



The
Graphene
Council

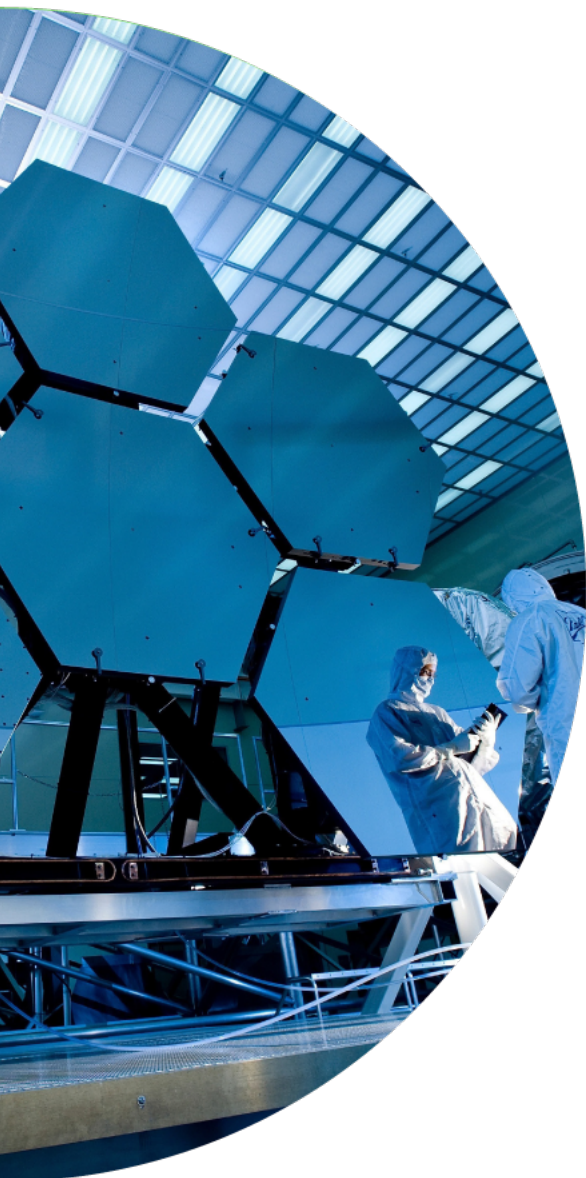
Graphene Classification & Standards

23 November 2023





The Graphene Council Represents the Global Graphene Sector



The
Largest
Trade Association

The largest independent organization championing the graphene industry, catalyzing opportunities, and powering growth.

The
Most
Trusted

The most comprehensive source of information on graphene research, development, and commercialization.

Over
35,000
Materials Professionals

The unified, unbiased voice that represents over 35,000 materials professionals worldwide who are engaged with graphene.

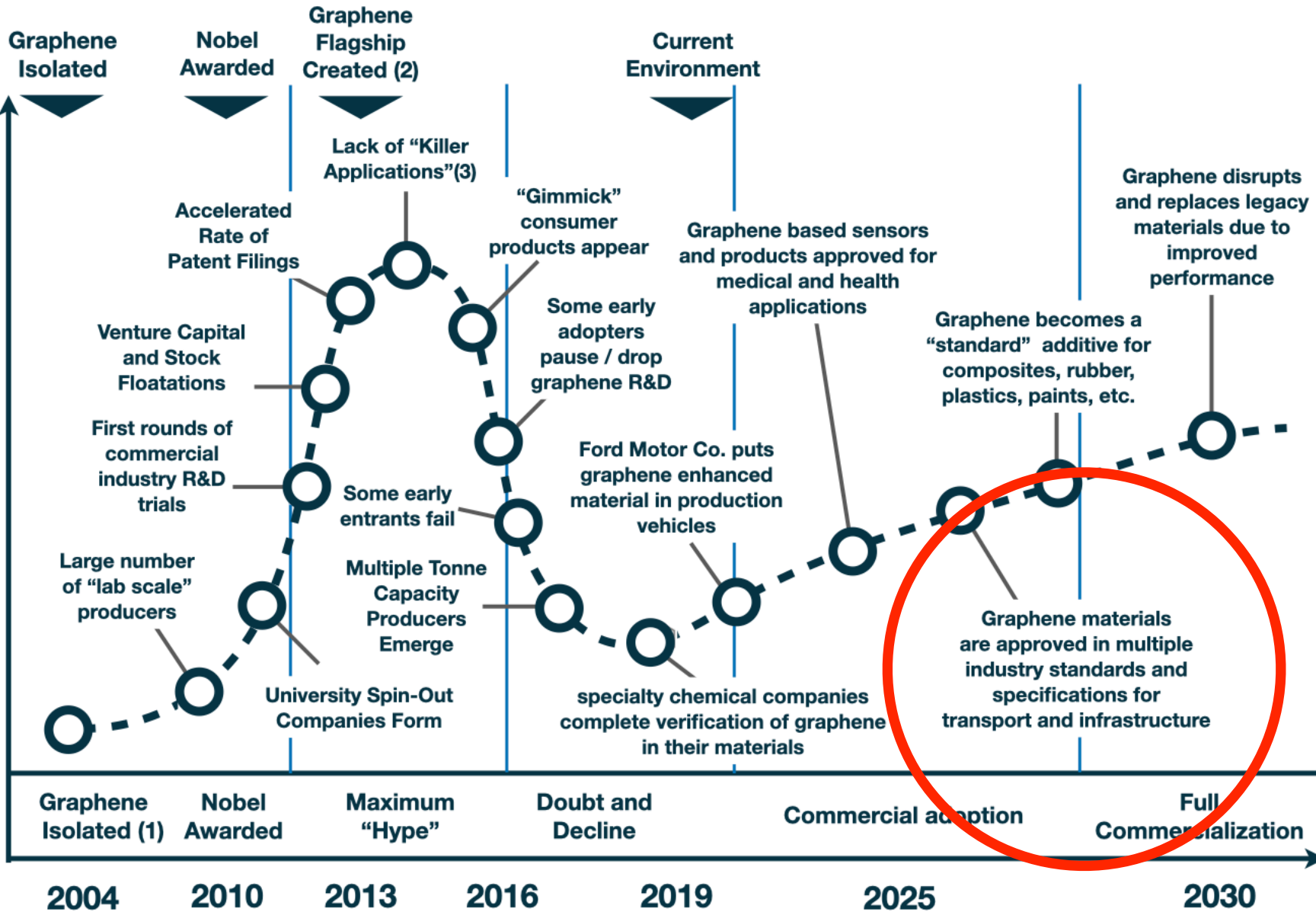


The Graphene "Hype Cycle"

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



Materializing the Future

Graphene applications are redefining and positively impacting almost every industry, laying the foundations for a low-carbon economy.

Application Areas for Graphene

Additive Manufacture

Aerospace

Automotive

Barrier Properties

Coatings

Composites

Concrete and Cement

Conductive Ink

Corrosion Resistance

Electrochemical

Electronics

Energy Generation

Energy Storage

Hall Effect Sensors

Lubricants

Magnets

Medical Applications

Optical Modulators

Opto Electronics

Photodetectors

Piezoelectric Devices

Plasmonics

Plastics

Polymers

Pressure Sensors

Opto Electronics

Photodetectors

Rubber and Synthetics

Semiconductors

Sound Transducers

Structural Materials

Thermal Management

Transistors

Touch Screens

Water Filtration

and much more...

Graphene Properties



Thermal Conductivity
Highest ever measured
at $\sim 4000 \text{ Wm}^{-1} \text{ K}^{-1}$



Strength
Graphene has a strength
of 130 GPa, higher
than steel



UV Resistance
Blocks harmful UV rays
by up to 70%



Electron Mobility
As high as 200,000
 $\text{cm}^2/\text{V}\cdot\text{s}$, much higher
than silicon



Electrical Resistance
Graphene electrical
resistivity of just
 $0.2 \times 10^{-6} \Omega \cdot \text{cm}$



Flame Resistant
Graphene significantly
reduces flammability if
added to polymers



High Surface Area
As much as 2,630 m^2/g ,
very high surface area



Flexibility
Graphene can stretch
up to 25% of its original
length



Transparent
Single layer graphene
transmits approximately
97.2% of light



Impermeability
Blocks all other elements,
even hydrogen

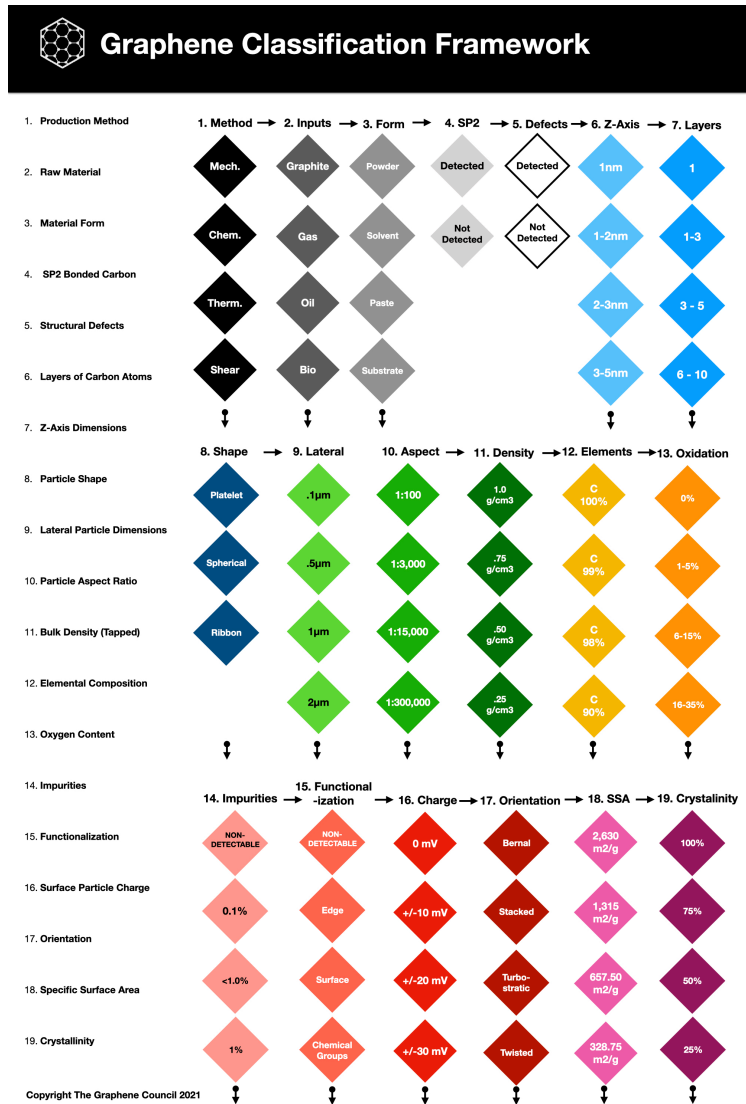


Thinness
A single layer of graphene
is just 0.345 nm



Stiffness
Young's modulus 0.95
to 1.1 TPa, some of the
highest ever measured

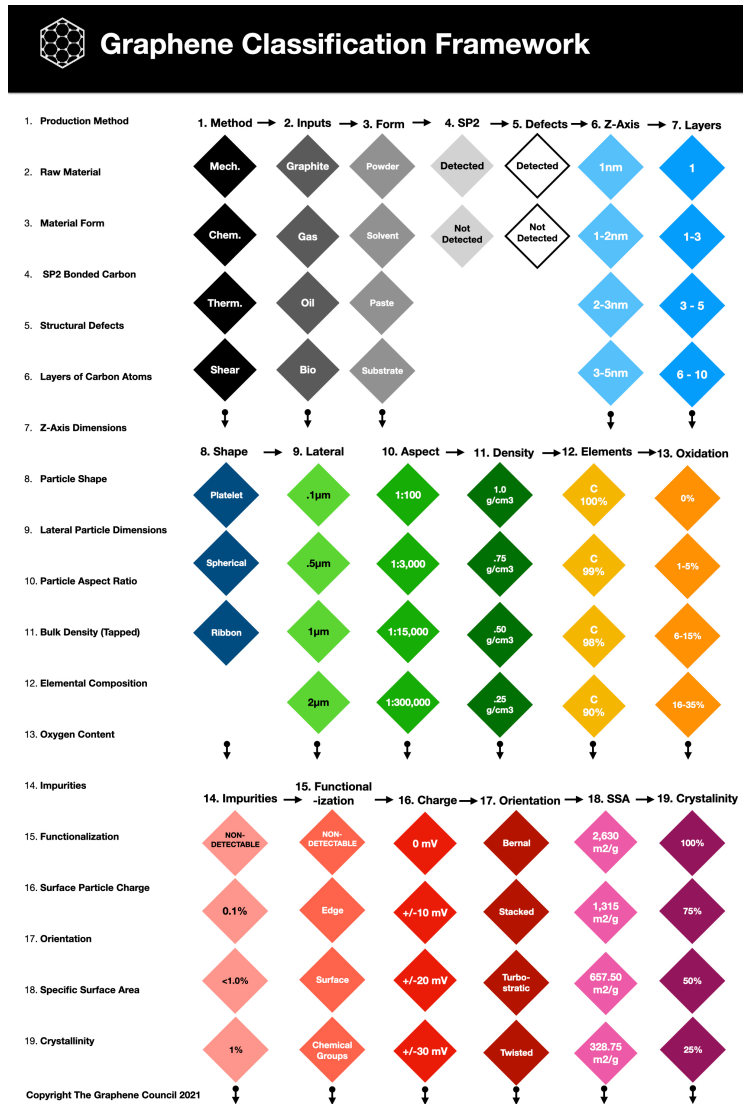
Graphene Classification Framework



It is imperative to systematically classify types or forms of graphene and related 2D materials so that;

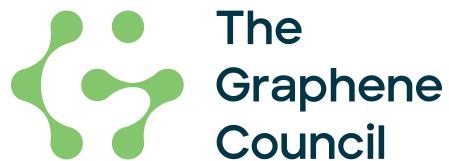
- the materials are regulated and registered in a consistent and predictable manner,
- producers / buyers can operate in a transparent, trusted market,
- bad actors and non-compliant materials are more easily identified.

Graphene Classification Framework



The **Graphene Classification Framework (GCF)** consists of;

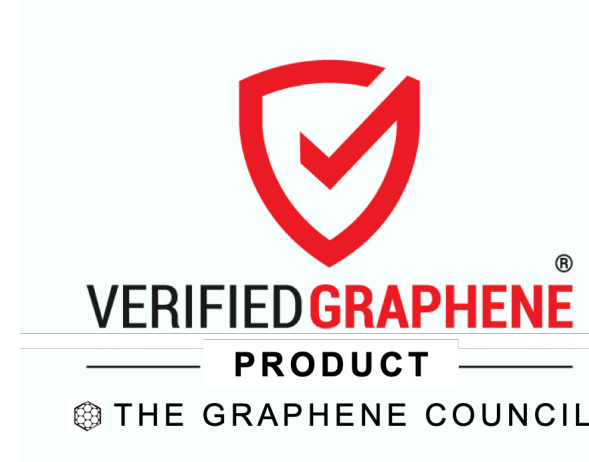
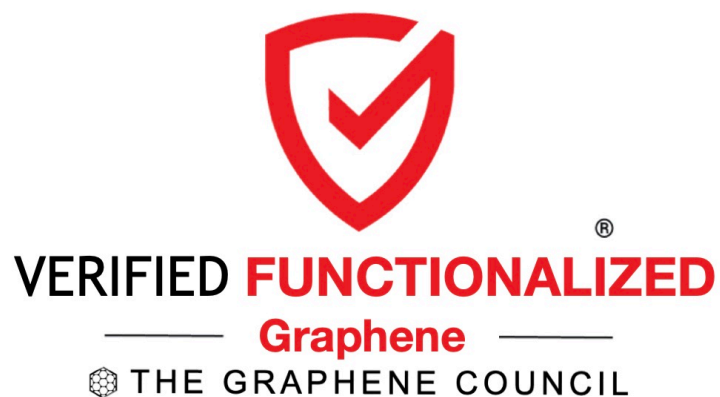
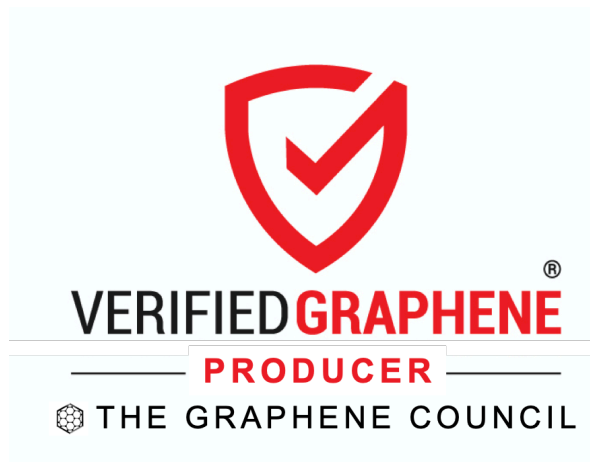
- List of material characteristics and properties that have been deemed most relevant for commercial use and application,
- Identification of the preferred method of testing for each of the material characteristics and properties identified in the GCF, and where applicable, acceptable alternative test methods,
- Where applicable, a range of measurement values for each of the material characteristics and properties that in turn may be used to define distinct types or forms of graphene materials,
- A syntax to be used for the consistent naming and description of different forms and types of graphene materials, and
- Template of a Technical Data Sheet that conforms to the GCF structure and format.

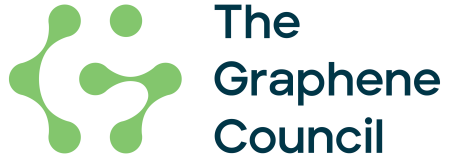


Graphene Verification Program

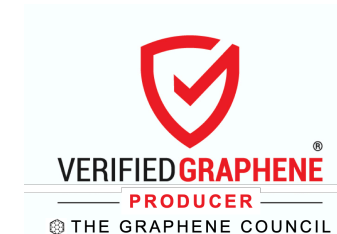
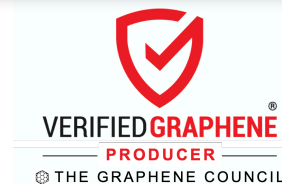
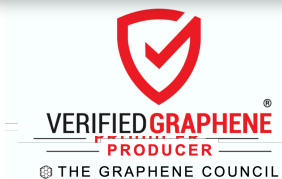
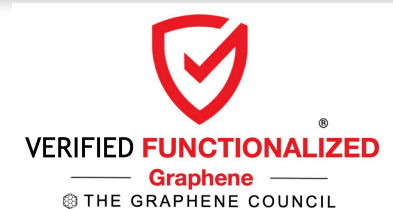
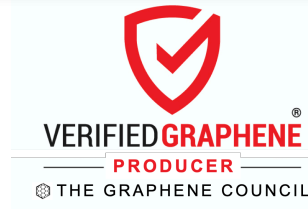
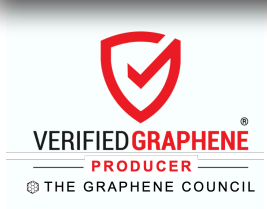
The only in-person inspection of graphene production facilities and processes.
Includes a detailed characterization of the material and products produced.

Exclusively administered by The Graphene Council world-wide
and based on international standards and best practices using
first class measurement laboratories and experts.





Verified Graphene Companies



Graphene Classification Framework

ISO/WD 9651

ISO TC 229/WG 4
Date: 2022-02-26

**ISO/WD 9651 Nanotechnologies –Classification framework for
graphene-related 2D materials**

Working Draft

The **Graphene Classification Framework (GCF)** has been provided (licensed) to ISO to convert into an official international standard.

Currently in the final stages of review by ISO TC 229 and Working Group form before being submitted for final balloting and publication in 1H 2024.

The Graphene Council in the meantime is already applying the principles and approaches through our material testing and characterization services, as well as our Verification Program.

Technical Data Sheet Inventory Project

SAMPLE TECHNICAL DATA SHEET

SUPPLIER	
COMPANY NAME AND CONTACT INFORMATION	
CAS NUMBER	PRODUCT
ID NUMBER	TRADE NAME

PRODUCT DESCRIPTION

USE SYNTAX FORMAT

PRODUCTION INFORMATION	
PRODUCTION METHOD	
RAW MATERIAL	
FORMS OF MATERIALS	
COMMENTS	

CHARACTERISTIC	TEST METHOD	VALUE (*D90)
SP2 Bonded Carbon		
Structural Defects		
Number of Layers		
Z-Axis Dimensions		
Primary Particle Shape		
Lateral Dimensions		
Aspect Ratio		
Tapped Bulk Density		
Chemical/Elemental Composition		
Oxygen Content %w		
Impurities %w		
Functionalization (type and %w)		
Surface Particle Charge		
Graphene Orientation	Only applicable to bi-layer up to 5 layer sheets	
Specific Surface Area (SSA)		
Crystallinity		

The Graphene Council and a group of volunteers has collected and categorized more than 500 Technical Data Sheets (TDS) for commercially available graphene and related 2D materials.

These TDS' will be grouped into different types and forms of graphene with similar characteristics (carbon layer count, chemical composition, primary particle morphology, etc.).

The intent is to develop a graphene material standard specification under ASTM so that engineers and users can specify a specific form of graphene.

This will make it easier to use graphene commercially.



The Graphene Sector is Driving a

Sustainable

Global

Transformation





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