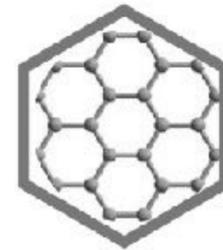


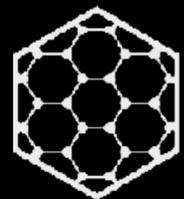
Graphene Commercialization Update

Presented by:



**The
Graphene
Council**





The Graphene Council

- **The largest and oldest trade body for the graphene sector**
- **Includes the entire value chain, from raw materials to end-users**
- **More than 30k material scientists from academia and commerce**
- **Partnerships with leading industry sectors connecting hundreds of thousands of engineers and product developers, world-wide**



Graphene Council Members

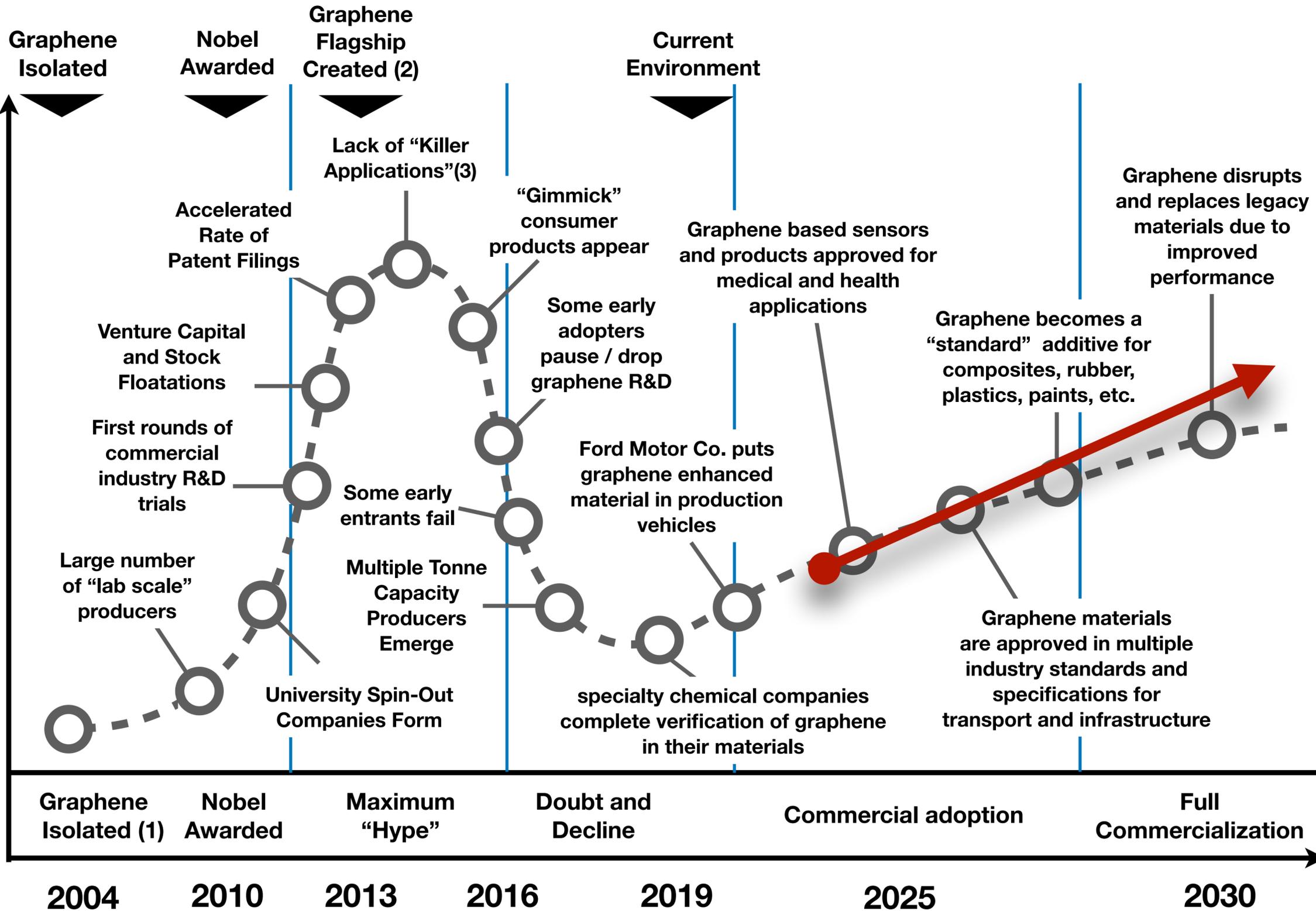


The Graphene "Hype Cycle"

1) "Electric Field Effect in Atomically Thin Carbon Films", K. S. Novoselov et. al, Science, Vol. 306, Issue 5696, pp. 666-669 (2004)

2) The Graphene Flagship is a 10 year, Euro 1 billion program sponsored by the European Union.

3) Focus was on the development of never before possible applications made entirely out of graphene, such as a "space elevator"



Note:

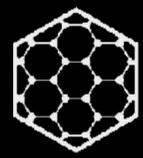
The evolution of a "hype cycle" is not uniform and is a gradual process where stages often overlap.

The dates indicated are based on our observations of the global graphene research and production environment.

Some geographic markets and industry sectors move faster than others and are therefore at different stages accordingly.

Source: The Graphene Council

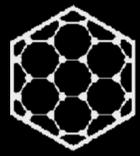




Graphene Production

- ❖ **TGC monitors nearly 300 companies that claim to produce graphene.**
- ❖ **Less than 100 companies are considered “Commercially Mature”.**
- ❖ **Of these, we have identified 70 that we feel are the most commercially mature and viable in the market.**
- ❖ **With the commissioning of their 4,000 mtn per annum automated facility in Canada, NanoXplore has the largest commercially operating production facility with plans to take it to 10,000 mtn pa.**
- ❖ **Collectively, production capacity for “bulk” or multi-layer graphene materials is approx. 9,000 - 10,000 mtn. per annum.**

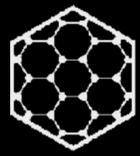




Graphene Production

-  **Graphene Production increasingly will use new production methods, including Laser Induced Graphene (LIG), Detonation, Flash Graphene, Bio-Fuel by-products, Petroleum Processing by-products, Steel Production by-products, etc.**
-  **New market entrants include HydroGraph, Tirupati Graphite, Ceylon Graphene Technologies, Green Lizard (bio-fuels) and Gerdau Graphene.**
-  **TGC has received queries from 4 different petroleum producers investigating how to produce graphene from oil distillates.**
-  **We have seen an increase of graphene companies enter into supply agreements with other producers/suppliers to reach new customers.**

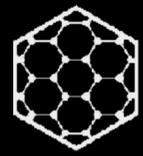




Graphene Production

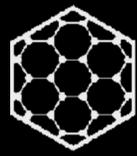
- ❖ **There have been several notable market transactions recently that indicate the graphene supplier landscape is maturing.**
- ❖ **Abalonyx, one of the earliest producers of Graphene Oxide, has been acquired by a group of private investors in Norway**
- ❖ **Garmor has been acquired by Asbury Carbons with the intent of increasing capacity.**
- ❖ **Mason Graphite and Thomas Swan created a new joint venture company, Black Swan, to become a new, high volume producer.**
- ❖ **NanoXplore and Martinrea have formed a joint venture to produce batteries that incorporate graphene materials.**





Industries and Graphene Applications





Commercial Applications & Market Forecasts

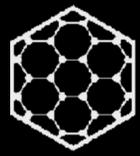
Application	Type of Graphene
Additive Manufacture (3D Printing)	Bulk
Aerospace	Bulk/Monolayer
Automotive	Bulk
Bio-Medical Applications	Bulk/Monolayer
Composites (Thermoplastics)	Bulk
Composites (Thermosets)	Bulk
Concrete and Cement	Bulk
Conductive Inks	Bulk
Corrosion Resistance	Bulk
Electronic Components	Monolayer
EMI/RFI Shielding	Bulk
Energy Generation	Bulk/Monolayer
Energy Storage (Batteries / Super Capacitors)	Bulk
Epoxies and Adhesives	Bulk
Films and Coatings	Bulk/Monolayer
Lubricants	Bulk
Magnets	Bulk
Medical Applications	Bulk/Monolayer
Nanoelectromechanical Systems NEMS	Monolayer
Optoelectronics	Monolayer

Application	Type of Graphene
Photodetector	Monolayer
Piezoelectric Effect	Monolayer
Plasmonics and Metamaterials	Monolayer
Plastics & Polymers	Bulk
Pressure Sensors	Monolayer
Quantum Computing	Monolayer
Rubber and Synthetics	Bulk
Semiconductors	Monolayer
Sensors	Monolayer
Sound Transducers	Bulk
Spintronics	Monolayer
Structural Materials	Bulk
Textiles and Fibers	Bulk
Thermal Management	Bulk
Touch Screens	Monolayer
Transistors	Monolayer
Transparent Conducting Electrodes	Monolayer
Water Filtration	Bulk/Monolayer
Waterproof Coating	Bulk
Wearables	Bulk/Monolayer

The markets where we are seeing the greatest commercial adoption and applications include:

-  **Energy Storage**
-  **Cement and Concrete**
-  **Coatings**
-  **Elastomers**
-  **Composites**
-  **Sensors and devices including bio-medical**





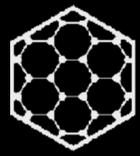
Graphene Accessible Markets

Graphene has been sufficiently tested and trialed to the point we know it is effective in applications that have been listed in the previous slide (cement, coatings, plastics, composites and energy storage), each of which is forecast to require more than 100,000 mtns of graphene per annum within the next 3-6 years.

Assuming regulatory approvals will be obtained, we can confidently forecast a global market demand for bulk graphene materials across the above set of applications in the range of **300k-700k mtns per annum within the next 3-6 years (by 2024 - 2027)***.

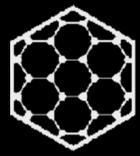
*Assumes ability to scale production at market acceptable price points.





Primary Obstacles to Adoption





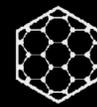
Graphene Commercial Trends

Over the past 10 years, the following challenges have emerged and at least in some cases, have been addressed;

- ❖ The ability to produce graphene materials, at least at lab scale (proof of concept production methods).
- ❖ Scale production from grams to kilograms.
- ❖ Batch to batch repeatability.
- ❖ Scale from pilot plant to commercial scale and tonne capacity.
- ❖ Identify markets and customers beyond universities and small R&D sales.
- ❖ Identify the right price / volume mix for profitability.
- ❖ Customer education (awareness, information, interest, evaluation, adoption).
- ❖ Increased regulatory scrutiny and requirements (e.g. REACH)
- ❖ Health and safety concerns (human exposure).
- ❖ Industry / Application adoption as a widely used material

Current status





Graphene Classification Framework

1. Production Method

2. Raw Material

3. Material Form

4. SP2 Bonded Carbon

5. Structural Defects

6. Layers of Carbon Atoms

7. Z-Axis Dimensions

8. Particle Shape

9. Lateral Particle Dimensions

10. Particle Aspect Ratio

11. Bulk Density (Tapped)

12. Elemental Composition

13. Oxygen Content

14. Impurities

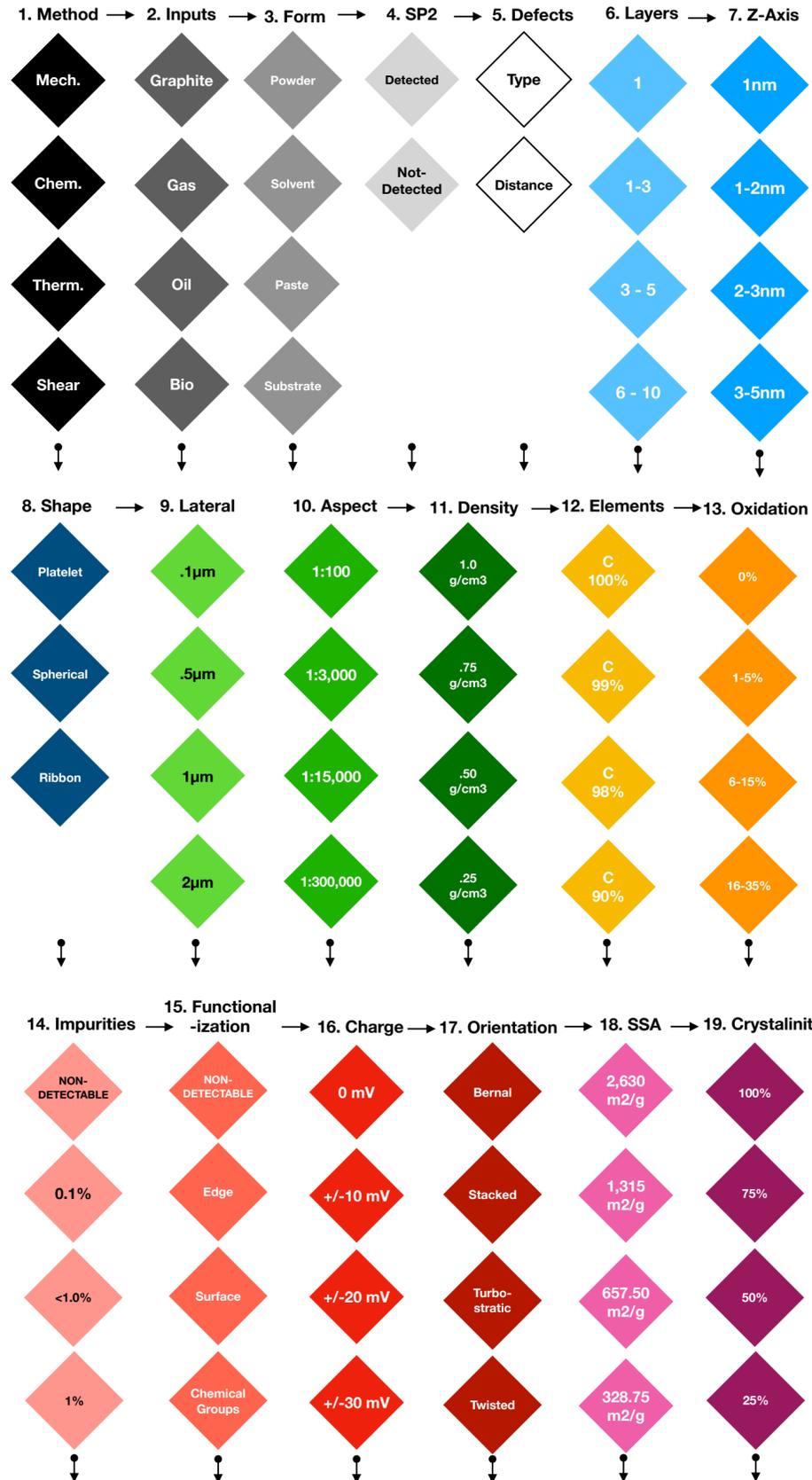
15. Functionalization

16. Surface Particle Charge

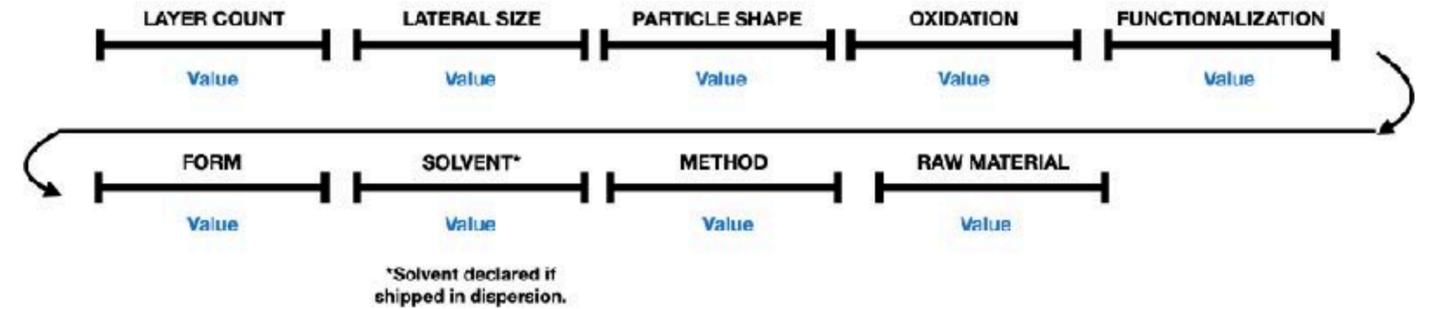
17. Orientation

18. Specific Surface Area

19. Crystallinity



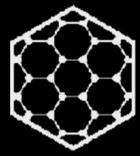
Syntax to Describe Graphene Types



NOTE: The intent of the syntax structure is to place a one sentence shorthand description for any given material in the "Description" section of the Technical Data Sheet. Additional detail may be given but every material description should include this minimum set of detail in this order.

Technical Data Sheet template

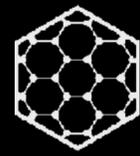
TECHNICAL DATA SHEET	
SUPPLIER	
CAS NUMBER	PRODUCT
ID NUMBER	TRADE NAME
PRODUCT DESCRIPTION	
PRODUCTION INFORMATION	
PRODUCTION METHOD	Other
RAW MATERIAL	Other
FORMS OF MATERIALS	Other (Master Batch, Pellet)
COMMENTS	
TEST	METHOD
SP2 Bonded Carbon	Escolher um item.
Structural Defects	Escolher um item.
Number of Layers	Escolher um item.
Dimensions	Escolher um item.
Shape and Form	Escolher um item.
Lateral Dimensions	Escolher um item.
Aspect Ratio	Escolher um item.
Bulk Density	Escolher um item.
Chemical/Elemental Composition	Escolher um item.
Oxygen Content	Escolher um item.
Impurities	Escolher um item.
Functionalization	Escolher um item.
Surface Particle Charge	Escolher um item.
Graphene Orientation	Escolher um item.
Specific Surface Area (SSA)	Escolher um item.
Crystallinity	Escolher um item.



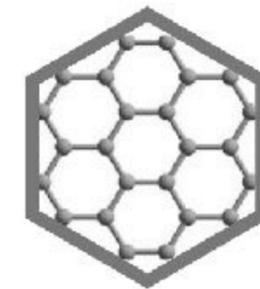
Graphene Commercialization Trends

- **New Market entrants** - As opposed to the small spinouts and entrepreneurs of the last 15 years, we see well funded new entrants to the market, often in tangent with other products (e.g. hydrogen production with graphene as a by-product).
- **Standards** - Graphene companies are already applying the Graphene Classification Framework to the testing of materials and updating their Technical Data Sheets.
- **Verified Graphene Producers** - We have seen strong interest in the Verified Graphene Producer program now that COVID-19 restrictions are lifting. We expect to have at least 4-5 companies verified by end of 2022.
- **Scale Up, Prices Down** - We have entered the phase of development whereby industrial quantities of material are being transacted (10's of metric tons per order). At the same, companies are developing more efficient methods of graphene production, reducing the direct cost to produce to under \$20/kg for certain forms of graphene.
- **Industrial R&D** - Major industrial companies including chemicals, petroleum, engineering, electronics, etc. have dedicated R&D departments working on incorporating graphene into physical products.





The Graphene Council



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