

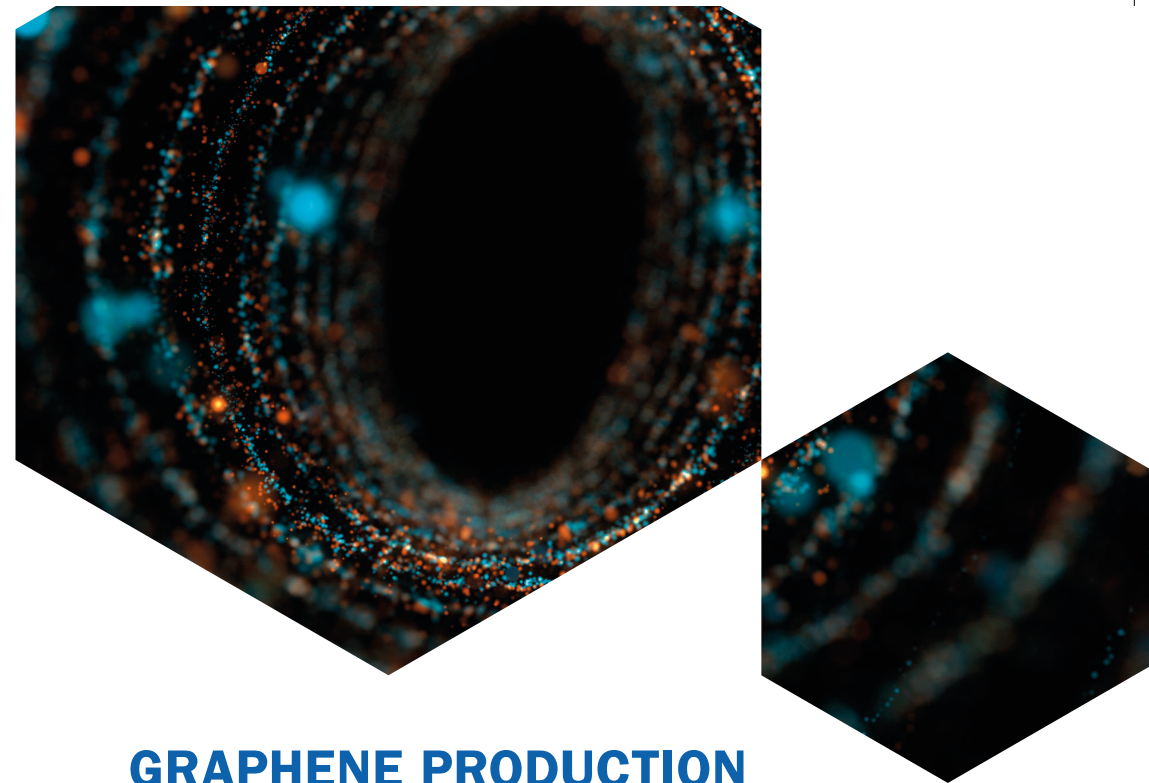
Examples of the different ways that graphene can be produced and the relationship between quality and price.

GRAPHENE MARKET

The Graphene Flagship's principal mission is to take technologies based on graphene from the laboratory to commercial applications. The full-scale application of graphene in commercial products is still several years in the future, which means there is time for Europe to secure a major role in this ongoing technological revolution in a market that is expected to exceed €100M by 2020 and reach €150-550M by 2025.

GRAPHENE PRODUCERS

Aixtron	aixtron.com	Graphensic	graphensic.com
Avanzare	avanzarematerials.com	Grupo Antolin	grupoantolin.com
Gnext	graphene-xt.com	M-Solv	m-solv.com
Graphenea	graphenea.com	TALGA	talgaresources.com
Graphenest	graphenest.com	Thales	thalesgroup.com/en
GrapheneTech	graphene-tech.net	Versarien	versarien.com



GRAPHENE PRODUCTION

A FAMILY OF MATERIALS

Graphene is part of a whole family of related materials, each with discrete properties and applications. Different types of graphene are produced and processed in different ways.

- 1) Graphene oxide is the product of liquid phase exfoliation by which monolayers or few layer flakes of graphene are exfoliated from graphite in a liquid medium. Graphene oxide is an important material for a range of applications in biomedicine, energy storage, nanocomposites and others.
- 2) Graphene crystals are grown on a variety of substrates for varying applications. Graphene grown on insulators, such as SiO₂, typically produces a film with small crystallites, whereas growth on the close-packed surfaces of metals yields highly crystalline films. These crystals can be grown on wafers for electronic applications.
- 3) Chemical Vapour Deposition (CVD) graphene is produced through a process by which carbon atoms are evaporated and then deposited on copper foil. CVD graphene can be used for applications like transparent and flexible electronics as well as anti-corrosion coatings.



GRAPHENE PRODUCTS BY THE GRAPHENE FLAGSHIP

Graphene Flagship partners and associated members produce a wide range of graphene products. Here are just a few:

Graphene films on wafer

- Produced by Chemical Vapor Deposition (CVD) allows for mass production.
- Used mainly in electronic applications
- High Electron Mobility graphene
- Already integrated in electronic devices production processes

Graphene Flagship partner Graphenea produces three sizes of graphene wafers at a scale of thousands per year:

	4000 8" wafers/year
	1000 6" wafers/year
	1000 4" wafers/year

Graphene Flakes

- Produced by several industrial exfoliation methods
- Available in bulk quantities
- High surface area material allows for low loadings
- Versatile material that can be used in composites, inks, energy storage, among others
- Available in powder format, dispersed in solvents and already dispersed in different matrices

In addition to wafers, Graphenea produces 250 tons of graphene oxide; graphene dispersed in a solvent, per year.



Graphite Electrodes

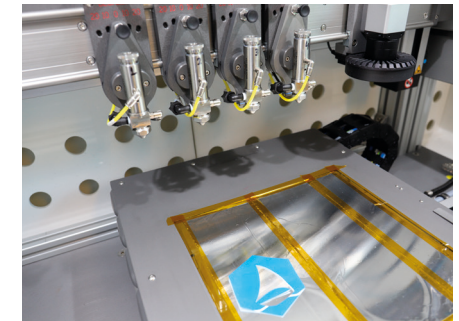
TALGA, a Graphene Flagship associated member, manufactures graphene products

- Graphene and other graphitic products are used in Li-ion battery anodes and cathodes
- Allow fast charging, high power, safer low temperature performance, corrosion protection of current collectors
- Si-enhanced anode material will increase Li-ion battery capacity in mWh/g
- Na-ion batteries are a potential future replacement for Li or lead acid batteries in cars

Graphene Inks

- Low-cost graphene inks can replace metal inks for printed circuits in a wide range of smart devices
- Flexible circuits and sensors will lead to the development of smart connections and the Internet of Things
- Graphene based inks give printed textiles added functionality of touch sensors and circuits

Graphene Flagship associated member GrapheneTech produces GraphInk, a non-toxic water-resistant paint which is conductive and can be used on a wide variety of materials.



Spray Deposition Machine

Through a collaboration fostered by the Graphene Flagship, partners Thales and M-SOLV have developed a Spray Deposition Machine.

- Used for the deposition of graphene-based materials for supercapacitor applications
- Spray deposition is an up and coming deposition technique in the battery and supercapacitor sector
- Versatility and large area capability allow electrodes and active materials to be deposited quickly over large areas
- By combining these with M-Solv's process capabilities, and combining laser, inkjet and spray deposition, a wide range of devices can be fabricated for energy storage