

# APPLICATION NOTE A103-CM99 - RESEARCH HIGH-QUALITY GRAPHENE PRODUCTION

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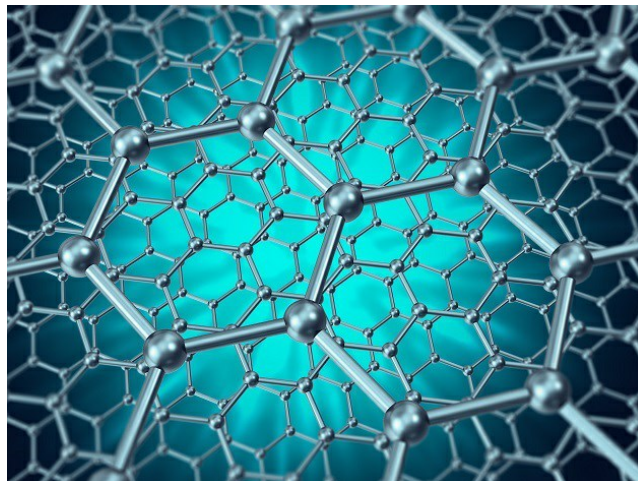
APPLICATION NOTE A103-CM99

## RESEARCH HIGH-QUALITY GRAPHENE PRODUCTION

**Graphene - carbon-based chicken wire on an atomic scale - is a material with great expectations. The attention of the scientific community on this light, transparent, flexible and electrically conducting single layer of graphite has increased substantially in the past years, and many applications in electronic, catalysis and energy storage fields are foreseen.**

One of the major hurdles to overcome is scaling up the production to an industrial level. Which means: to manufacture large quantities of graphene of a good quality at a sufficiently low price.

The University of Cordoba in Spain investigates the production of high-quality graphene on a large scale by using an atmospheric pressure plasma-based technique. This university is a customer of [Iberfluid Instruments S.A.](#), - distributor of Bronkhorst in Spain - and in their research they use devices from Bronkhorst.



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### Application requirements

The [University of Cordoba](#) investigates the production of high-quality graphene powder in one step by means of a special microwave plasma torch with ethanol as carbon source and argon as carrier gas. In this setup, ethanol vapour has to be generated in a controlled way, resulting in an accurate and stable ethanol vapour flow. The system should be able to operate efficiently with respect to the amount of ethanol used, and should be able to scale-up easily.

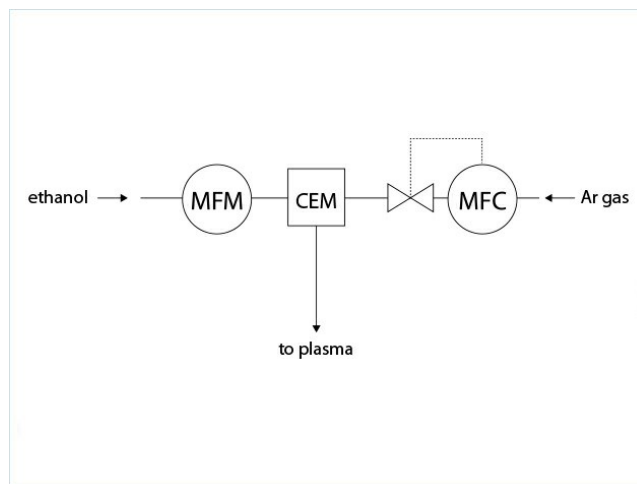
### Important topics

- CEM replaces bubbler with better performance, stability and accuracy
  - Scalability
  - Efficient use of chemical compounds
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## Process solution

A Controlled Evaporator Mixer system (CEM) of Bronkhorst is used to generate a controlled flow of ethanol vapour that is brought into the plasma where it is converted into graphene powder at atmospheric pressure. Argon acts as carrier gas for the ethanol vapour flow. As part of this vapour flow control system, a thermal Mass Flow Controller (MFC - series EL-FLOW Select) controls the gas flow of argon, and a liquid Mass Flow Controller (MFC - series mini CORI-FLOW) controls the flow of ethanol. These devices are connected to a CEM unit, which is a temperature controlled mixing/evaporation instrument, where the vapour/gas mixture is generated.

Iberfluid Instruments S.A. integrated the components of the CEM system into an in-house designed single panel. Just before the liquid Mass Flow Controller, liquid ethanol is present in a small vessel that is pressurised with helium gas. The atmospheric microwave plasma technique for graphene powder production inside a glass reactor with quartz window uses a TIAGO torch as plasma generator and a SAIREM microwave generator.



Flow scheme

A typical flow of argon gas (99.999 % purity) of 1000 ml/min is used, since earlier investigations at the university showed that this flow favours the formation of solid carbon from ethanol decomposition. An ethanol flow of 2 g/h is chosen - corresponding with 2 vol% ethanol in the vapour/gas mixture - because higher concentrations would result in flame extinction.

Using this setup, the quality of the resulting graphene is comparable to graphene produced by traditional chemical vapour deposition (CVD) or new graphite exfoliation techniques. However, the scale-up of the current plasma-based technique can be conducted rather easy by connecting several devices in series. The CEM based vaporisation system can replace traditional bubblers, with better performance, stability and accuracy in favour of the former.

The university claims that the technique they use is environmentally friendly because no metal catalysts are needed to activate the graphene growth process. Furthermore, if ethanol is obtained from the fermentation of agricultural processes, it can be considered as a 'clean & green' carbon source.

Download research paper of the University of Cordoba: [Scalable graphene production from ethanol decomposition by microwave argon plasma torch](#).

## Recommended Products



**CEM EVAPORATOR W-102A**

Max. 30 g/h liquid;  
Max. 4 l/min gas  
Pressure rating 100 bar  
Very stable vapor flow  
Flexible gas/liquid ratio



**EL-FLOW SELECT F-201AV**

Min. flow 0,4...20 l/min  
Max. flow 0,6...100 l/min  
Pressure rating 64 bar  
Compact design  
High accuracy and repeatability



**MINI CORI-FLOW™ M12**

Min. flow 0,1...5 g/h  
Max. flow 2...200 g/h  
Pressure rating 200 bar  
Independent of fluid properties  
High accuracy, fast response



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