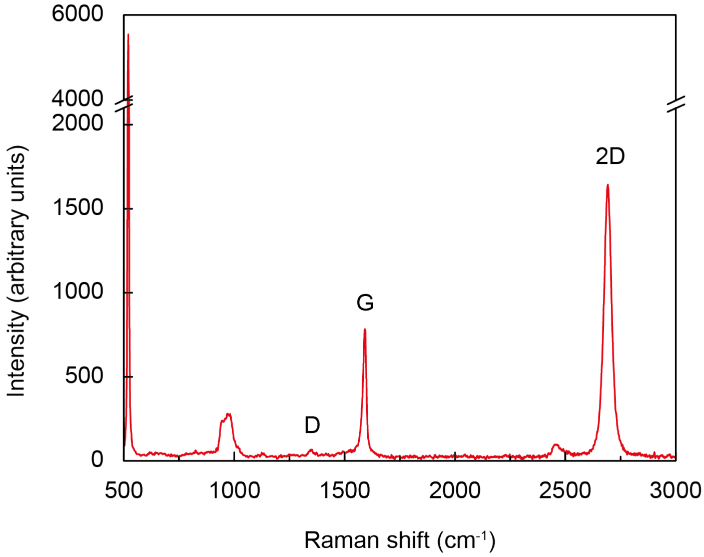
nanoCVD-8G

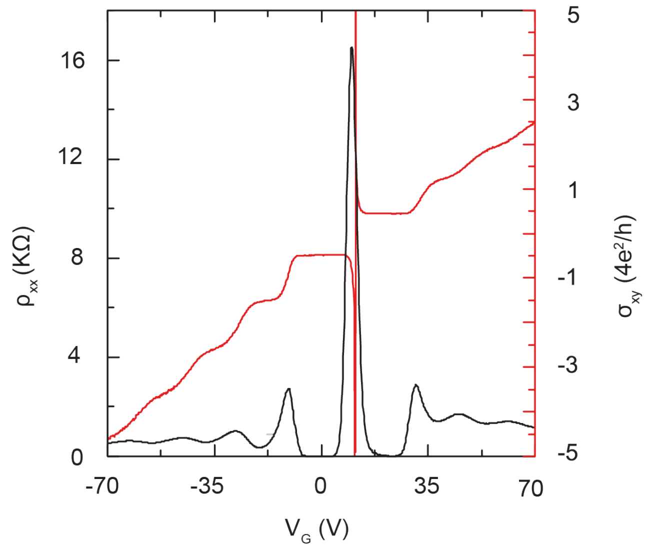
nanoCVD-8G Graphene:

Graphene samples synthesised using a nanoCVD-8G have been characterised using Raman spectroscopy, high magnetic field transport, and electron and optical microscopies. The graphene produced was shown to be monolayer, have high quality with low intrinsic doping, and macroscopic uniformity.

Transistor devices show high charge carrier mobilities, 3300 $cm^2/(V \cdot s)$ at 1.4 K and 2773 $cm^2/(V \cdot s)$ at room temperature. Hall bar devices at high magnetic fields indicated the half integer quantum Hall effect (unique to monolayer graphene). Such observations provide strong evidence for the exceptional quality of the material that can be produced using the nanoCVD-8G.

For full results, see reference 1.

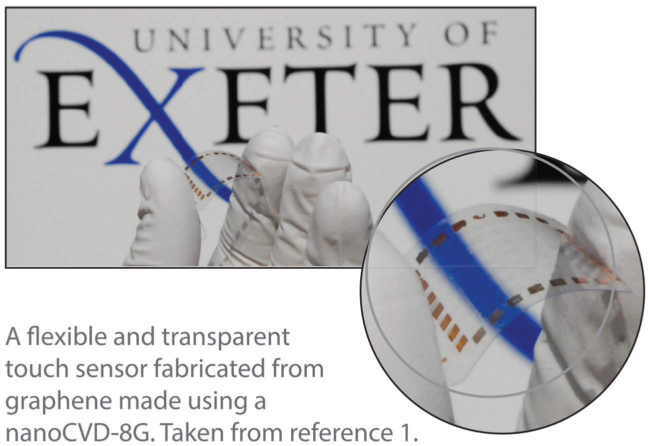




Characterisation indicating high-quality, defect-free graphene produced using a nanoCVD-8G. Left: Raman spectrum. Right: Longitudinal resistivity and Hall conductance data indicating half integer quantum Hall effect unique to monolayer graphene (data taken from reference 1).

Graphene produced with the nanoCVD-8G has found multiple applications:

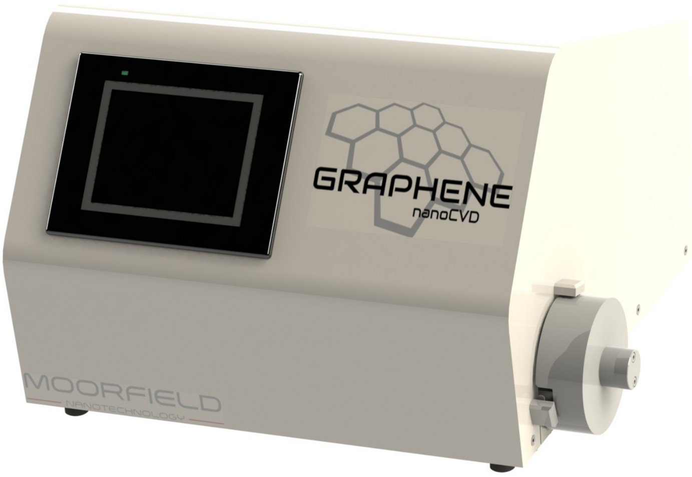
- Optoelectronics: As electrodes for flexible and transparent touch sensors, and in photovoltaic devices.
- Biosensors: Functionalisation of graphene surfaces has allowed for detection of specific proteins using electrical transport techniques.
- CVD growth mechanisms: Given its rapid heating/cooling abilities and cold-walled design, the nanoCVD-8G and its graphene have allowed for detailed studies of CVD synthesis.
- Fundamental transport: Investigation of exotic physics in graphene with low intrinsic doping, such as the quantum Hall effect over large areas, and high charge carrier mobilities.

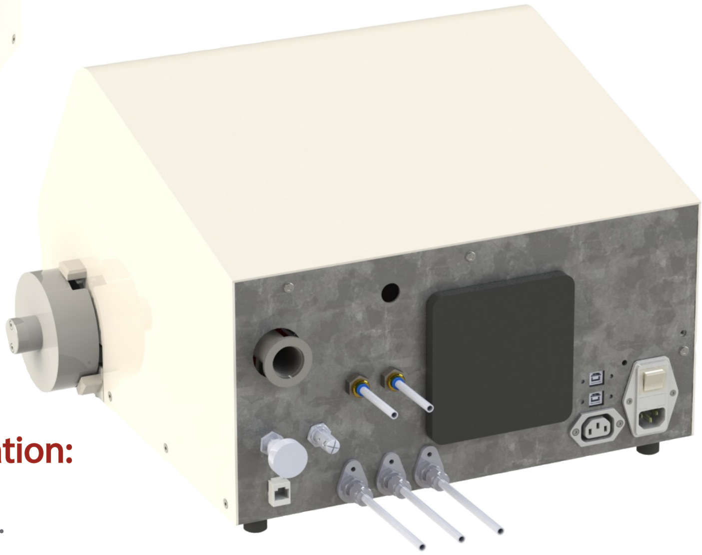


A flexible and transparent touch sensor fabricated from graphene made using a nanoCVD-8G. Taken from reference 1.

References:

1. Bointon, T. H., et al. "High Quality Monolayer Graphene Synthesized by Resistive Heating Cold Wall Chemical Vapor Deposition" *Adv. Mater.* 2015 DOI: 10.1002/adma.201501600
2. Neves, A. I. S., et al. "Transparent Conductive Graphene Textile Fibers" *Sci. Rep.* 2015 DOI: 10.1038/srep09866
3. Lupina, G., et al. "Residual Metallic Contamination of Transferred Chemical Vapor Deposited Graphene" *ACS Nano* 2015 DOI: 10.1021/acsnano.5b01261





System Requirements—Standard Configuration:

- Substrates: Typically foils/films of various metals.
- Process gases: 25 psi supplies of methane, hydrogen and argon.
- Service gas: Dry inert (e.g., nitrogen or argon), 60–80 psi supply.
- Power: Single-phase 230 V, 50 Hz, 10 A.
- Exhaust extraction.

Applications:

- Fundamental research.
- Education.
- Product R&D.

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