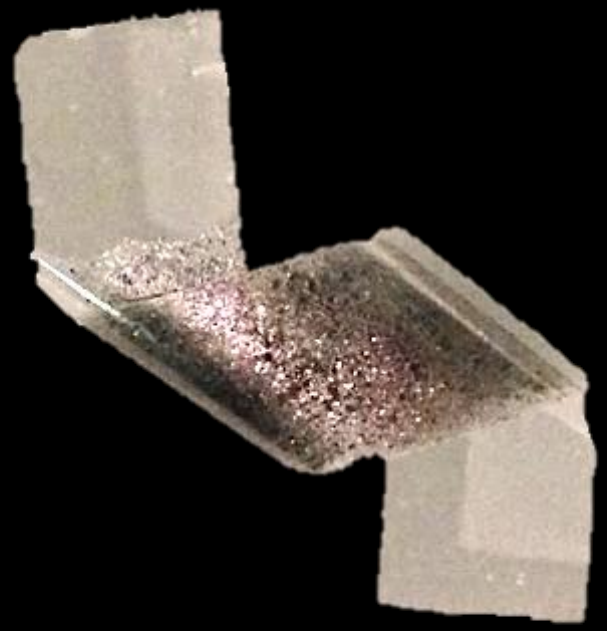
Nixene Publishing



Space Elevators
A Bridge to the Stars

U3A

21st May 2026

ISEC

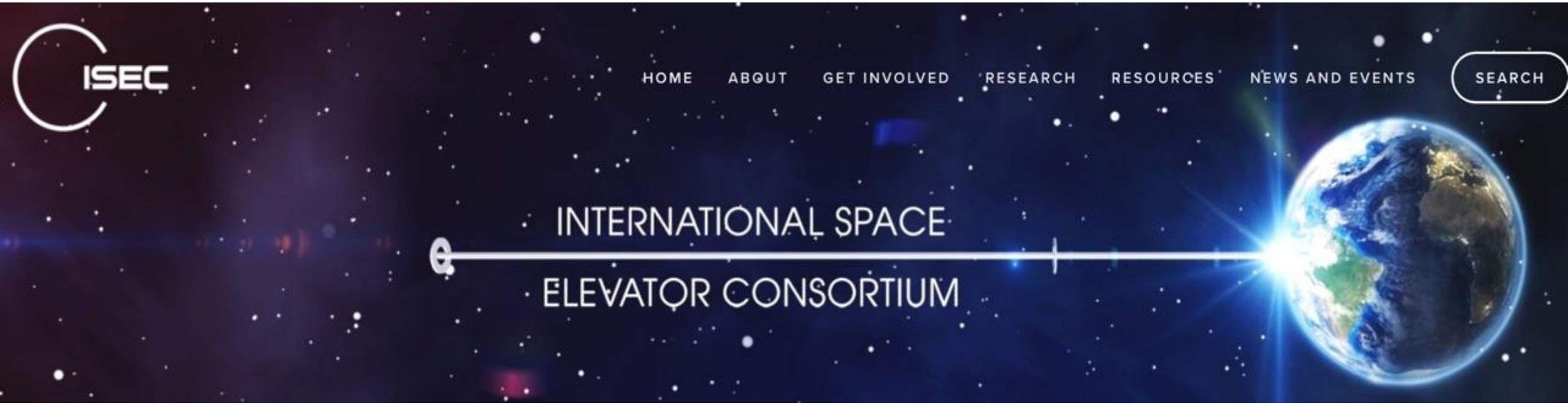
International Space Elevator Consortium

What we will talk about…

- Who we are
- Graphene the origin story: Impossible to Industrial
- Examples of graphene applications
- How rockets work and their limitations
- What is a space elevator and how it overcomes these limitations
- The state of the art in tethered lift manufacturing
- Could a space elevator really be built?

Who we are

International Space Elevator Consortium



An international not-for-profit organisation
based in California, USA
members worldwide

www.isec.org

About
WHAT WE DO
WHY SPACE ELEVATORS?
SPACE ELEVATOR 101 (VIDEO)
WHO WE ARE
SPACE ELEVATOR: WHAT IT IS AND WILL DO
TETHER MATERIALS
DUAL SPACE ACCESS ARCHITECTURE
TOP53
ELEVATOR TOP 5

International Space Elevator Consortium
Who We Are …

OFFICERS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President


Larry Bartoszek
Vice-President


Sandee Schaeffer
Treasurer


Martin Lades Ph.D
Secretary

DIRECTORS


Dan Gleeson


Steven Griggs Ph.D


John Knapman Ph.D


Adrian Nixon


Michael Schaeffer


Pete Swan Ph.D

Adrian Nixon

Editor
of the Nixene Journal

NixeneJournal

Member of the Royal Society of Chemistry and Chartered Chemist

ROYAL SOCIETY OF CHEMISTRY
Chartered Chemist

Over 30 years' experience in industry Technical Service, Industrial R&D, strategic level consulting

Member of the board of directors of the International Space Elevator Consortium (ISEC)

ISEC
International Space Elevator Consortium

The searchable database:

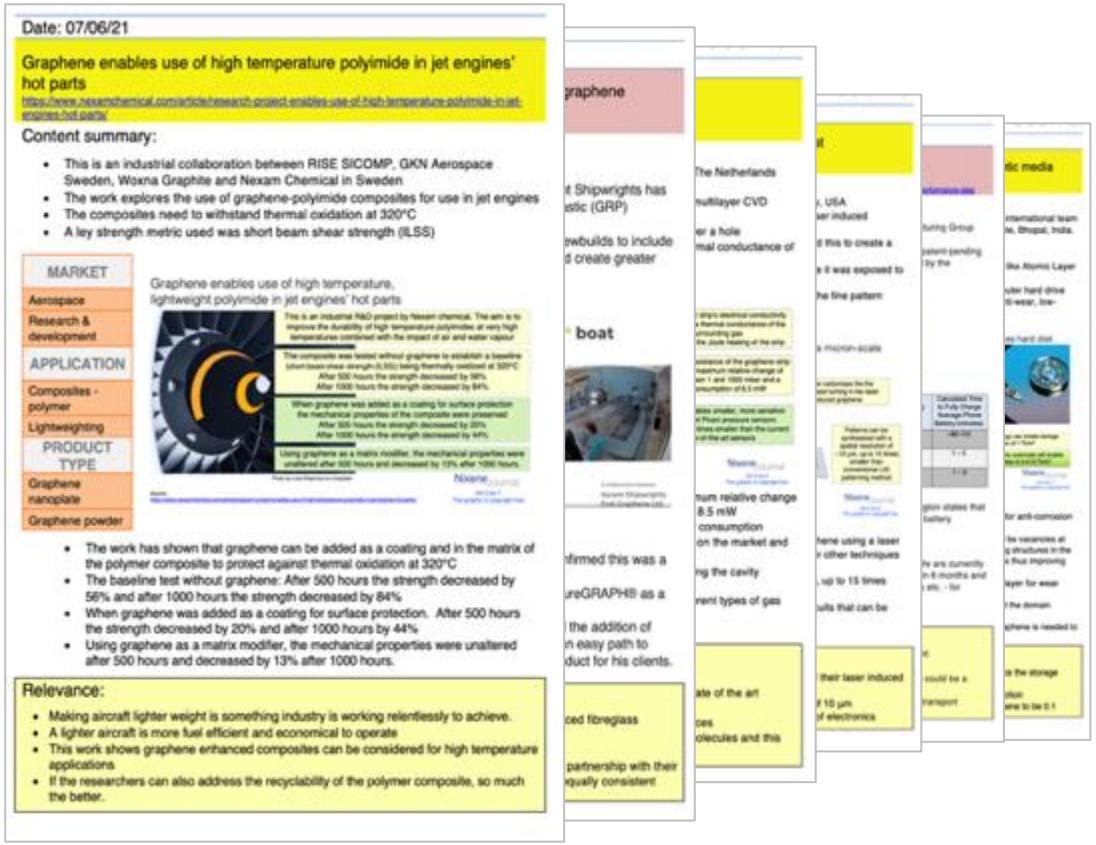
over two thousand pages of insight, and counting…

We have built an archive of structured content dedicated to graphene and 2D materials since 2017

Can be searched by any keyword:

Location
Application
Product type
Market segments

Our database returns knowledge rather than just data or information



Data, Information, Knowledge

NixeneJournal

Nixene Publishing is based at the Graphene Engineering Innovation Centre (GEIC), Manchester

The GEIC Masdar building. Image credit: Adrian Nixon

A world-class, multi-million-pound centre for industry-led development in graphene applications in partnership with academics.

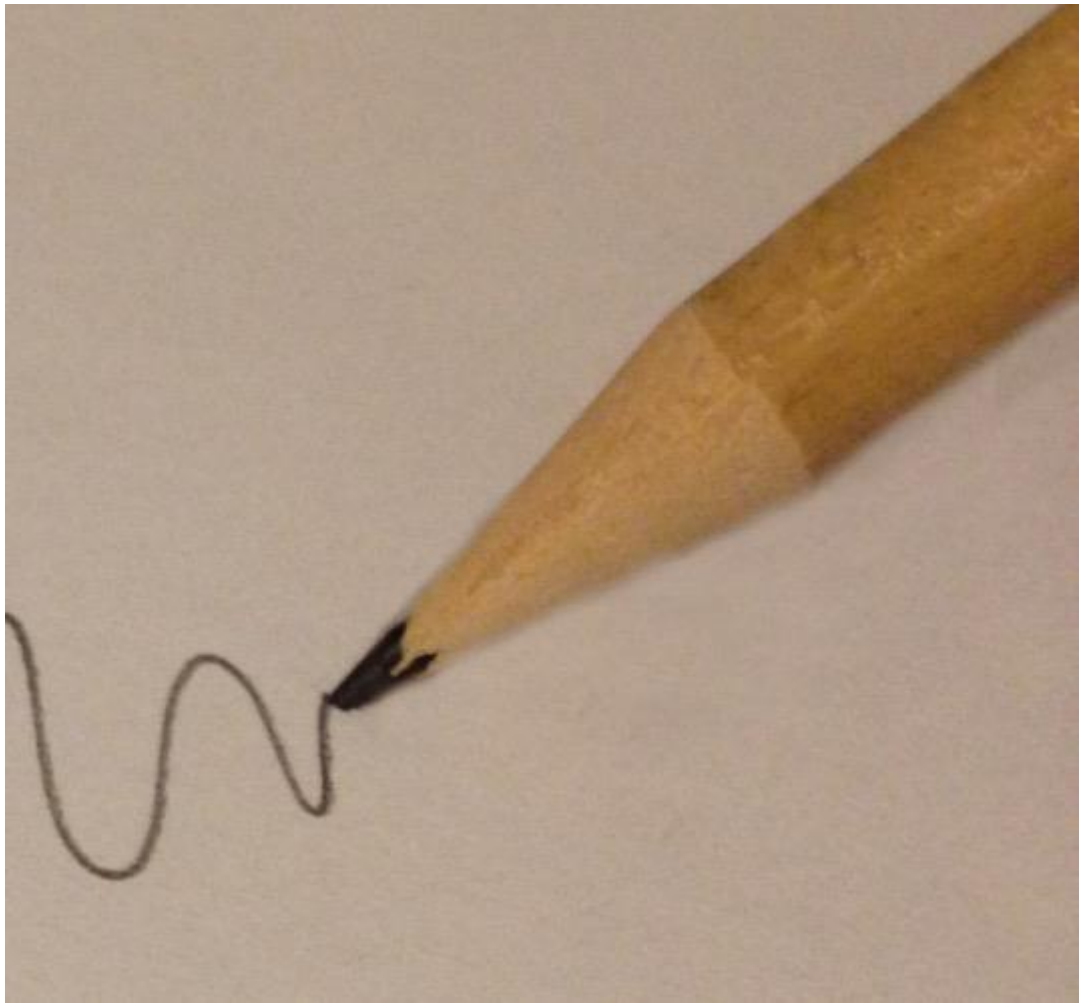
The GEIC specialises in the rapid development and scale up of graphene and other 2D materials applications

Nixene Publishing

Graphene: The origin story.

Impossible to Industrial

Pencils



Pencil line. Image credit: Adrian Nixon

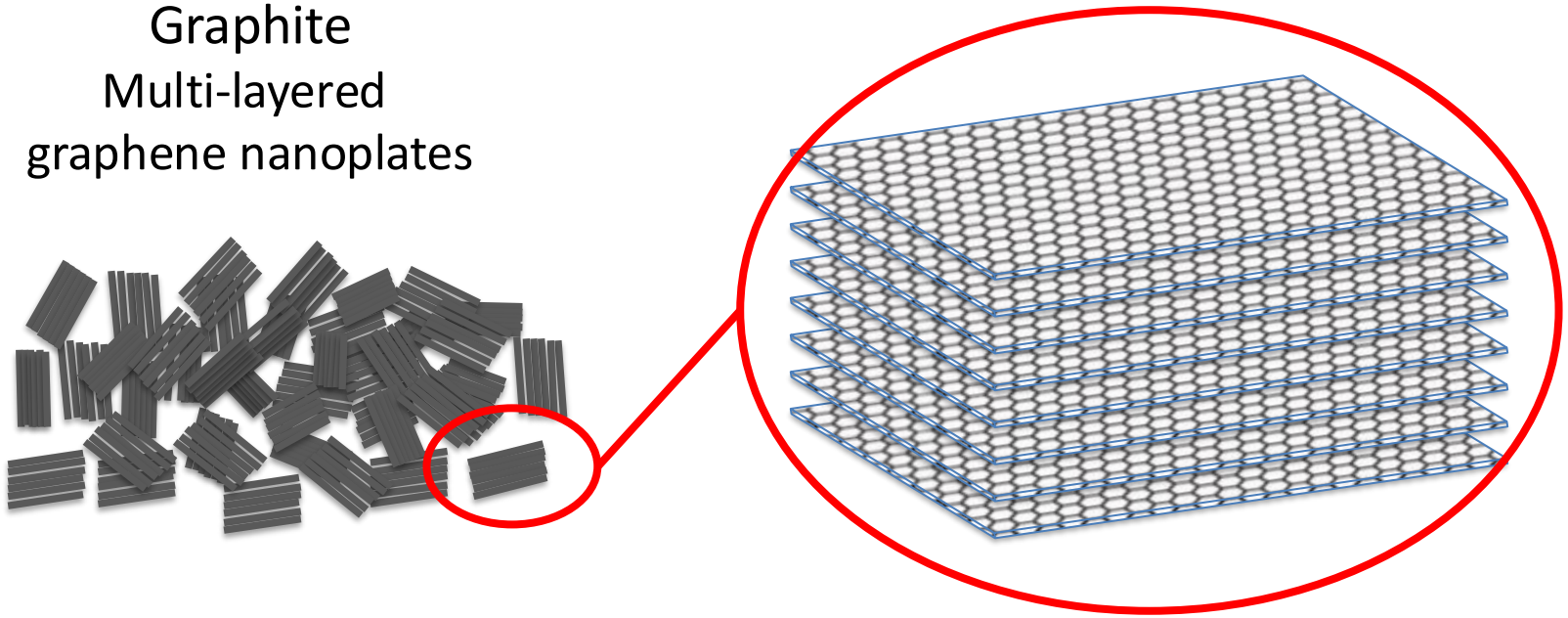
The part of a pencil that draws the line is called lead

It is not lead (Pb)

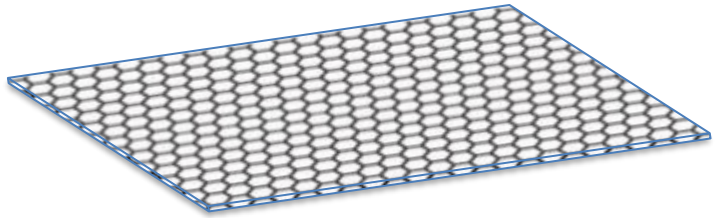
It is graphite

Graphite and Graphene

Graphite
Multi-layered
graphene nanoplates



Graphene
single atomic layer of carbon



Multilayer graphene exists in nature as graphite
The bulk material is made of jumbled stacks of nanoplates

Monolayer graphene is a
two-dimensional (2D) material

Sources:
Sachdeva, G. (2011). Graphene: The coolest material that shouldn't exist. Available at:
https://sitn.hms.harvard.edu/flash/2011/graphene-the-coolest-material-that-shouldnt-exist/ [Accessed 22 Nov. 2023].

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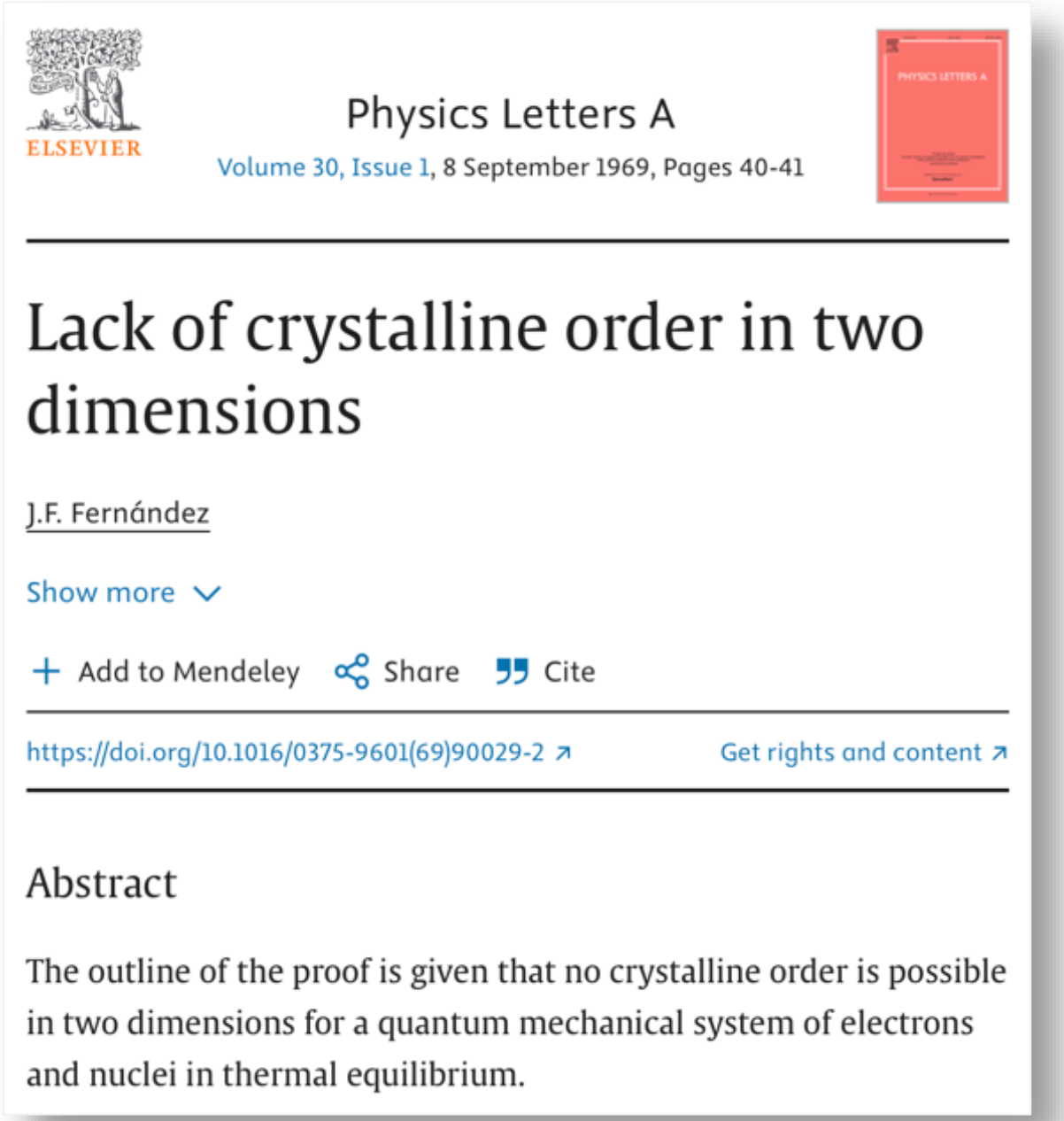
Graphene is a two-dimensional material:

Proved in 1969 it cannot exist

During the 20th century physicists argued convincingly that materials like graphene would be too thermodynamically unstable to exist

…So, nobody tried to isolate graphene



ELSEVIER

Physics Letters A

Volume 30, Issue 1, 8 September 1969, Pages 40-41

Lack of crystalline order in two dimensions

J.F. Fernández

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https://doi.org/10.1016/0375-9601(69)90029-2 ↗ Get rights and content ↗

Abstract

The outline of the proof is given that no crystalline order is possible in two dimensions for a quantum mechanical system of electrons and nuclei in thermal equilibrium.

Source:
Fernández, J.F. (1969). Lack of crystalline order in two dimensions. Physics Letters A, 30(1), pp.40–41. doi:https://doi.org/10.1016/0375-9601(69)90029-2.

Nixene Publishing

Nobel Prize in Physics 2010: Graphene
Pencils and scotch tape

Graphite

2004

Graphene isolated as world's first 2D material using sticky tape

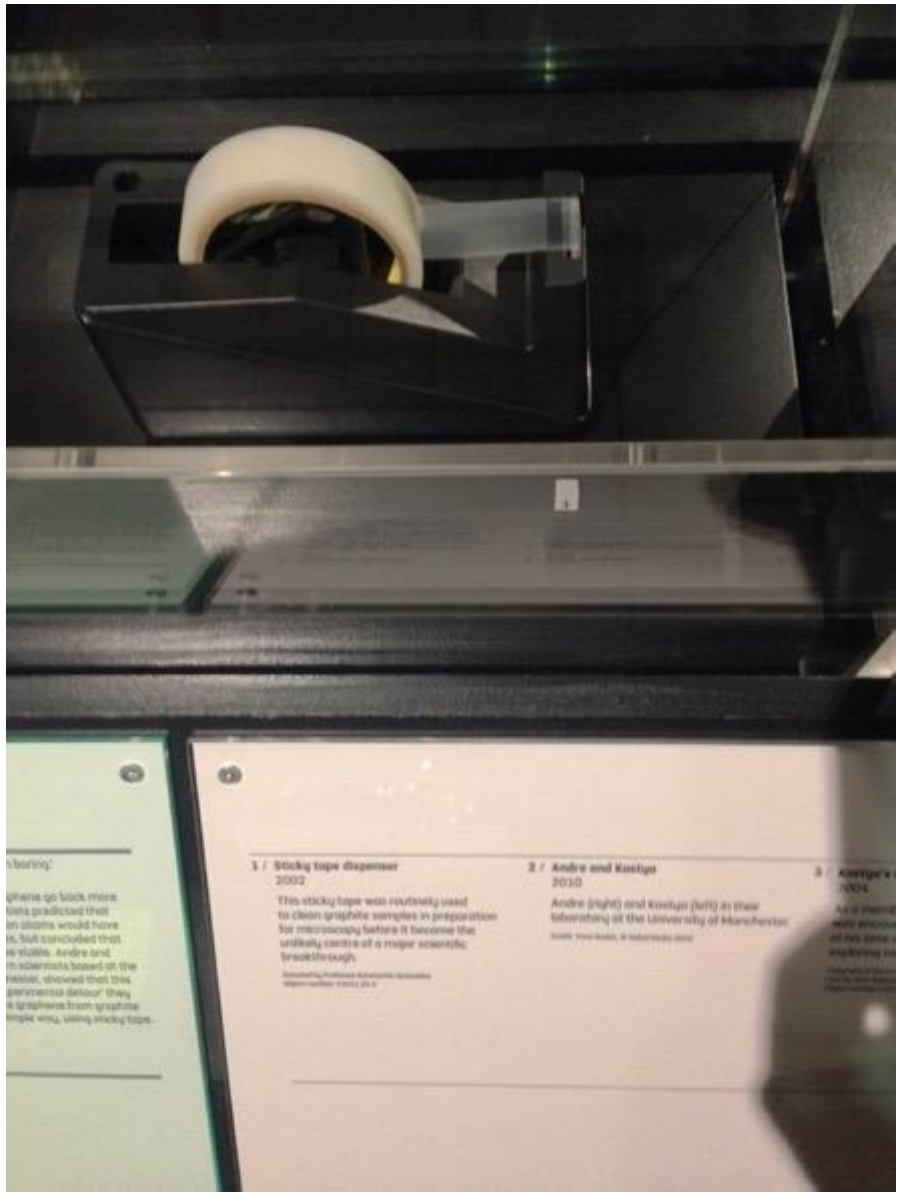
2010

Andre Geim & Konstantin Novoselov Win Nobel Prize

For preparing and characterising graphene

Nixene Publishing

Graphene: Sticky tape



1 / **Sticky tape dispenser**
2002

This sticky tape was routinely used to clean graphite samples in preparation for microscopy before it became the unlikely centre of a major scientific breakthrough.

Donated by Professor Konstantin Novoselov
Object number: Y2011.25.3

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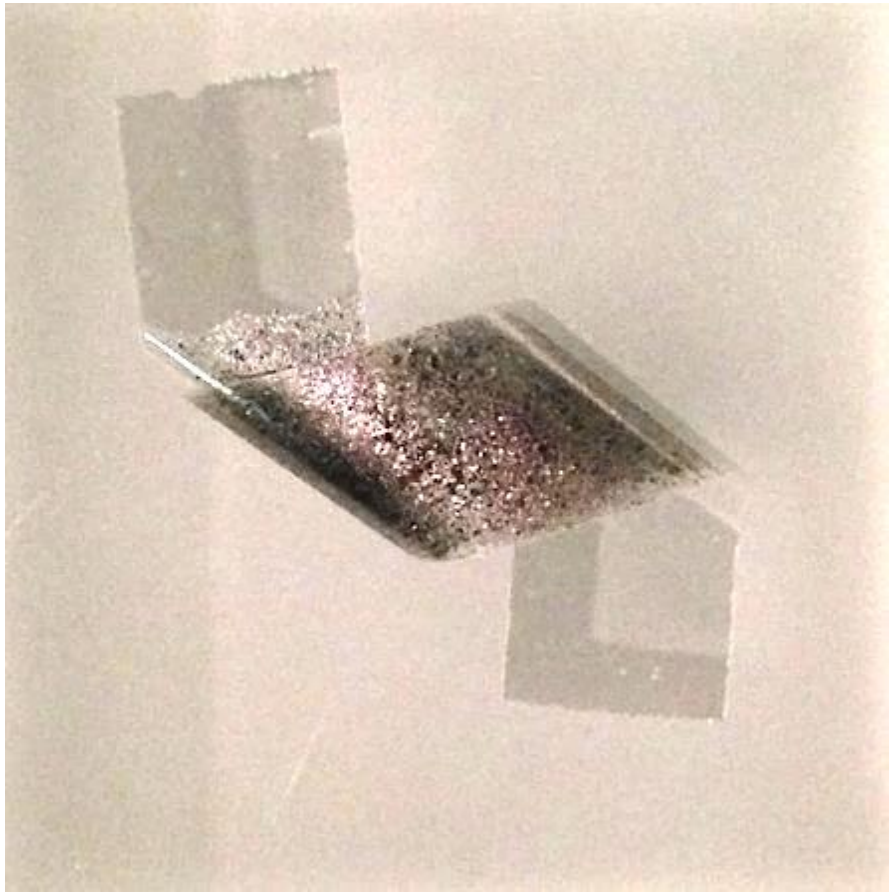
The impossible…



Scotch tape used for isolating graphene from graphite
Museum of Science and Industry at Manchester, UK
Image credit: Adrian Nixon

Everyone accepted the view that graphene was impossible to isolate from graphite

For years researchers have been using sticky tape to prepare graphite samples for electron microscopy work

'What those guys did not realise, was that throwing away the Scotch tape they were throwing away the Nobel Prize as well.'

Andre Geim

Highfield, R. (2015). *Secret of Scientific Creativity revealed by Andre Geim*. [online] Science Museum Blog. Available at: https://blog.sciencemuseum.org.uk/secret-of-scientific-creativity-revealed-by-andre-geim-godfather-of-graphene/ [Accessed 28 Oct. 2025].

Graphene: A two-dimensional (2D) form of carbon

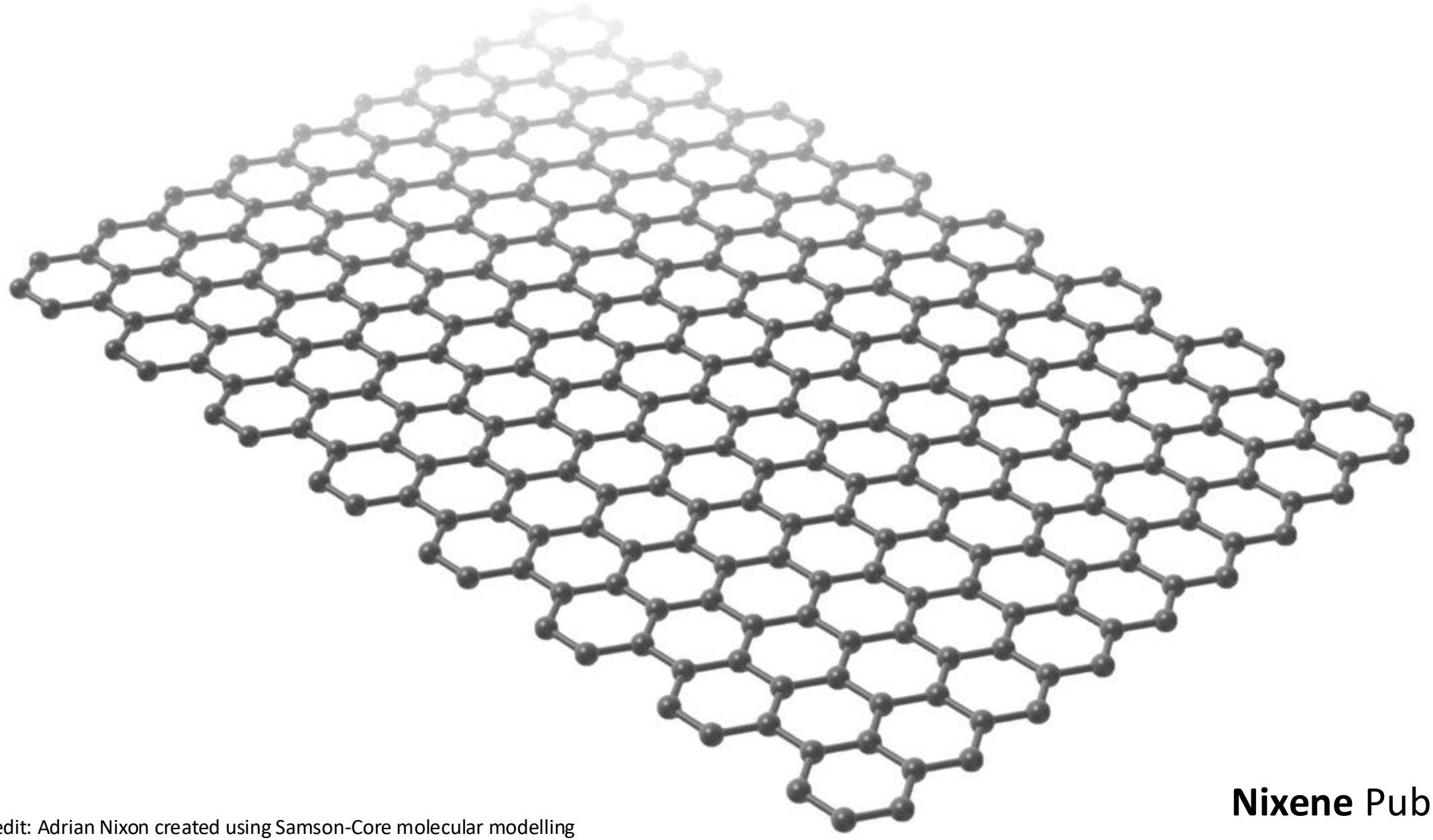
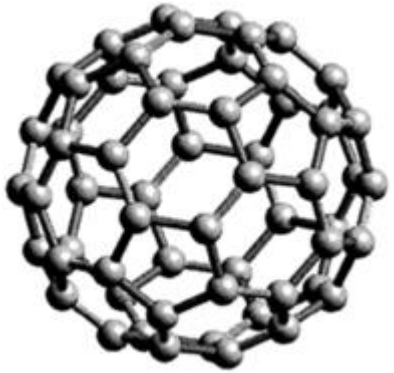


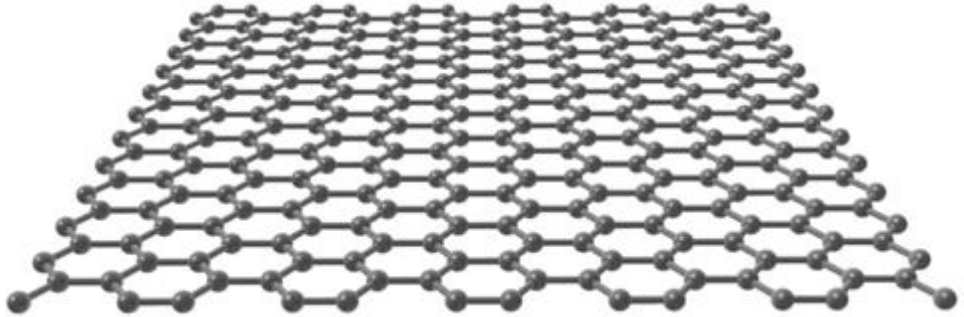
Image credit: Adrian Nixon created using Samson-Core molecular modelling

Nixene Publishing

Carbon Allotropes: Dimensions

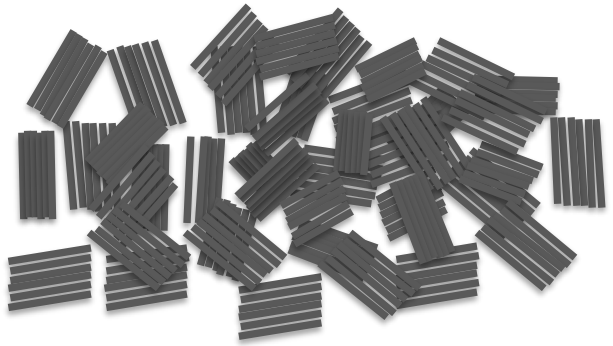


Fullerenes:
0D material

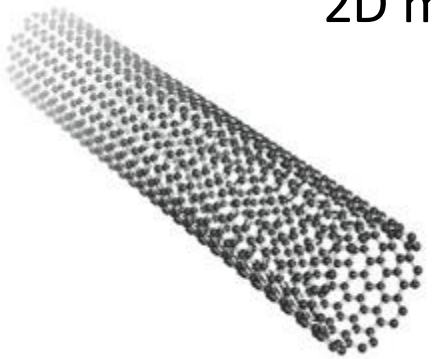


Graphene:
2D material

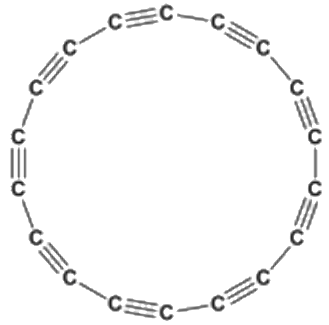
Amorphous Carbon:
range of materials with 1D 2D and 3D content



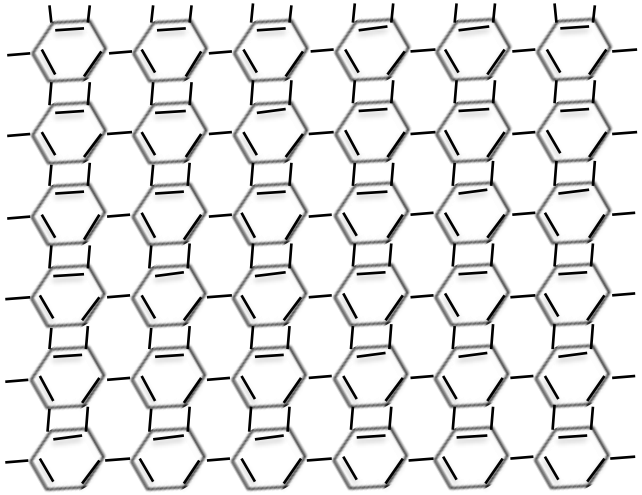
Graphite:
3D stacks of graphene



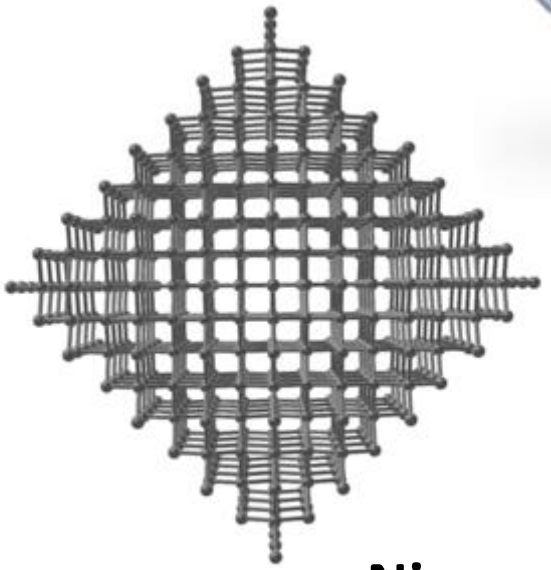
Carbon nanotubes:
1D material



Cyclocarbon:
0D material



Biphenylene Network
2D material



Diamond,
3D material

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Ten things to know about Graphene:
The new advanced material revolution

200 times
stronger than steel

Highest melting point of any
material in a vacuum

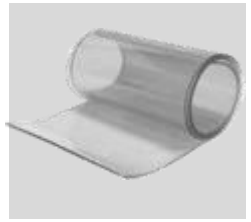
World's best
conductor of electricity

100 times more
tear resistant than steel

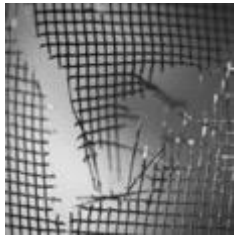
Very stable material
Non-toxic

One of the World's best
conductors of heat (hBN)

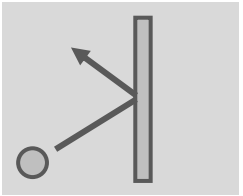
Flexible and
transparent



World's most
fatigue resistant material



World's most
impermeable material



Scratch resistant
to diamond

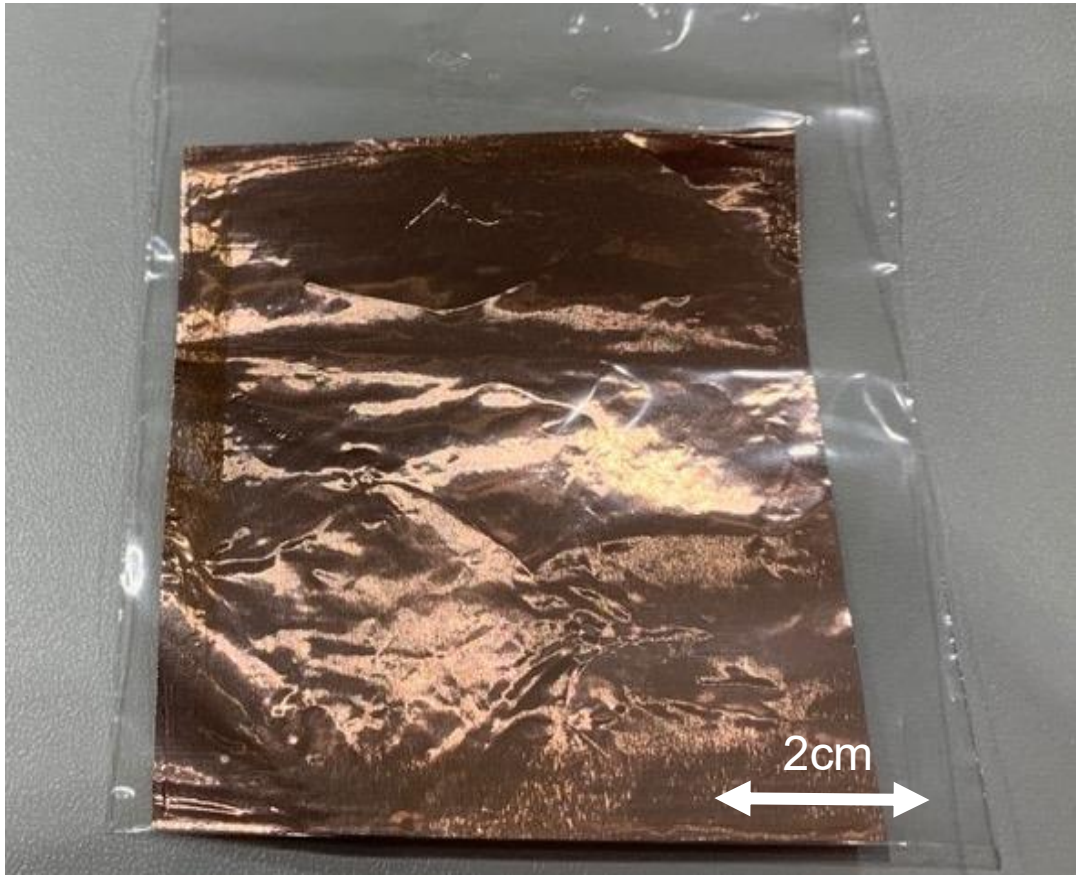
Source: https://www.nobelprize.org/uploads/2018/06/advanced-physicsprize2010.pdf

Graphene Powder and Sheet/ Film

Two types of graphene manufacturing

Graphene currently manufactured as powders

Commercial applications starting to evolve



Single layer film graphene on metal foil

Image credit Adrian Nixon

Sheet or Film graphene is a far higher value market

Defect free sheet graphene is the ideal graphene film and is called Single Crystal Graphene

Examples of graphene applications,

the industrial…

Graphene in consumer products

Ford cars

Graphene cooling systems in smart phones

Fireproof
lithium-ion batteries

Graphene membranes for earbuds

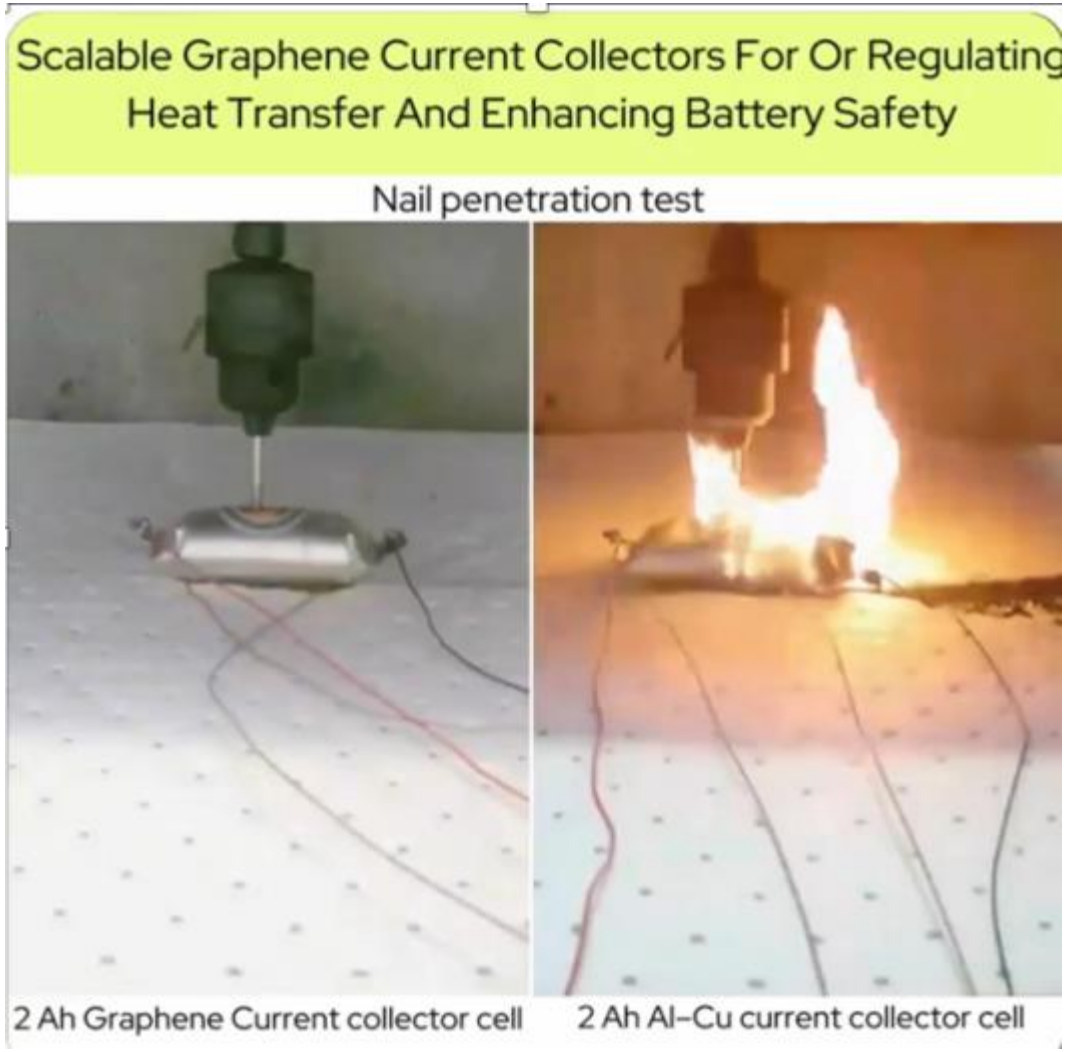
Graphene enhanced running shoes

Graphene enhanced tyres

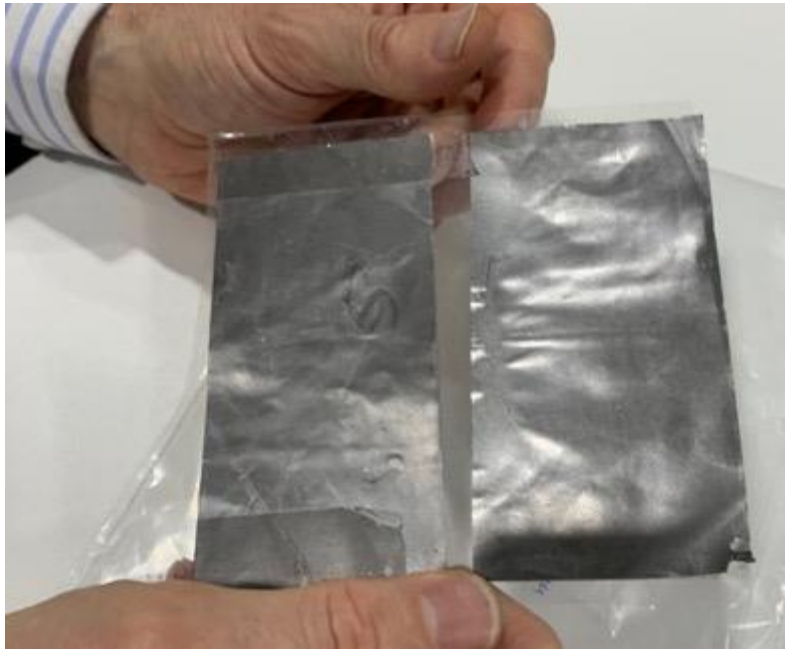
NixeneJournal

Paint-on wiring with conductive graphene ink

Roll-to-roll process for lithium-ion battery current collector made from graphene thermally conductive foil makes a safer battery



Working prototype pouch cells could be pierced with a nail without causing a fire
because the graphene foil conducted away the heat preventing a runaway chemical reaction



Source:
Li, L., Yang, J., Tan, R., Shu, W., CheeTong John Low, Zhang, Z., Zhao, Y., Li, C., Zhang, Y., Li, X., Zhang, H., Zhao, X., Kou, Z., Xiao, Y., Verpoort, F., Wang, H., Mai, L. and He, D. (2024). Large-scale current collectors for regulating heat transfer and enhancing battery safety. *Nature Chemical Engineering*, 1(8), pp.542–551. doi:https://doi.org/10.1038/s44286-024-00103-8.

Graphene in industrial products

Rubber tyres

Graphene asphalt Italy

Graphene asphalt UK

Graphene enhanced concrete

Graphene enhanced plastic packaging

Antifouling coatings for ships

0.01% graphene powder makes concrete 30% stronger

54 x14 metre mezzanine floor

The finishers could begin work while the pour was still taking place at the far end

Image credit: Concretene

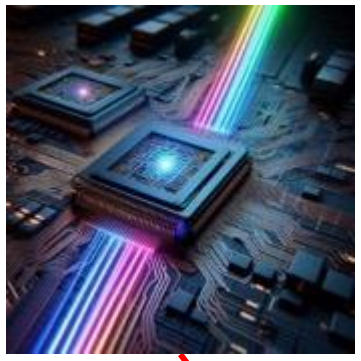
Normal concrete takes 28 days to achieve its strength

Graphene-enhanced Concretene achieves 28-day strength in 24 hours

Source:
Anon, 2021. *Secret sauce: how graphene lowers building costs and CO2*. [online] Secret sauce: how graphene lowers building costs and CO2. Available at: <https://www.manchester.ac.uk/discover/news/roller-disco-vs-climate-change--how-graphene-is-transforming-the-construction-industry/>

$1.3 billion invested in graphene applications 2020 to 2024

$10million
Graphene coatings
for tanker fleets
+3 to 4% fuel savings and
noise reduction
500 tonnes CO_2 saved
every day



$272 million
Graphene
interconnects
for photonic
computing

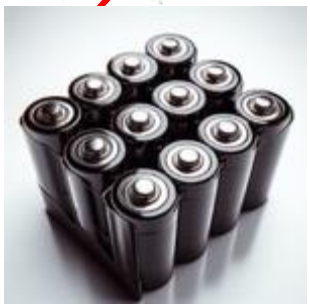
$245million
Graphene enhanced
supercapacitors for electric
KERS systems in public
transport

$10 million
Graphene
enhanced
concrete
30% stronger
2% global CO_2
reduction

$249million
Graphene enhanced
Li-ion batteries
faster charging and
non-flammable

$22million
Graphene enhance
Aluminium-ion
batteries for electr
vehicles and coolar

$410million
Graphene enhanced
Lithium Sulphur batteries
with 3x energy density of Li-
ion



$85 million
Graphene Hall sensors and field
effect biosensors

$24 million
Graphene
foam biosensors

$13.5 million
carbon capture and
hydrogen generation

Source:
Nixene Journal volumes 4 to 8

Nixene Publishing

There are now two Billion-dollar graphene companies

Image credit : CEO Magazine

Kjirstin Breure
HydroGraph Clean Power Inc,

$1.4 billion valuation

$1.7 billion valuation

Image credit : Adrian Nixon

Dr. Vivek Koncherry
Graphene Innovations Manchester (GIM)

Sources:
Nixon, A. (2025). Hydrograph becomes a billion-dollar graphene company. *Nixene Journal*, 9(11), p.31.
Nixon, A. (2025). GIM has achieved unicorn status as a billion-dollar graphene company *Nixene Journal*, 9(11), p.35.
https://digitalmag.theceomagazine.com/kjirstin-breure/?r=global

Dr. Vivek Koncherry's 24 carat gold waterless concrete floor tiles

Vivek has invented and patented a way of making waterless concrete from plastic waste using graphene

His GIM company will be making these special floor tiles with a coating of 24 carat gold here in Manchester at his new factory

Sources:
Koncherry, V. (2025). *GIM Black n Gold*. [online] Blackandgold.world. Available at: https://blackandgold.world [Accessed 10 Nov. 2025].

Nixene Publishing

There is so much more to tell you about graphene and other 2D materials

However, we must move on…

How rockets work and their limitations

Up Close Personal View of an Atlas 5 Launch

The rocket equation

$$\Delta v = ve \ln \frac{m_0}{mf} = I_{\mathrm{sp}}\, g_0 \ln \frac{m_0}{mf}$$

Where:

$v_e = I_{\mathrm{sp}}\, g_0$ is the effective exhaust velocity

I_{sp} is the specific impulse in dimension of time

g_0 is standard gravity

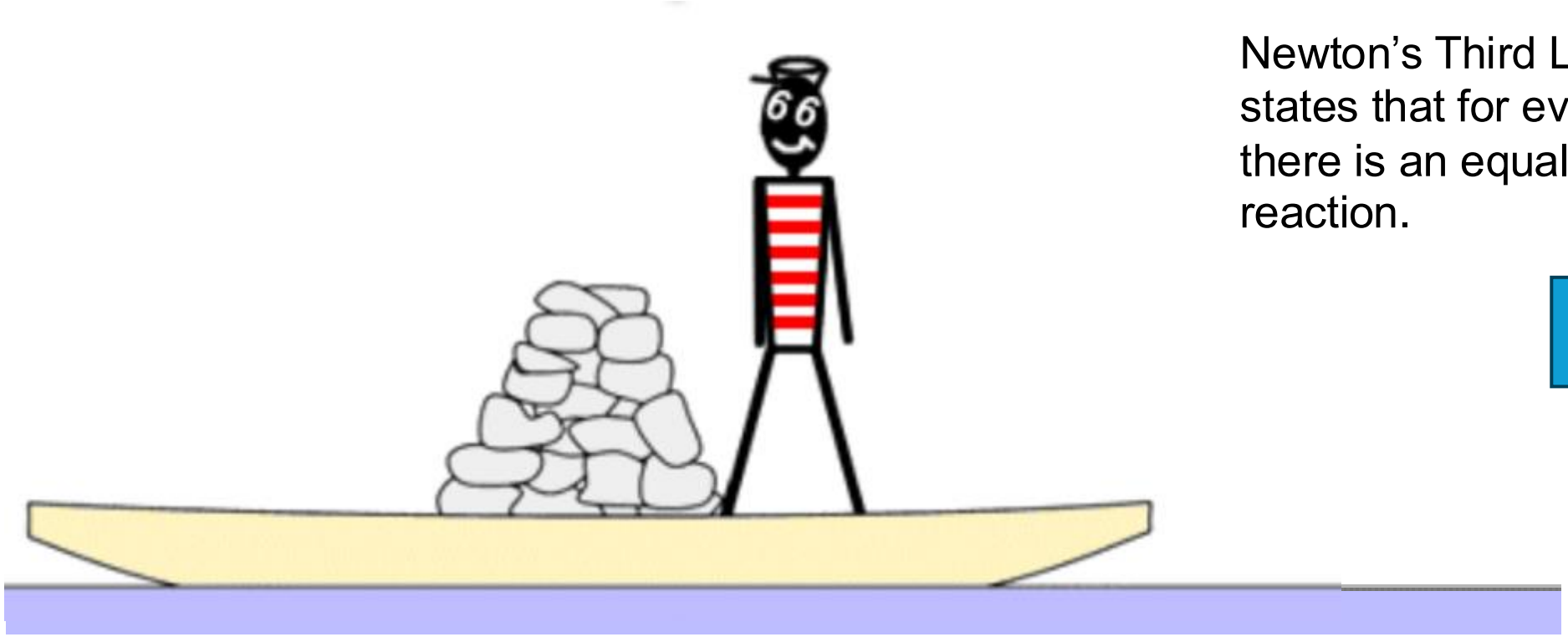
$\ln$ is the natural logarithm function

m_0 is the initial total mass, including propellant, a.k.a. wet mass

mf is the final total mass without propellant, a.k.a. dry mass

Another way of looking at the rocket equation. The boat experiment

Imagine you are in a boat away from the shore without oars.
You want to reach this shore.
You notice that the boat is loaded with a certain quantity of stones…



Newton's Third Law of Motion states that for every action, there is an equal and opposite reaction.

3 Laws

Source:
Konstantin Tsiolkovsky. 1903. The rocket equation https://en.wikipedia.org/wiki/Tsiolkovsky_rocket_equation

Rockets have limitations

Rockets are good for lifting people

But: Rockets have limited capacity

- 4% of launch pad mass gets to Low Earth Orbit (LEO)
- 2% of launch pad mass gets to Geostationary orbit (GEO)
- 0.5% of launch pad mass gets to the Moon and Mars
- Only 20,000 tonnes have been delivered to space: 1957 to 2020
- $^1/_2$ m tonnes required for moon base
- 1m tonnes required for Mars

Sustainability

In 2021 rockets put one million kg of black carbon pollution directly into the stratosphere

Sources:
[1] Swan, P., Swan, C., Phister, P., Dotson, D., Bernard-Cooper, J. and Molloy, B., 2022. *The Green Road to Space*. ISEC Position Paper # 2021-1. [online] Santa Ana: International Space Elevator Consortium.
[2] Maloney, C., Portmann, R., Ross, M. and Rosenlof, K., 2022. The Climate and Ozone Impacts of Black Carbon Emissions From Global Rocket Launches. *Journal of Geophysical Research: Atmospheres*, 127(12). https://doi.org/10.1029/2021JD036373

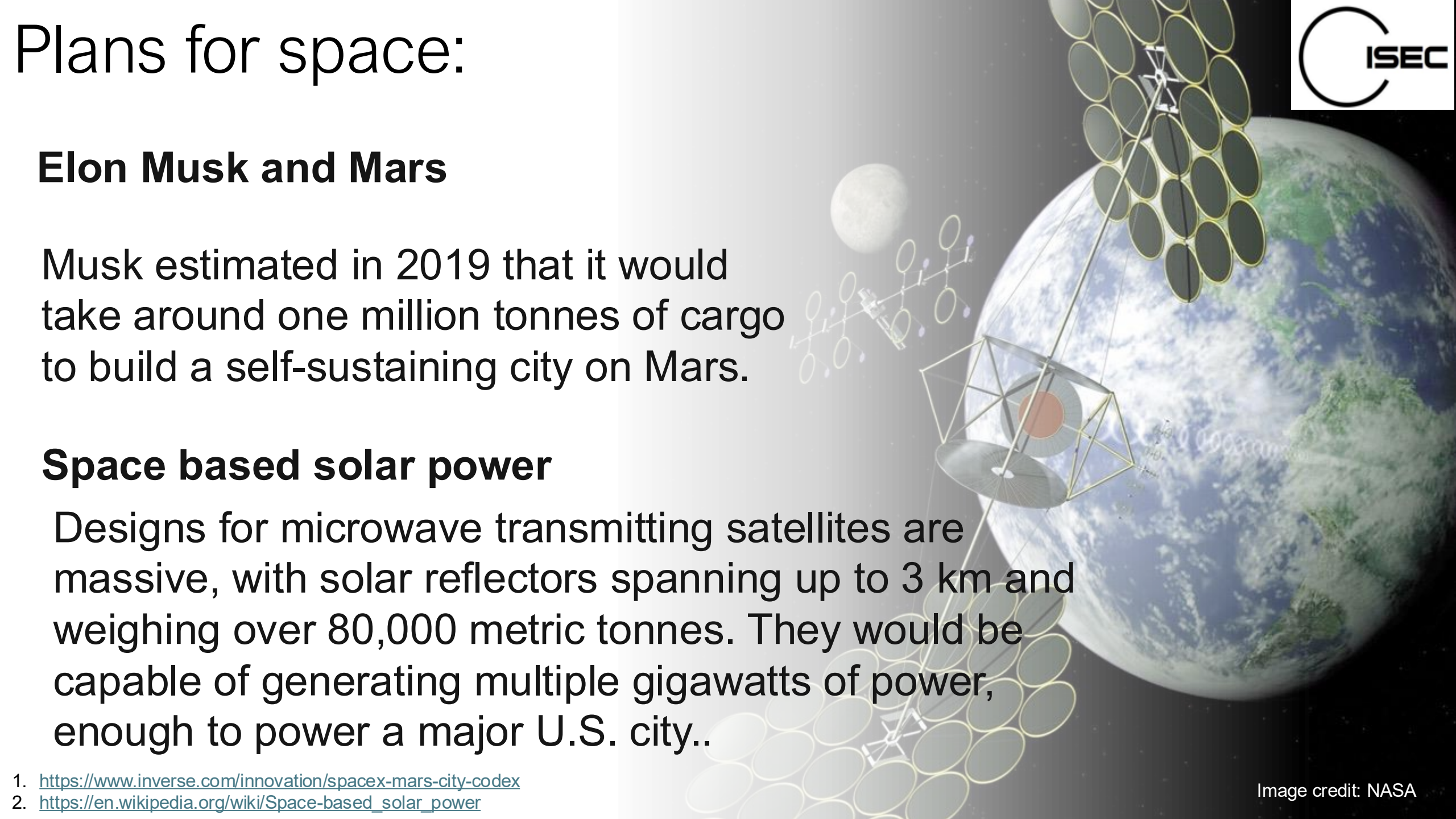
Plans for space:

Elon Musk and Mars

Musk estimated in 2019 that it would take around one million tonnes of cargo to build a self-sustaining city on Mars.

Space based solar power

Designs for microwave transmitting satellites are massive, with solar reflectors spanning up to 3 km and weighing over 80,000 metric tonnes. They would be capable of generating multiple gigawatts of power, enough to power a major U.S. city..



1. https://www.inverse.com/innovation/spacex-mars-city-codex
2. https://en.wikipedia.org/wiki/Space-based_solar_power

Image credit: NASA

Lifting large amounts of mass to space

In the history of rockets
from 1957 to 2020
only 20,000 tonnes of mass
has been lifted into space

Rockets cannot deliver the mass
needed for future planning

A space elevator can lift
more mass than rockets

1. https://www.linkedin.com/pulse/space-elevators-overview-part-3-international-space-elevator-conso/

Image credit: SpaceX

The Space Elevator

The Space Elevator idea spans 3 centuries

The 19th Century

- *Konstantin Tsiolkovski:* a tower reaching geosynchronous orbit first published in 1895

The 20th Century

- *Artsutanov, Yuri*. **1960**. V Kosmos na Elektrovoze, Komsomolskaya Pravda, contents described in Lvov 1967 Science 158:946 "*to the cosmos by electric train"*
- Jerome Pearson **1975**. "The Orbital Tower: A Spacecraft Launcher Using the Earth's Rotational Energy" Acta Astronautica. Vol. 2. pp. 785-799. Pergamon Press 1975
- *Clarke, A.C*. **1979**. The Space Elevator: 'Thought Experiment', or Key to the Universe. Adv. Earth Oriented Appl. Science Techn. 1:39

The 21st Century

- **2011** ISEC "*Appears Technically Feasible*"
- **2023** Current status "*Ready to start development*

Konstantin Tsiolkovsky 1857 - 1935

$$\Delta v = v_e \ln \frac{m_0}{mf} = I_{sp}\, g_0 \ln \frac{m_0}{mf}$$

As well as defining the rocket equation, Tsiolkovsky was the first to think about alternative ways of accessing space

Konstantin Tsiolkovsky saw the Eiffel Tower and thought of keeping going...

He proposed a tower reaching geosynchronous orbit first published in 1895

Space Elevator Inventor [1]

Yuri Artsutanov (1929-2019)

born in Leningrad : a graduate of Leningrad Technological Institute

"в космос на электровозе"
Komsomolskaya Pravda, 31 July 1960
(English translation "Into the cosmos by electric train" by Vladimir Lvov in Science, Vol 158, Issue 3803, pp 946-947, 1967)

Described the basic concept of the Earth Space Elevator

Space Elevator Inventor [2]

Jerome Pearson (1938-2021)

ELSEVIER

Acta Astronautica

Volume 2, Issues 9–10, September–October 1975, Pages 785-799

The orbital tower: A spacecraft launcher using the Earth's rotational energy

Jerome Pearson

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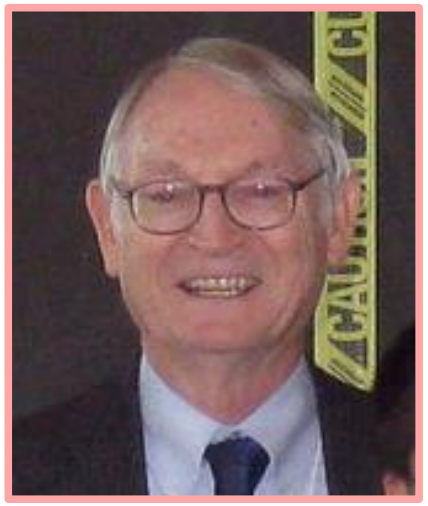
https://doi.org/10.1016/0094-5765(75)90021-1 Get rights and content

Abstract

The theoretical possibility is examined of constructing a tower to connect a geostationary satellite to the ground. The "orbital tower" could be built only by overcoming the three problems of buckling, strength, and dynamic stability. The buckling problem could be solved by building the tower outward from the geostationary point so that it remains balanced in tension and stabilized by the gravity gradient until the lower end touches the Earth and the upper end reaches 144,000 km altitude. The strength problem could be solved by tapering the cross-sectional area of the tower as an exponential function of the gravitational and inertial forces, from a maximum at the geostationary point to a minimum at the ends. The strength requirements are extremely demanding, but the required strength-to-weight ratio is theoretically available in perfect-crystal whiskers of graphite. The dynamic stability is investigated and the tower is found to stable under the vertical forces of lunar tidal excitations and under the lateral forces due to payloads



"The Orbital Tower: A Spacecraft Launcher Using the Earth's Rotational Energy",
Acta Astronautica Vol. 2, pp. 785–799, Sep/Oct 1975

Presented at the 27th IAC
in Anaheim, California (10-16 October 1976)

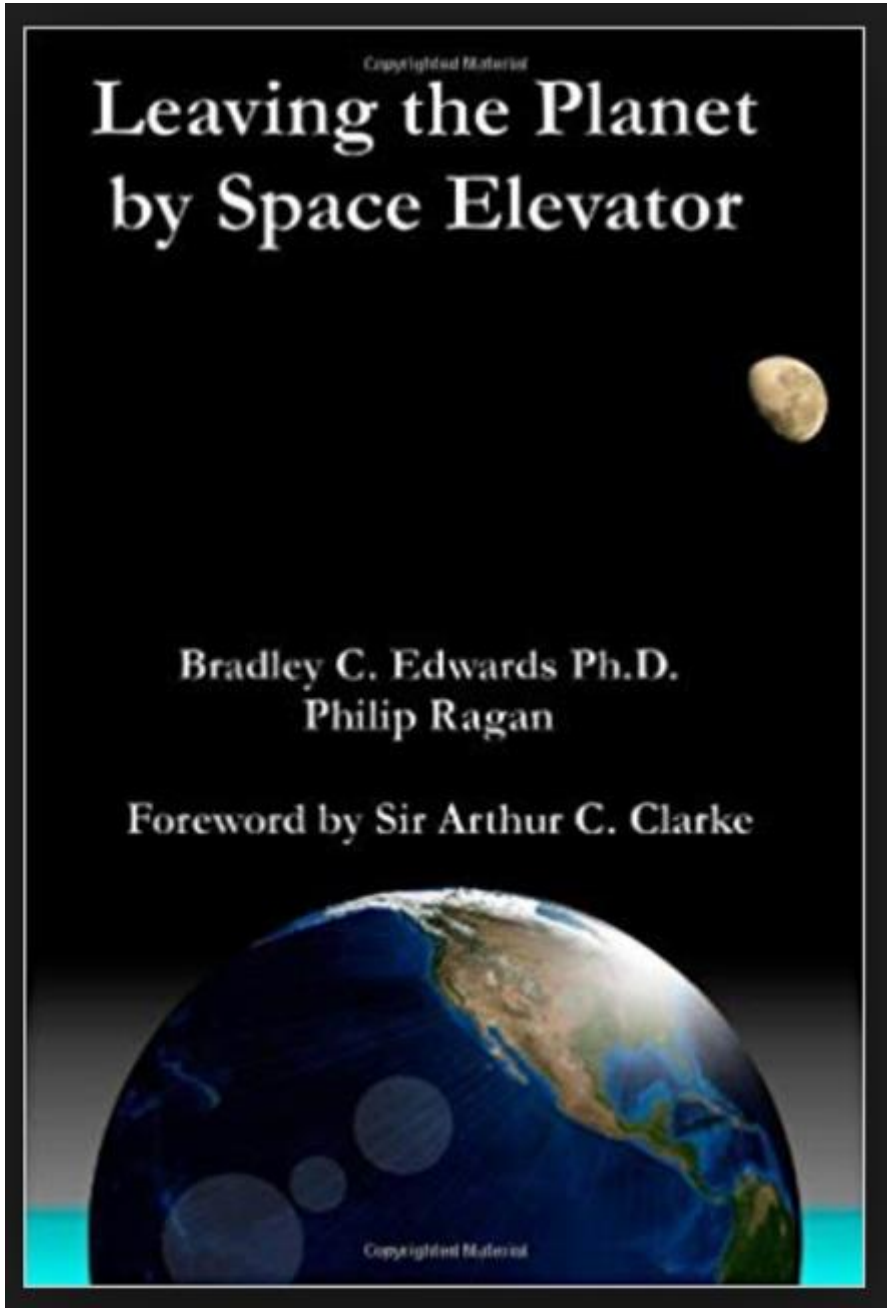
Detailed mathematical analysis

Is the space elevator feasible?

In 2000 NASA's Institute for Advanced Concepts NIAC Commissioned Dr. Bradley C Edwards to examine the reality of the space elevator

He reported phase 1 in Oct 2000
Phase 2 in March 2003

Asked is this do-able with today's technology?
Answer, **Yes** – Apart from one thing…



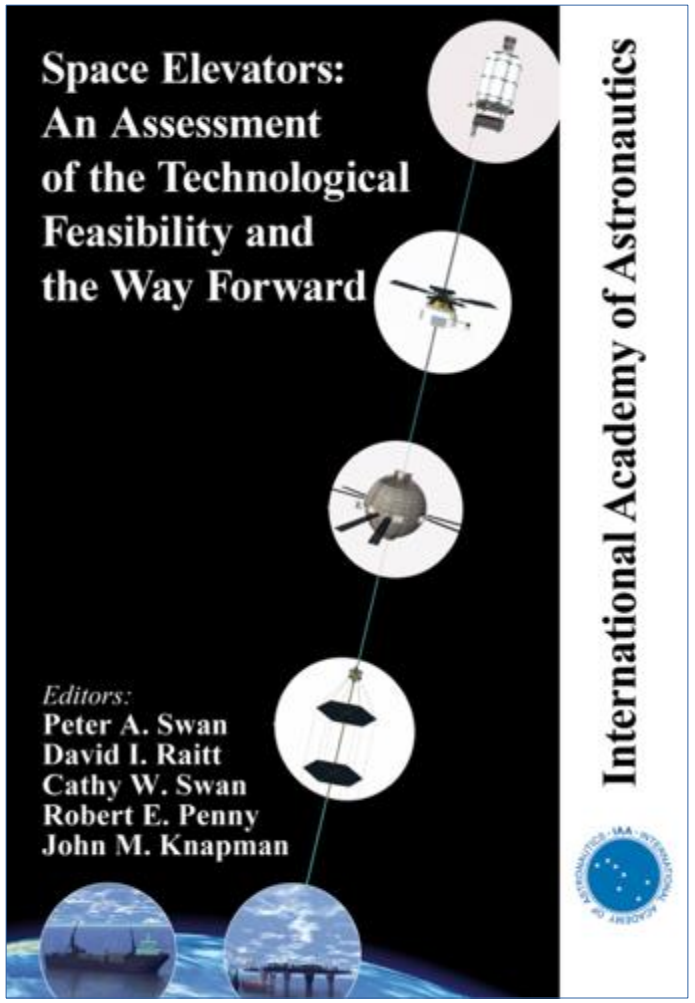
https://en.wikipedia.org/wiki/Bradley_C._Edwards

https://www.amazon.co.uk/Space-Elevators-Assessment-Technological-Feasibility/dp/2917761318

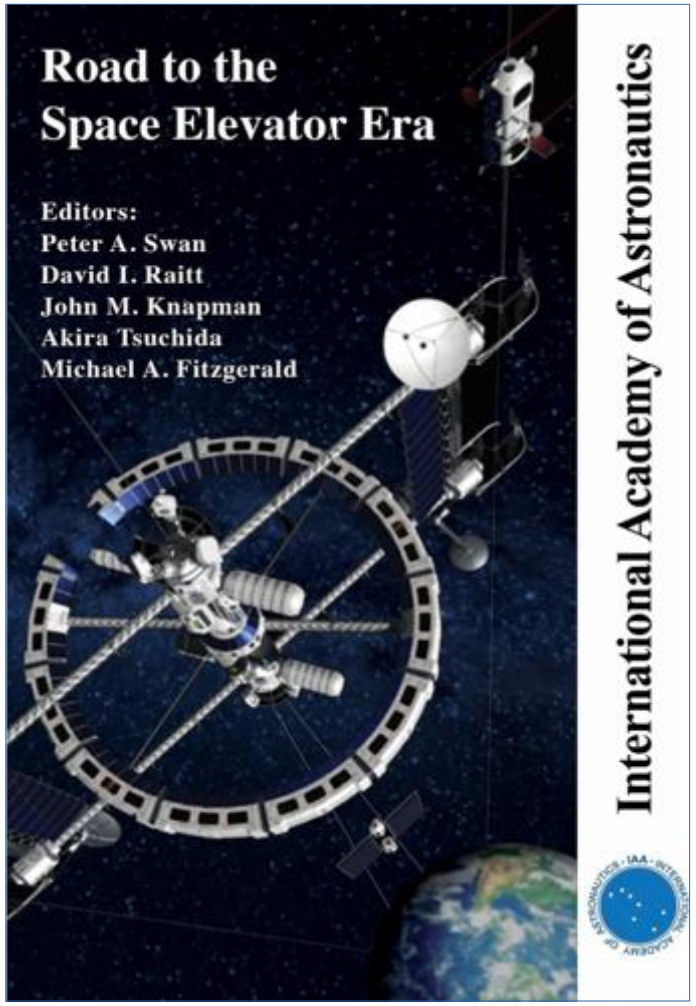
Space Elevator Science Fact: IAA/ ISEC

In 2013 The IAA
Looked at technical and commercial issues
Asked is this feasible to build, and how might we actually do this?

Answer, This can be done – Apart from one thing…



2013 IAA Publication



2019 IAA Publication

What is a space elevator?

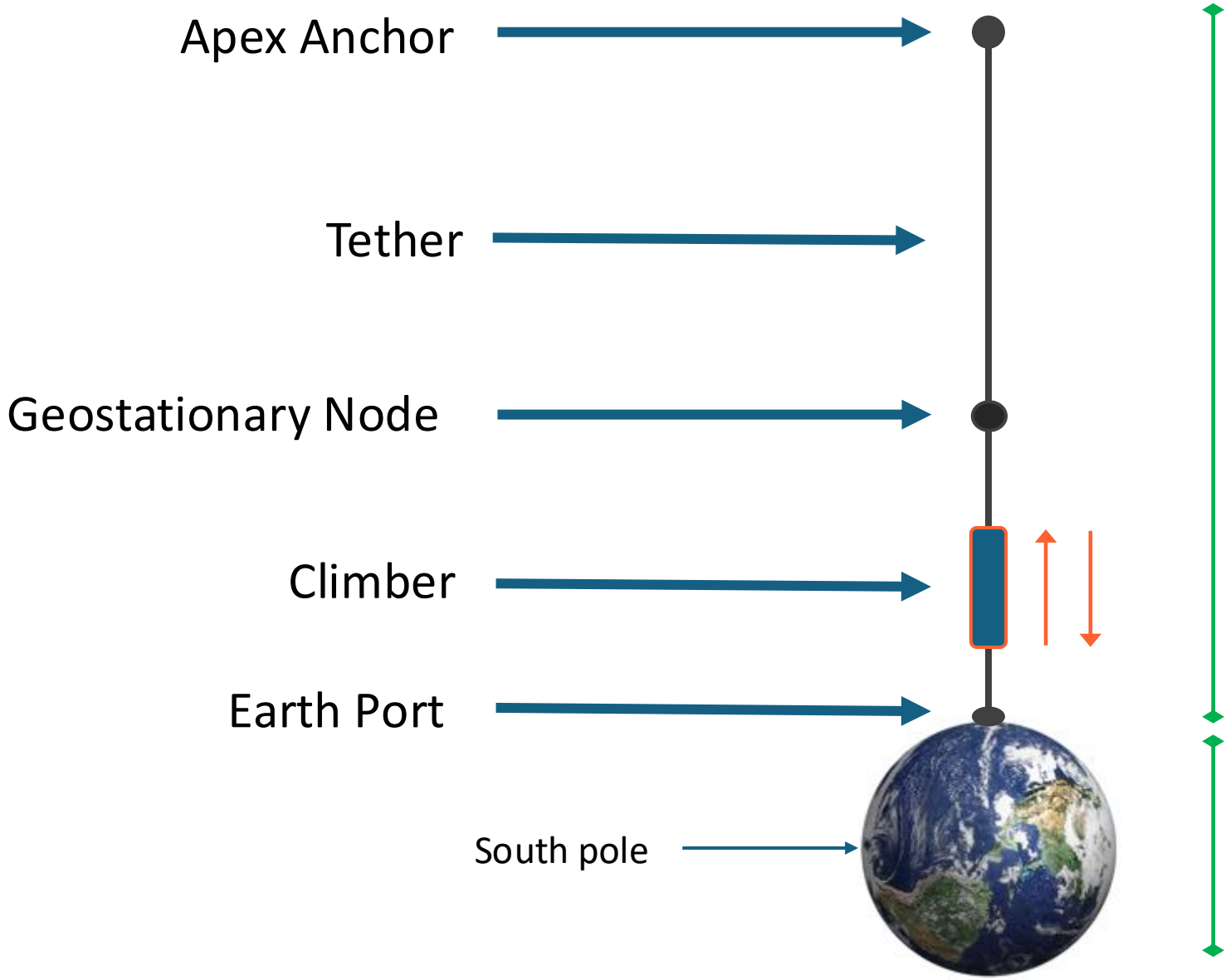
- A space elevator is conceived as a cable fixed to the equator and reaching into space.

- A counterweight at the upper end keeps the center of mass well above geostationary orbit level.

- This produces enough upward centrifugal force from Earth's rotation to fully counter the downward gravity, keeping the cable upright and taut.

- Climbers carry cargo up and down the cable.

The Space Elevator components (not to scale)



Tether length
100,000 km

Diameter of earth
12,742 km

The Space Elevator

The space elevator: Image generated by an AI with additional content by A. Nixon

The space elevator is a direct lift from the surface of the Earth up into space and back down again

It is based on solid foundations of science and engineering

It will be the biggest civil engineering infrastructure ever created

This will be challenging to build. However, it is not impossible

The space elevator tether

Image credit: Galactic Harbour Associates

The ‘just one thing’: The tether material problem

Imagine you are standing at the edge of an infinitely high cliff

You lower a super strong cable over the edge

The cable eventually breaks under its own weight

Image credit: D. Valdermaras, Unsplash

Tether materials need to be super strong

The tether material needs to be both lightweight and super strong

Strength is measured in Pascals (Pa)

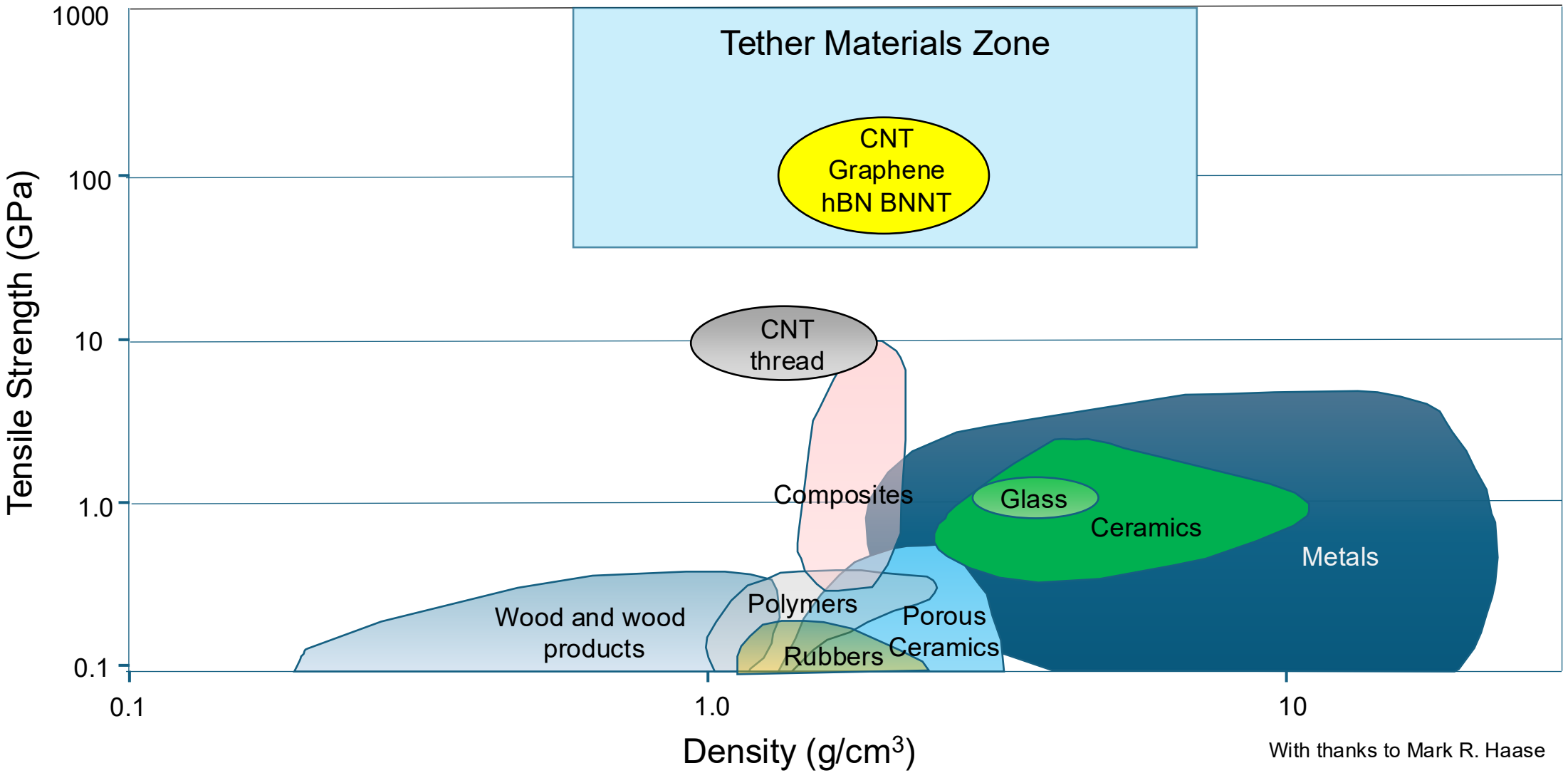
Today's super strong materials such as Kevlar have strengths around 3.7 GPa

The space elevator tether requires material with a tensile strength of over 60 GPa, preferably 100 GPa

Edwards. B, (2003) The Space Elevator NASA Institute for Advanced Concepts (NIAC) Phase II Final Report
http://images.spaceref.com/docs/spaceelevator/521Edwards.pdf

Space elevator tether materials

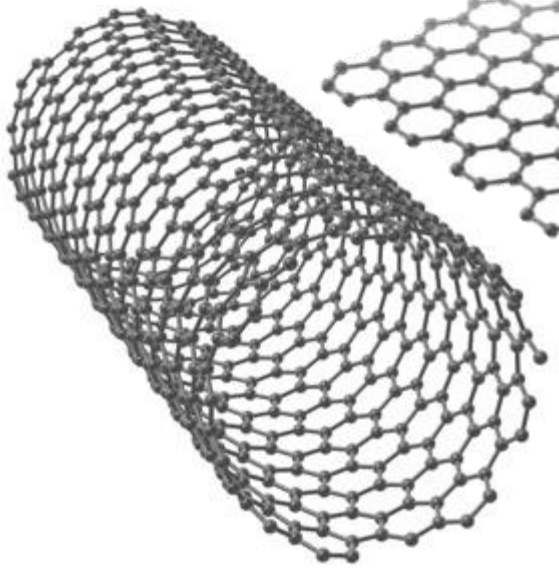
New materials are strong and light enough to make this a reality



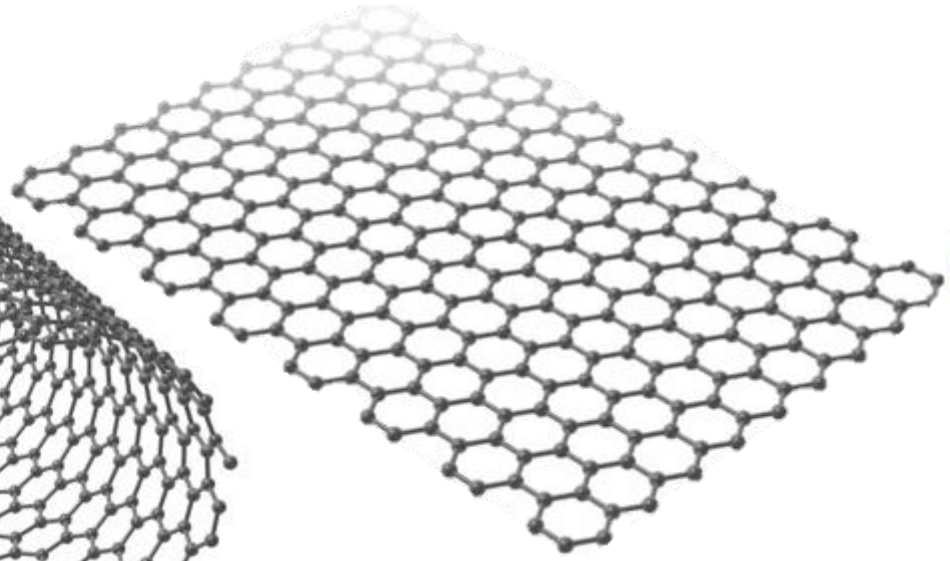
With thanks to Mark R. Haase

The candidate tether materials

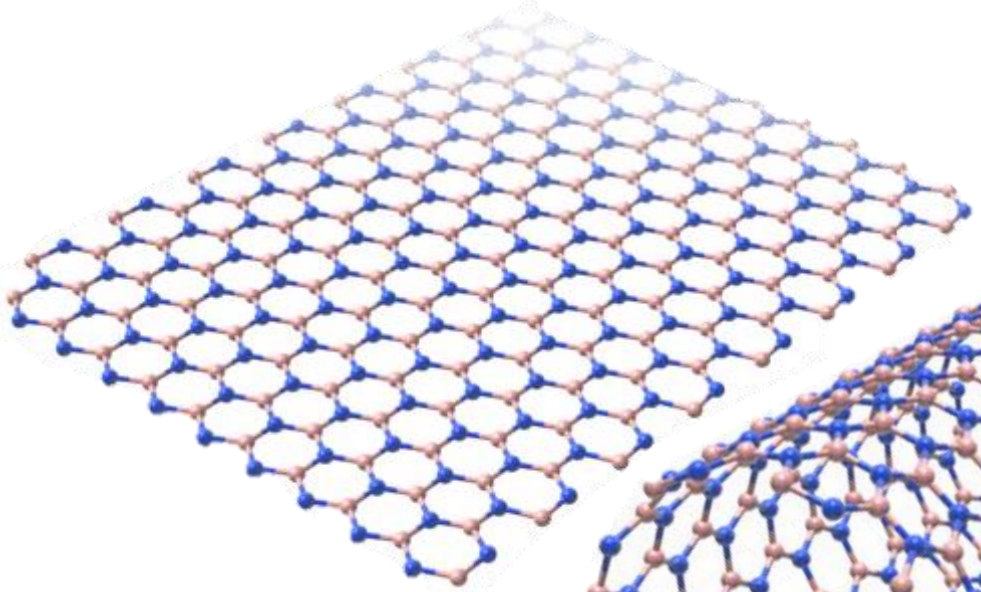
Candidate tether materials for the space elevator



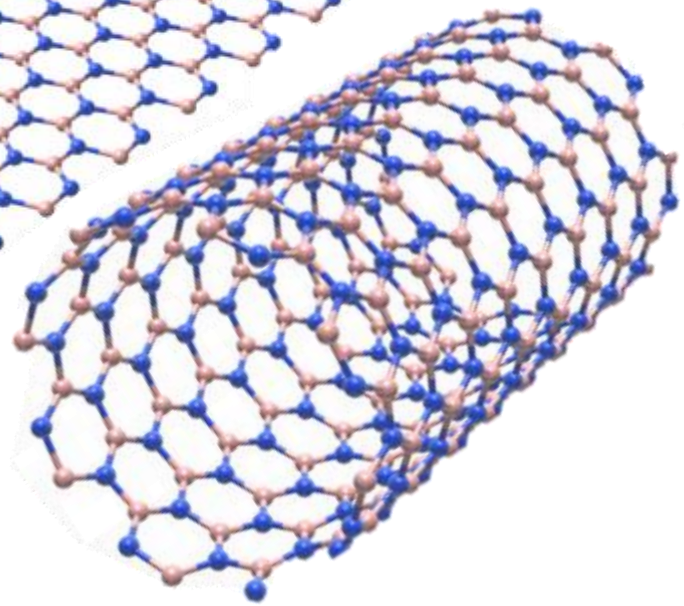
Single crystal carbon nanotubes (CNT) 1D material (77 to 200 GPa)



Single crystal graphene 2D material (130 GPa)



Single crystal hexagonal boron nitride (hBN) 2D material (100 GPa)



Single crystal hexagonal boron nitric nanotubes (BNNT) 1D material (30 to 159 GPa)

Carbon

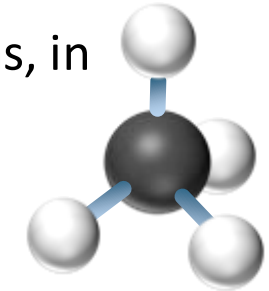
Boron

Nitrogen

Laboratory scale manufacture of tether candidate materials

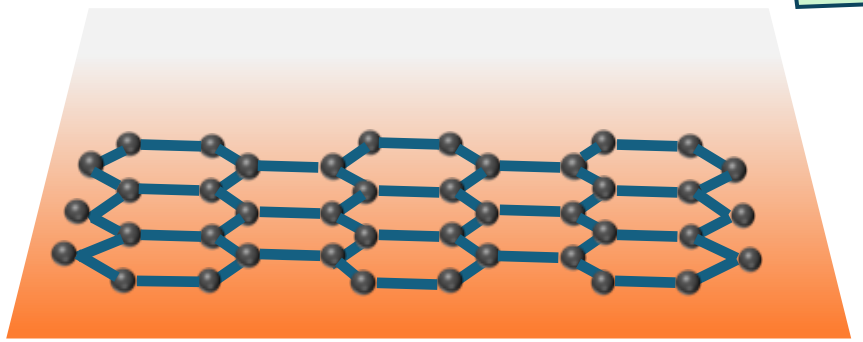
Laboratory scale manufacturing of graphene and carbon nanotubes

Carbon containing feedstock gas, in this case methane (CH_4)

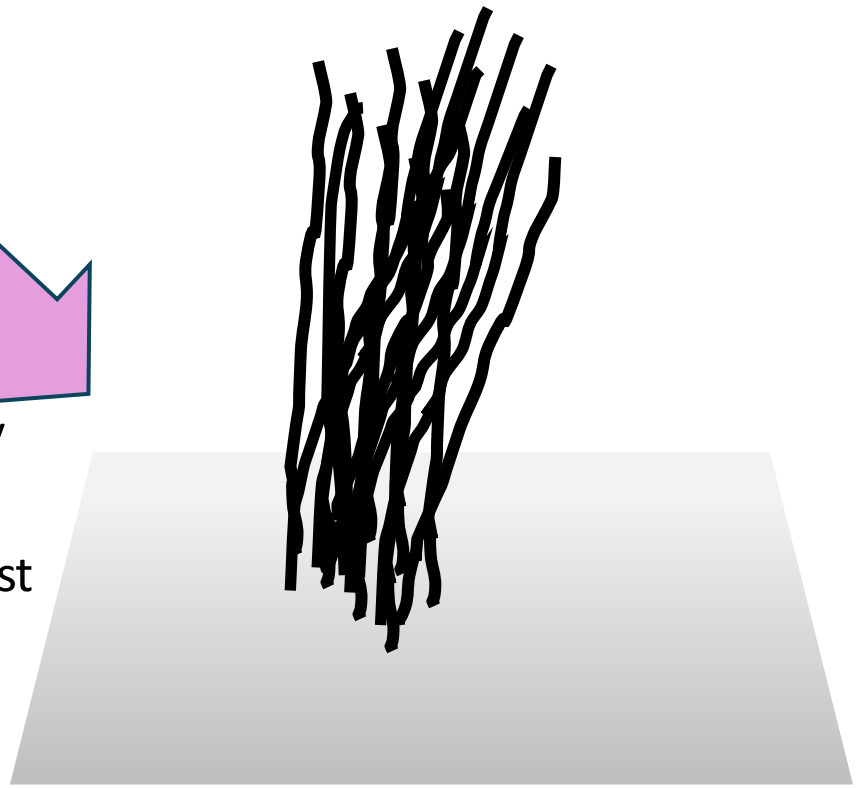


Copper or Nickel metal catalyst 1000°C

Iron / Gadolinium / Aluminium oxide ($Fe/Gd/Al_2O_3$) catalyst 750°C



Graphene monolayer



Carbon nanotube forest

The metal acts as a catalyst and substrate enabling the carbon material to form and providing a platform for growth
similar processes make the boron nitride equivalents

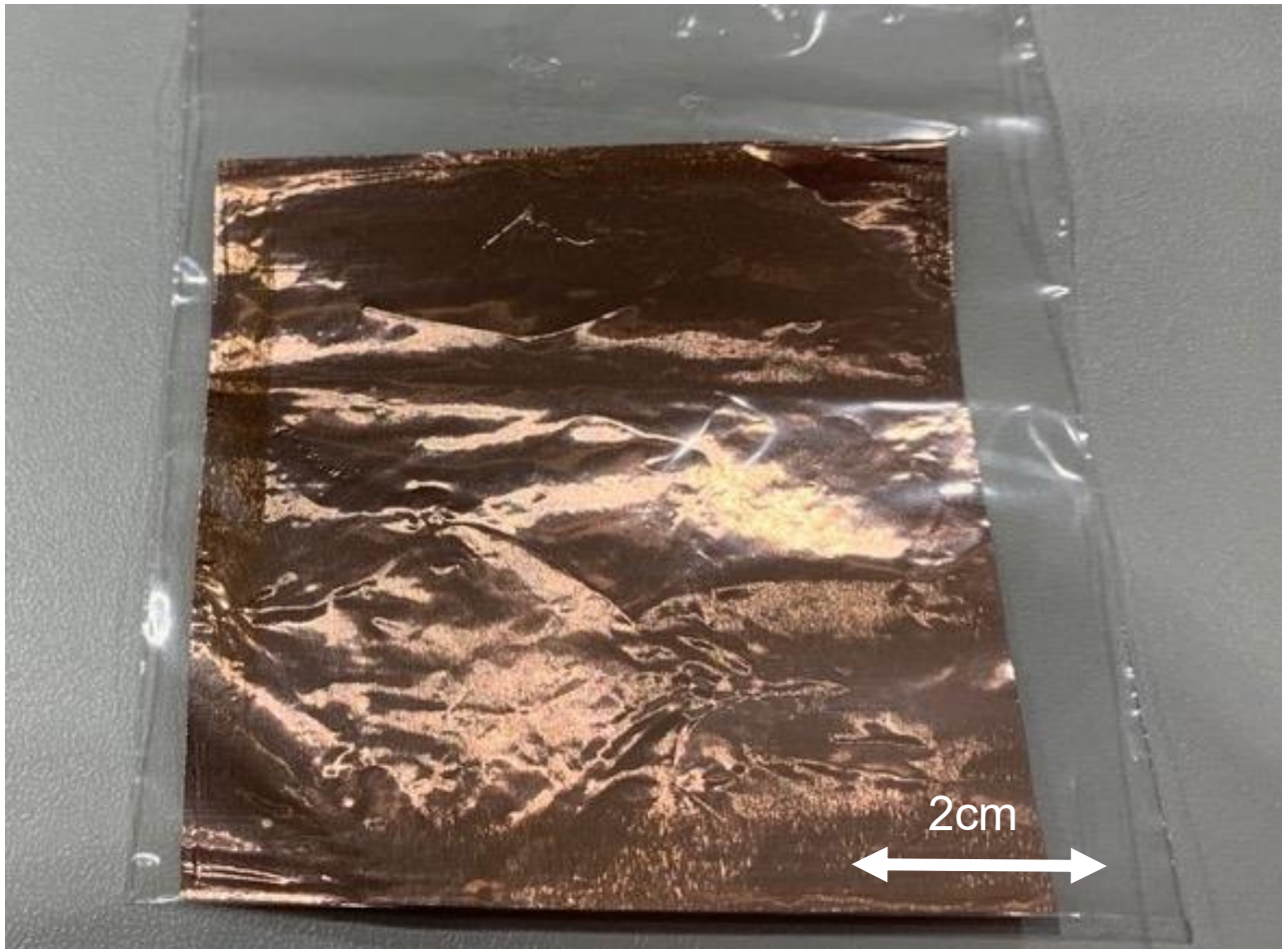
Source:
Sugime, H., Sato, T., Nakagawa, R., Hayashi, T., Inoue, Y. and Noda, S., 2021. Ultra-long carbon nanotube forest via in situ supplements of iron and aluminum vapor sources. *Carbon*, 172, pp.772-780.

Graphene Powder and Large-area sheet CVD graphene

Two types of graphene manufacturing

Graphene currently manufactured as powders

Commercial applications starting to evolve



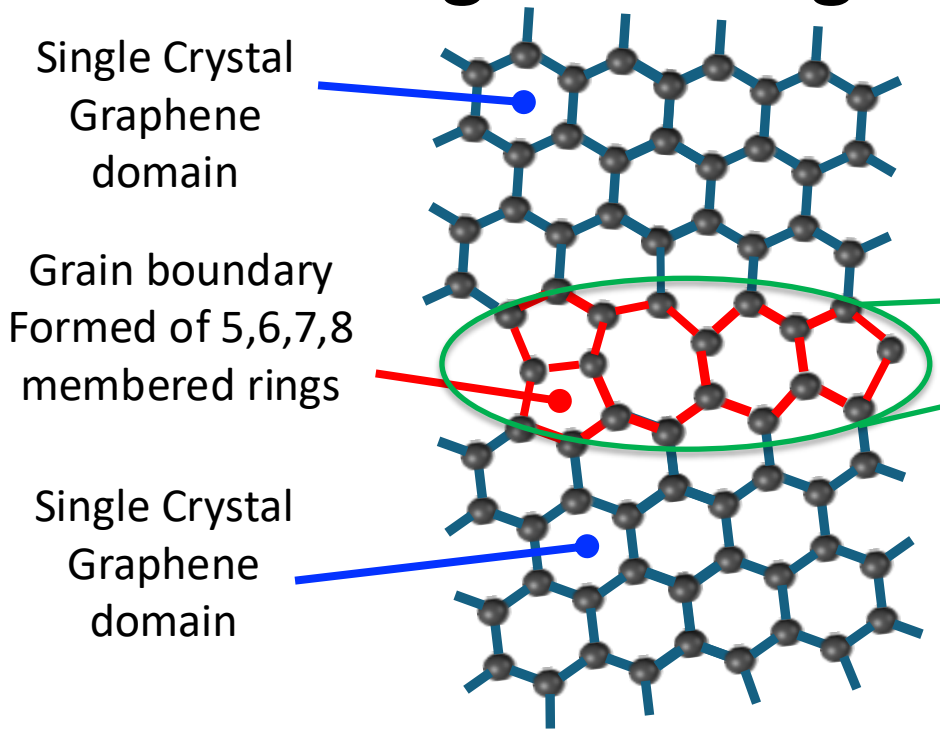
Single layer film graphene on metal foil

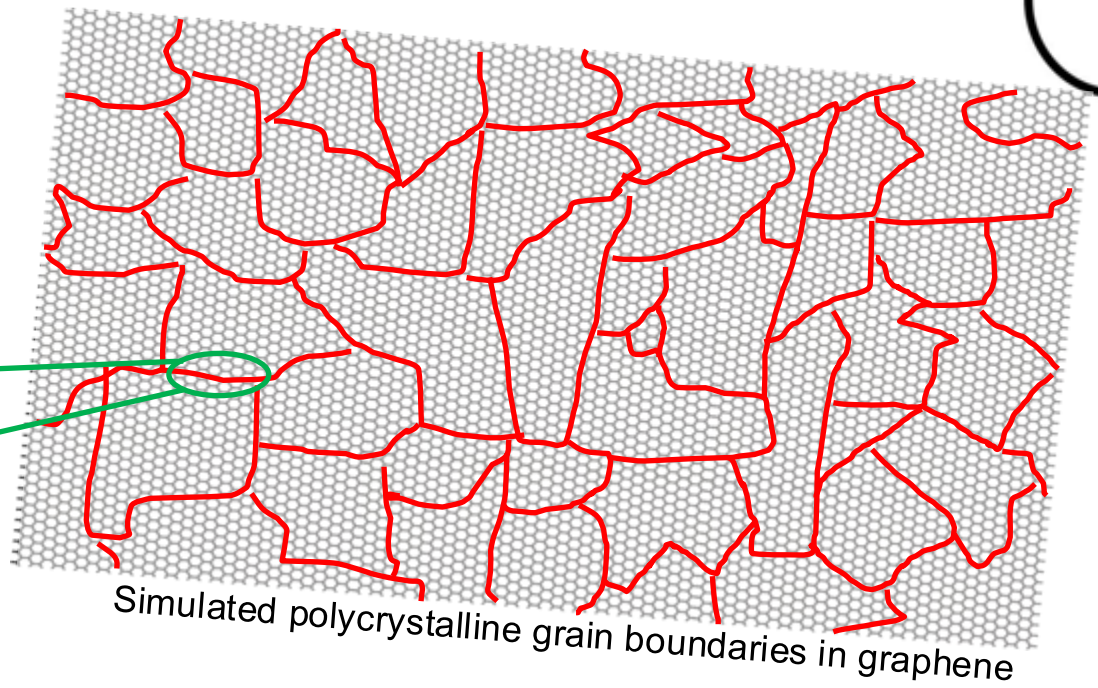
Image credit: Adrian Nixon

Large-area sheet CVD graphene is a far higher value market

Defect free sheet graphene is the ideal graphene film and is called Single Crystal Graphene

Single crystal and polycrystalline CVD graphene tensile strength testing





Polycrystalline graphene made by the chemical vapour deposition (CVD) method has been tested in the laboratory and found to have strength close to that of single crystal graphene

Material	Tensile strength GPa
Single crystal graphene with no grain boundary defects	130
Polycrystalline graphene made by the chemical vapour deposition (CVD) method	90 to 99

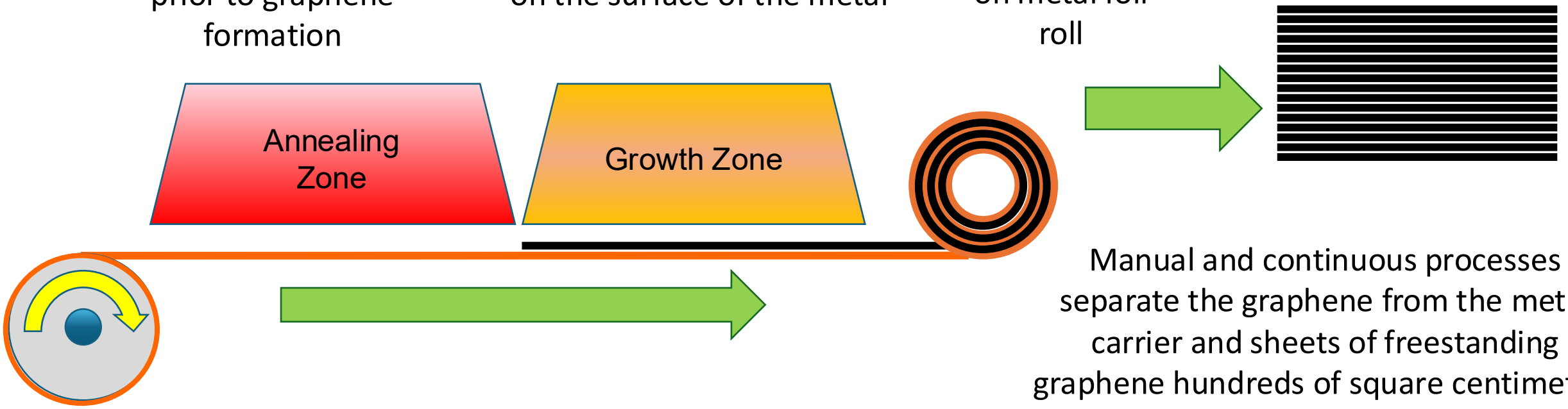
Source:
Lee, G.-H. ., Cooper, R.C., An, S.J., Lee, S., van der Zande, A., Petrone, N., Hammerberg, A.G., Lee, C., Crawford, B., Oliver, W., Kysar, J.W. and Hone, J. (2013). High-Strength Chemical-Vapor-Deposited Graphene and Grain Boundaries. *Science*, 340(6136), pp.1073–1076. doi:https://doi.org/10.1126/science.1235126.

Industrial scale graphene manufacturing by the roll-to-roll chemical vapour deposition (CVD) process can make large-area sheet graphene

The annealing zone conditions the metal foil prior to graphene formation

The growth zone forms the graphene crystal domains on the surface of the metal

Large-area sheet Graphene on metal foil roll



Bare metal foil roll

Continuous processes like this typically manufacture polycrystalline graphene

Manual and continuous processes separate the graphene from the metal carrier and sheets of freestanding graphene hundreds of square centimetres stacked up to 30 layers thick have already been made

Continuous CVD graphene manufacturing at the Graphene Engineering Innovation Centre (GEIC), UK

Aixtron Neutron BM vertical roll-to-roll CVD furnace with copper metal foil rolls

150mm wide up to 50m in length
Speeds of metres per hour

The system has a capacity of up to 20,000 square meters of graphene per year

Aixtron Neutron roll to roll continuous manufacturing machine for CVD graphene at the GEIC
L-R Rob Whieldon, Dennis Wright, John Knapman, James Baker, Image credit: Adrian Nixon

CVD graphene on glass made at the GEIC

CVD Graphene made at the GEIC on glass using a dry transfer method to create 3-layer graphene

This was made for electrical conductivity testing

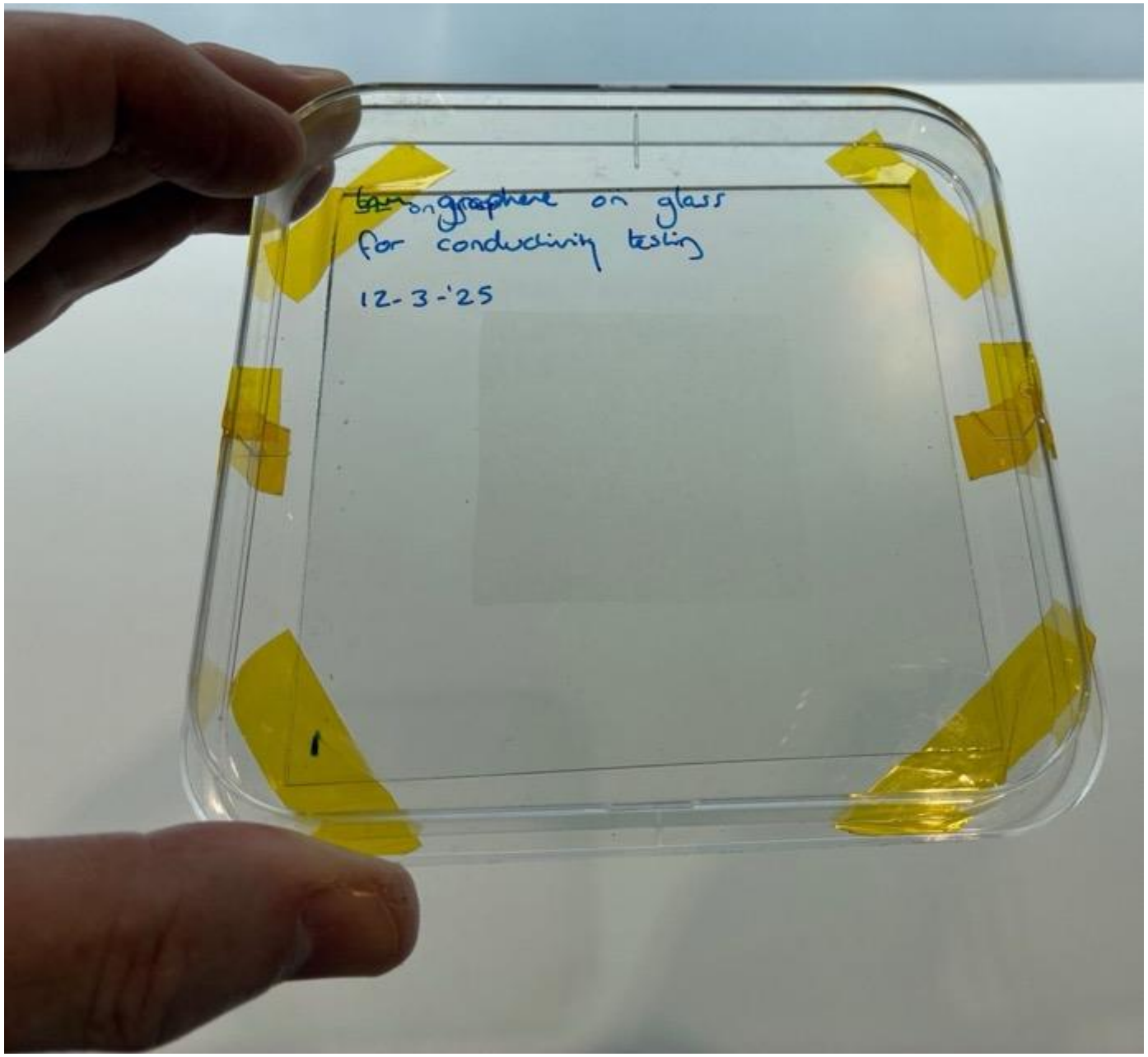


Image credit: Adrian Nixon

CVD graphene now mass produced in the Republic of Korea at speed of two metres per minute and in lengths of one kilometre

LG can make CVD sheet graphene at:

- Speed of 1 metre per minute
- Lengths up to 1kilometre
- On copper foil 400 mm wide

Vertical roll-to-roll CVD furnace with copper metal foil rolls approx. 3 metres high

Graphene roll to manufacture Image credit: LG

Graphene roll to roll transfer to polymer film, Image credit: You Tube and CharmGraphene

Charmgraphene can make CVD sheet graphene at:

- Speed of 2 metres per minute
- Lengths up to 1 kilometre
- On copper foil 300 mm wide

These companies are focussed on making graphene for the electronics industry

Source:
https://nano.market/news/graphene/charmgraphene-starts-mass-producing-cvd-graphene-using-a-roll-to-roll-process/
https://www.youtube.com/watch?v=NcTPjBIAbGE [Accessed 25th August 2024]

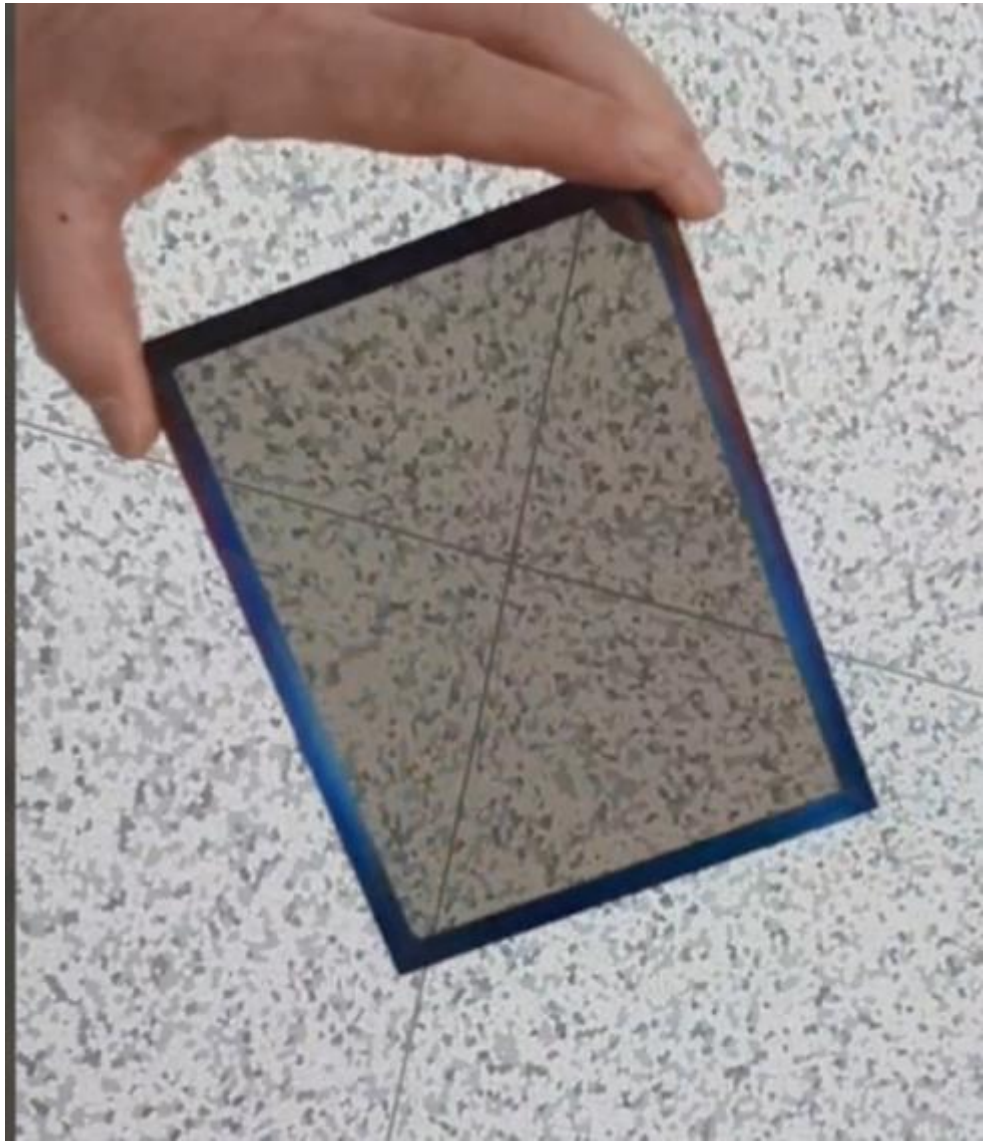
Multilayer graphene material has now been made

30 atoms thin
large area sheet CVD graphene made by
Charmgraphene in the Republic of Korea

The company is making this material for the manufacture of semiconductor computer chips

This is not tether quality yet
it is polycrystalline layered graphene rather than a van der Waals homostructure

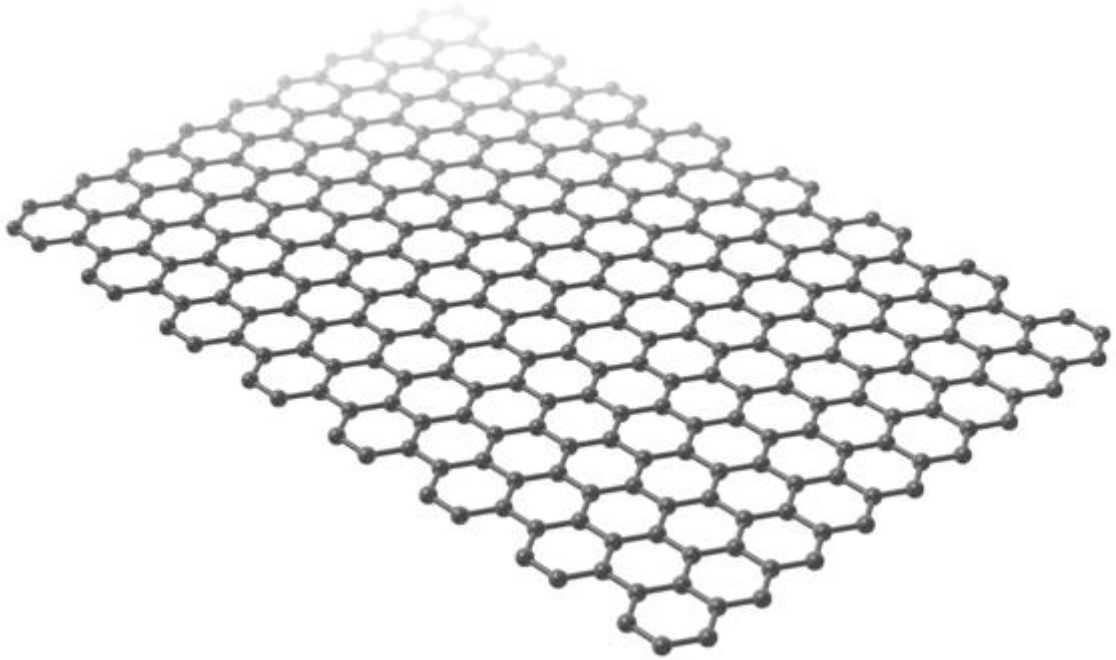
However, this is an impressive feat

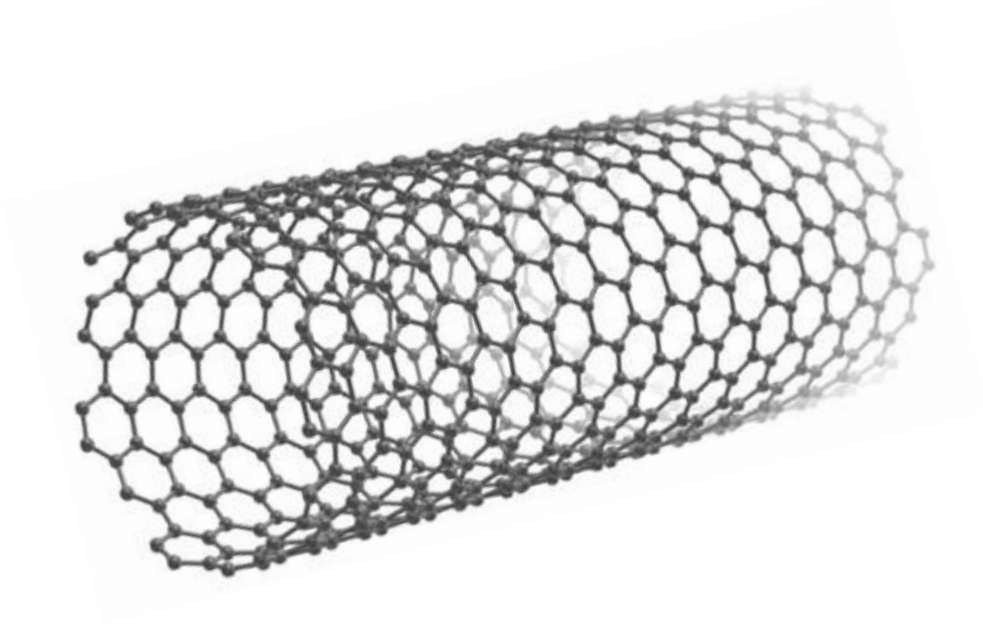


30 atomic layers of large area sheet CVD graphene in a frame, Image credit: CharmGraphene

Why graphene is the leading candidate tether material over carbon nanotubes for the space elevator tether

Images credit: Adrian Nixon
Created using Samson-Core molecular modelling





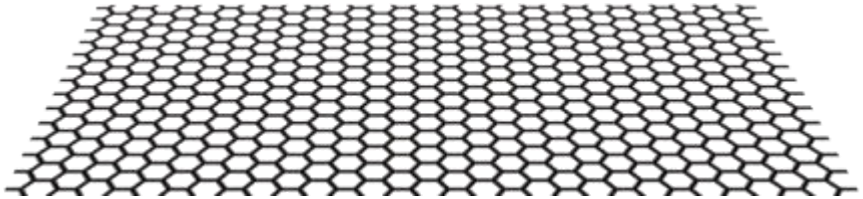
Graphene and Graphene Super Laminate (GSL)		
High strength	More than 100 GPa	✅
Current manufactured length	1 kilometre	✅
Current manufactured speed	2 metres per minute	✅

Carbon nanotubes (CNT)		
High strength	More than 100 GPa	✅
Current manufactured length	140 millimetres	❌
Current manufactured speed	1 metre per week	❌

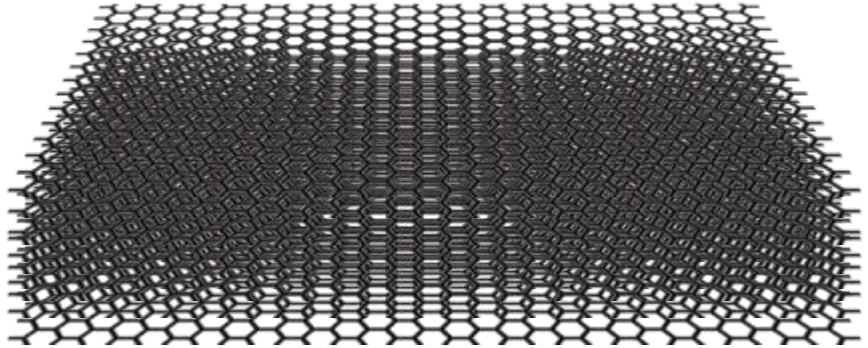
Nixon, A., Knapman, J. and Wright, D.H. (2023). Space elevator tether materials: An overview of the current candidates. *Acta Astronautica*, [online] 210, pp.483–487. doi:https://doi.org/10.1016/j.actaastro.2023.04.008 ISSN 0094-5765.

This is so new even the descriptive language is evolving…

Single Crystal Graphene is one layer of graphene



Thousands and millions of layers
of Single Crystal Graphene
make a new kind of material,
a form of coherent synthetic graphite
we will not have seen before:
A van der Waals Homostructure
Graphene Super-Laminate (GSL)



This is not graphite

Sheet materials made from Graphite, HOPG GL and GSL

Graphite	Highly Oriented Pyrolytic Graphite (HOPG)	Multi-layered sheet polycrystalline graphene Graphene laminate (GL)		Multi-layered sheet single crystal graphene Graphene super-laminate (GSL)
Hot pressed and calendered		GL with vacancies	GL with no vacancies	GSL with no vacancies

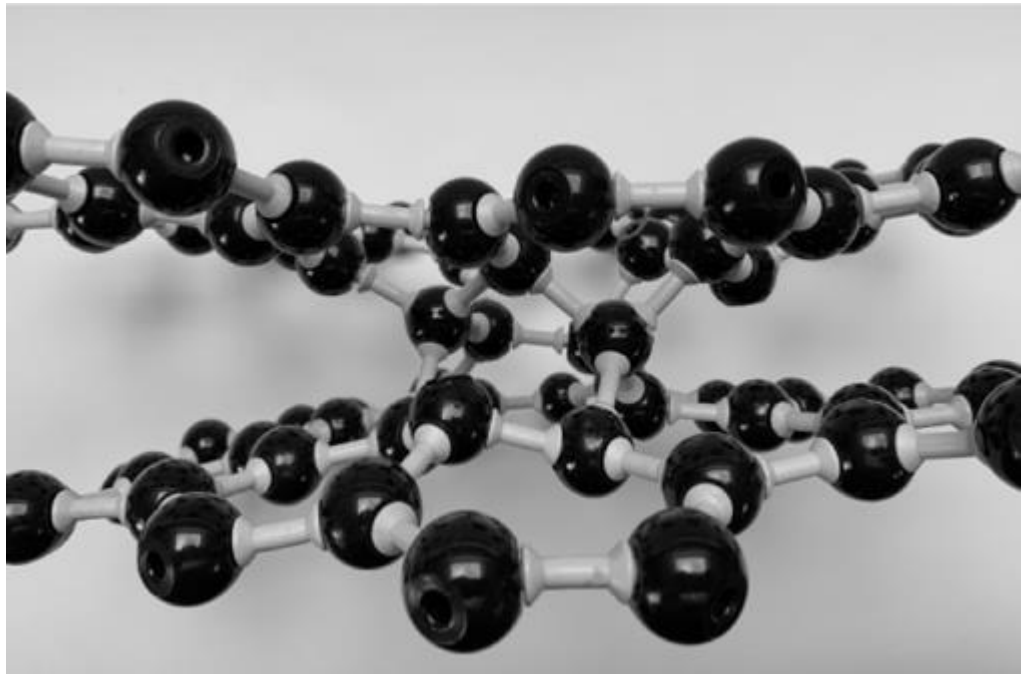
Increasingly self supporting and strong material

Each black line represents a single layer of graphene

Source:
Nixon, A. (2021). The graphene and graphite landscape: Indications of unexplored territory. *Nixene Journal*, 5(10), pp.9–20.

Two final hypotheses…

September 2022
We proposed a hypothesis for spot-welding layers in graphene laminate



We further proposed that these cross links would create a form of diamond known as hexagonal diamond or Lonsdaleite

ISEC

2022 Newsletters

2022 FEBRUARY
2022 MARCH
2022 APRIL
2022 MAY
2022 JUNE
2022 JULY
2022 AUGUST
2022 SEPTEMBER
2022 OCTOBER
2022 NOVEMBER
2022 DECEMBER
OTHER YEARS

International Space Elevator Consortium
September 2022 Newsletter

In this Issue:

Nixon, A. (2022). *Sliding of Layers in Graphene Super Laminate*. [online] International Space Elevator Consortium. Available at: https://www.isec.org/space-elevator-newsletter-2023-march/#tether [Accessed 5 Sep. 2025].

In 2025 the cross-linking of graphene super laminate was actually done and formed Lonsdaleite (superdiamond)

nature

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Article | Published: 30 July 2025

Synthesis of bulk hexagonal diamond

Liuxiang Yang, Kah Chun Lau, Zhidan Zeng, Dongzhou Zhang, Hu Tang, Bingmin Yan, Guoliang Niu, Huiyang Gou, Yanping Yang, Wenge Yang ✉, Duan Luo ✉ & Ho-kwang Mao ✉

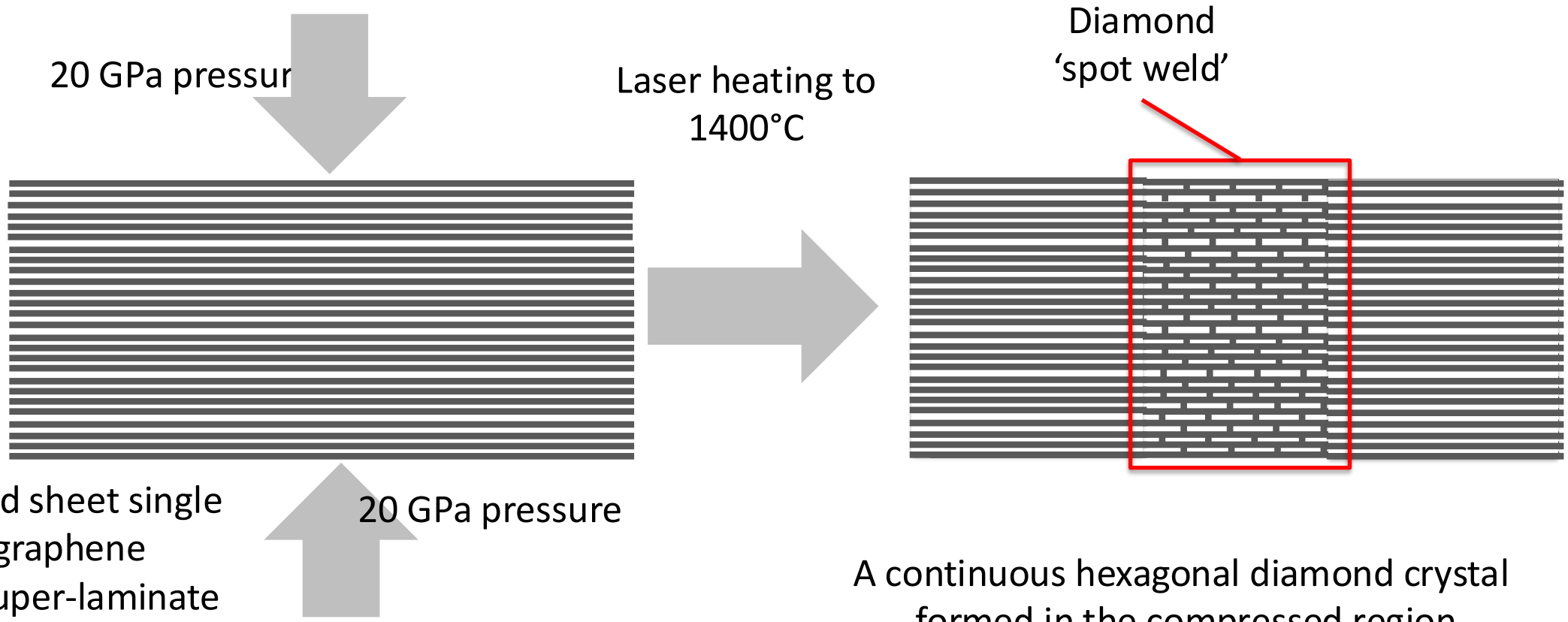
Nature **644**, 370–375 (2025) | Cite this article

Abstract

Hexagonal diamond (HD), with anticipated physical properties superior than the known cubic diamond, has been pursued relentlessly since its inception 60 years ago[1]. However, natural and synthetic HD has only been preserved as a highly disordered component in fragile, heterogeneous mixtures of other nanocarbon structures that precludes determination of bulk properties and identification of HD as a bona fide crystalline phase[2,3,4]. Here we report the synthesis, recovery and extensive characterization of bulk HD by compressing and heating high-quality graphite single crystals under controlled quasi-hydrostatic conditions. We demonstrate the successful synthesis of 100-μm-sized to mm-sized, highly ordered, bulk HD. We observed direct transformation of graphite $(10\bar{1}0)$ orientation to HD (0002) and graphite (0002) to HD $(10\bar{1}0)$. The bulk sample consists of threefold intergrowth of tightly knitted 100-nm-sized crystals, predominantly HD with trace imperfections of cubic diamond. The interlayer bonds in HD are shortened with respect to intralayer bonds to optimize the HD structure. Notably, the hardness of HD is only slightly higher than cubic diamond. We anticipate that purifying the precursor graphite carbon and fine-tuning the high pressure–temperature (P–T) synthesis conditions may lead to higher-quality HDs.

Source:
Yang, L., Lau, K.C., Zeng, Z., Zhang, D., Tang, H., Yan, B., Niu, G., Gou, H., Yang, Y., Yang, W., Luo, D. and Mao, H.-K. (2025). Synthesis of bulk hexagonal diamond. *Nature*. doi:https://doi.org/10.1038/s41586-025-09343-x.

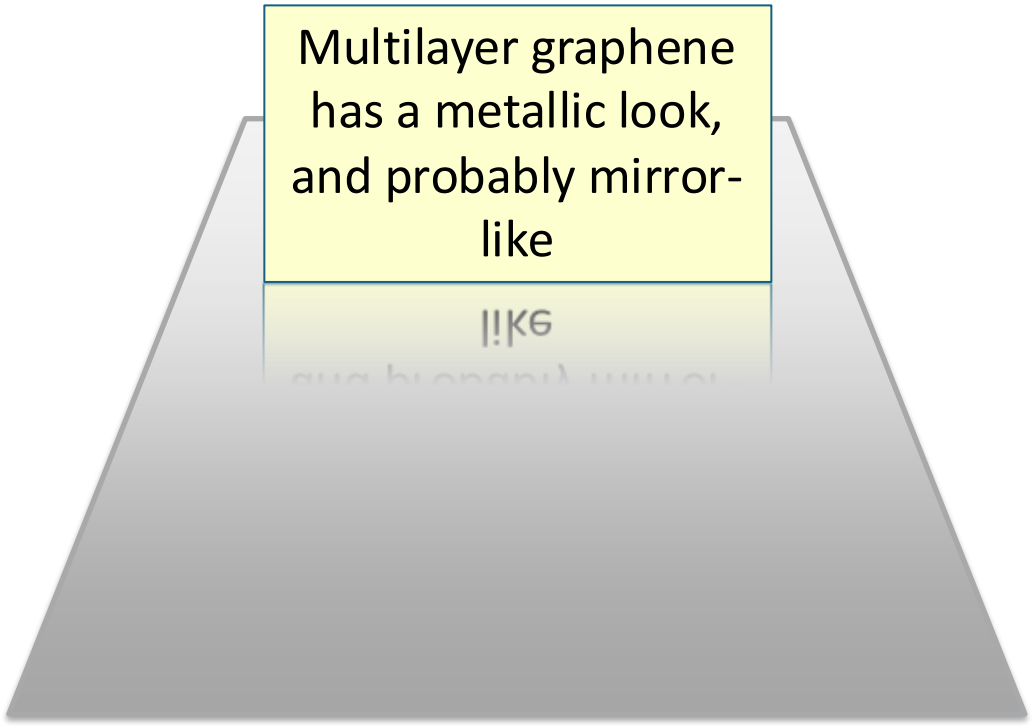
In 2025 the cross-linking of graphene super laminate was actually done and formed Lonsdaleite (superdiamond)



Source:
Yang, L., Lau, K.C., Zeng, Z., Zhang, D., Tang, H., Yan, B., Niu, G., Gou, H., Yang, Y., Yang, W., Luo, D. and Mao, H.-K. (2025). Synthesis of bulk hexagonal diamond. *Nature*. doi:https://doi.org/10.1038/s41586-025-09343-x.
Wakely, M. (2025). *Rare diamond with unique hexagonal structure is harder than natural counterpart*. [online] Chemistry World. Available at: https://www.chemistryworld.com/news/rare-diamond-with-unique-hexagonal-structure-is-harder-than-natural-counterpart/4021939.article [Accessed 28 Aug. 2025]

December 2020

We proposed a hypothesis that a tether made from graphene super laminate would have a mirror-like appearance



Nixon, A. (2020). *What would a tether made from 2D materials look like?* [online] International Space Elevator Consortium. Available at: https://www.isec.org/space-elevator-newsletter-2020-december/#geic [Accessed 5 Sep. 2025].

2020 Newsletters

2020 FEBRUARY
2020 MARCH
2020 APRIL
2020 MAY
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2020 JULY
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2020 SEPTEMBER
2020 OCTOBER
2020 NOVEMBER
2020 DECEMBER
OTHER YEARS

International Space Elevator Consortium
December 2020/January 2021 Newsletter

In this Issue:

August 2025:
Synthesis of Mirror-Like graphite films (Graphene laminate)

nature communications

Article

https://doi.org/10.1038/s41467-025-62227-6

Synthesis and properties of mirror-like large-grain graphite films

Received: 25 January 2024

Accepted: 11 July 2025

Published online: 12 August 2025

Check for updates

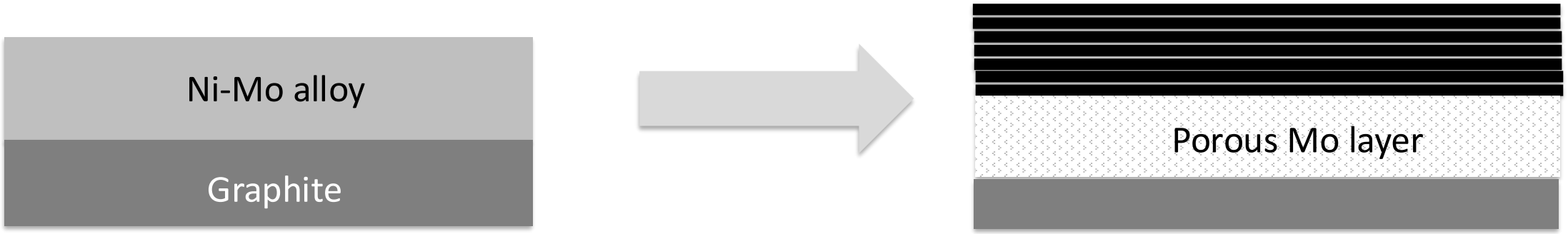
Liyuan Zhang[1,2,7], Meihui Wang[1,3,7], Dongho Jeon[1,4], Yongqiang Meng[1,4], Sun Hwa Lee[1], Myeonggi Choe[1,5], Yunqing Li[1,4], Mengran Wang[1,2], Sherilyn J. Lu[1], Zonghoon Lee[1,5], Won Kyung Seong[1] & Rodney S. Ruoff[1,4,5,6]

Graphite films with large grain sizes have been reportedly obtained by using metal as catalysts, but the obtained graphite is mostly heavily wrinkled, thus containing defects that degrade its properties. We report the synthesis of mirror-like and large-grained graphite films with only a few nano kinks and controllable dimensions, achieved by using flat Ni-Mo alloy melts of the same lateral dimensions as the metal foils used to make this alloy melt. The graphite film exhibited few nano kinks and a mirror-like appearance because the deliberate evaporation of much of the Ni produced a porous substrate, which in turn dramatically weakened the substrate-graphite film interaction before cooling. The mirror-like graphite appears to be 100% AB-stacked with millimeter-sized grains that are much larger than the multi-micron grain size of highly oriented pyrolytic graphite and rivaled in size only by a small percentage of natural graphite. Our graphite films have an electrical conductivity of 2.25×10^4 S cm^{-1} at 300 K. Tensile loading of macroscale samples showed an average Young's modulus of 969 ± 69 GPa and average fracture strength of 1.29 ± 0.203 GPa, and Frequency Domain Thermoreflectance revealed an average in-plane thermal conductivity of 2034.4 ± 68 W m^{-1}·K^{-1}.

Source:

Zhang, L., Wang, M., Jeon, D., Meng, Y., Lee, S.H., Choe, M., Li, Y., Wang, M., Lu, S.J., Lee, Z., Seong, W.K. and Ruoff, R.S. (2025). Synthesis and properties of mirror-like large-grain graphite films. *Nature Communications*, 16(1). doi:https://doi.org/10.1038/s41467-025-62227-6.

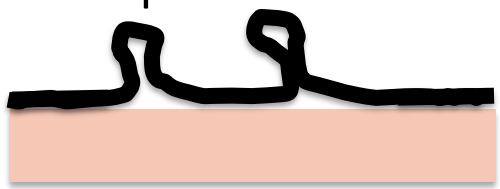
August 2025:
Synthesis of Mirror-Like graphite films (Graphene laminate)



Carbon dissolves in the Ni-Mo alloy
Forming multilayer graphene on the surface

The nickel evaporates leaving a porous substrate that does not compress and wrinkle the graphene leaving a mirror-like surface of graphene laminate

Standard CVD process



wrinkles form in the graphene on cooling caused by contraction of the metal

Laboratory testing:

Electrical conductivity of 2.25×10^4 S cm^{-1} at 300 K.
Young's modulus of 969 ± 69 GPa
Average fracture strength of 1.29 ± 0.203 GPa,
Average in-plane thermal conductivity 2034.4 ± 68 W $m^{-1} \cdot K^{-1}$

This implies well stitched together polycrystalline graphene layers with some vacancy defects

Source:
Zhang, L., Wang, M., Jeon, D., Meng, Y., Lee, S.H., Choe, M., Li, Y., Wang, M., Lu, S.J., Lee, Z., Seong, W.K. and Ruoff, R.S. (2025). Synthesis and properties of mirror-like large-grain graphite films. *Nature Communications*, 16(1). doi:https://doi.org/10.1038/s41467-025-62227-6.

What the Space elevator tether will look like

The space elevator tether
Image generated by an AI with additional content by A. Nixon

Perfectly smooth mirror-like flat ribbon

100 thousand kilometres long

Thinner than aluminium kitchen foil

On a floating platform on the ocean at the equator

Rising straight up into the sky, disappearing out of sight

Will support elevator climbers of tens and hundreds of tonnes in weight

Source:
Nixon, A. (2020). *2020 December International Space Elevator Consortium Newsletter*. [online] International Space Elevator Consortium. Available at: https://www.isec.org/space-elevator-newsletter-2020-december/#geic [Accessed 5 Sep. 2025].

Space Elevators: A Bridge to the Stars

Thank you for your time

Happy to answer any questions

Adrian Nixon

adrian.nixon@isec.org

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