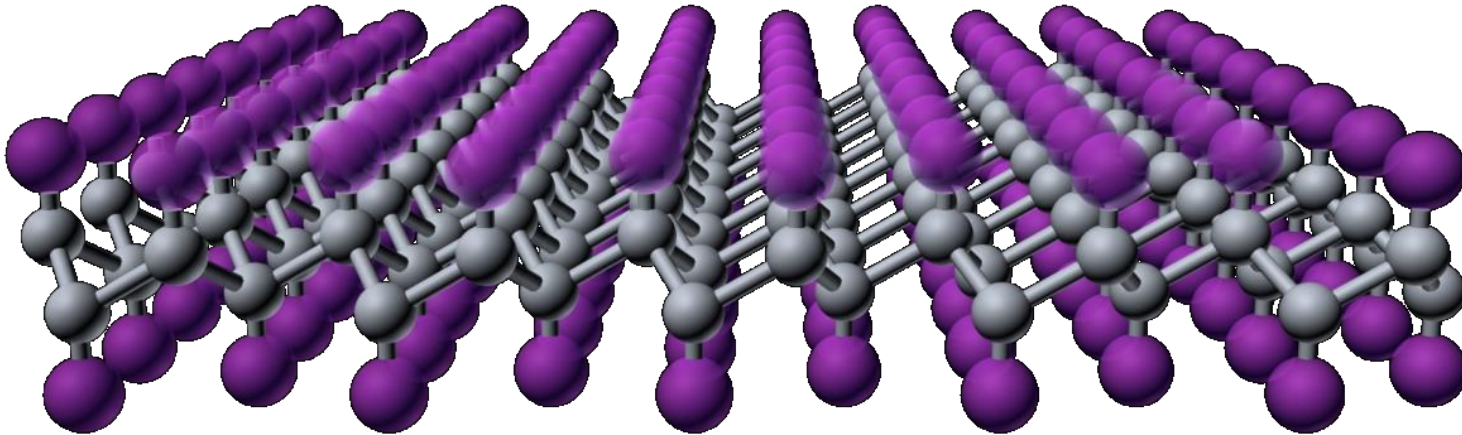


Graphene Nanocomposites



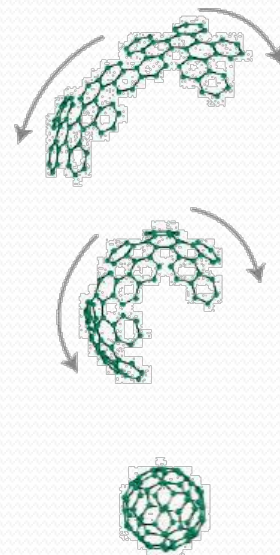
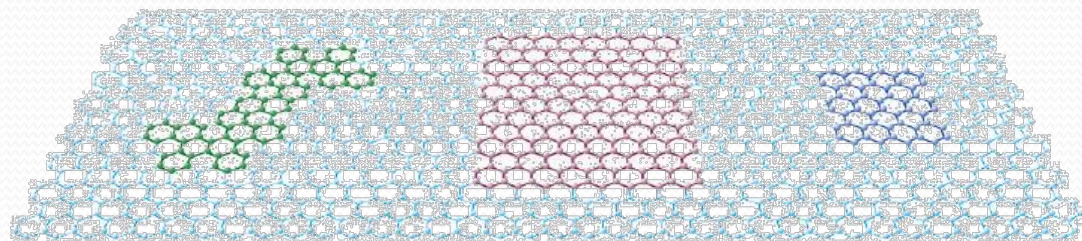
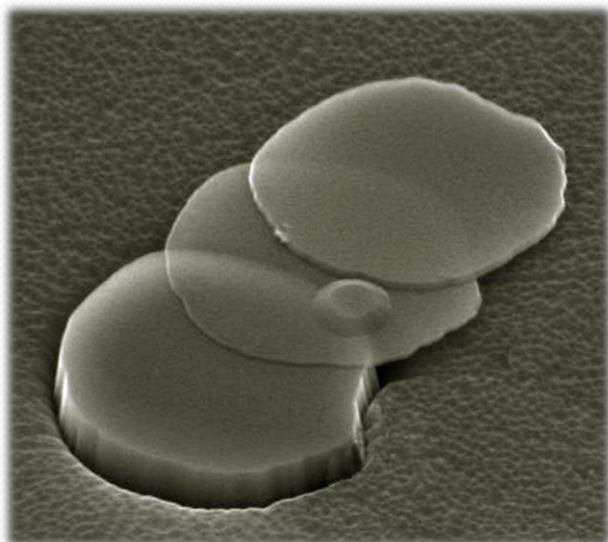
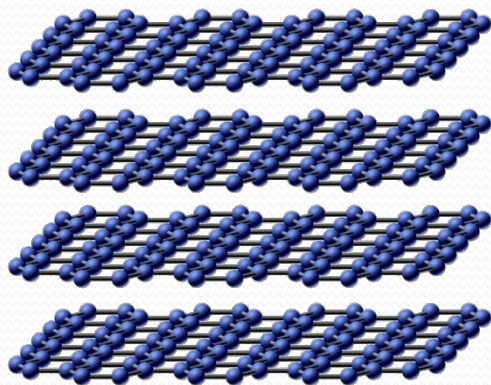
Dr Zheling Li (Bennie)

National Graphene Institute
School of Materials
The University of Manchester

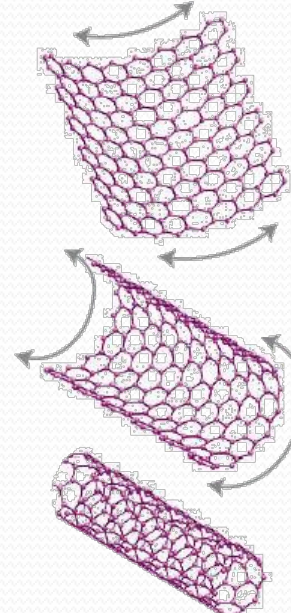
zheling.li@manchester.ac.uk

Introduction

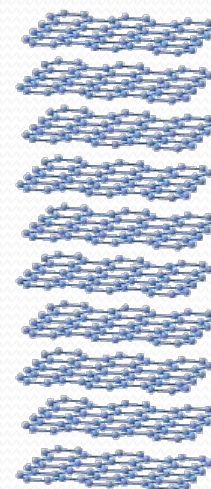
Slice down to one atomic plane



Buckyballs



Carbon Nanotubes



Graphite

Introduction

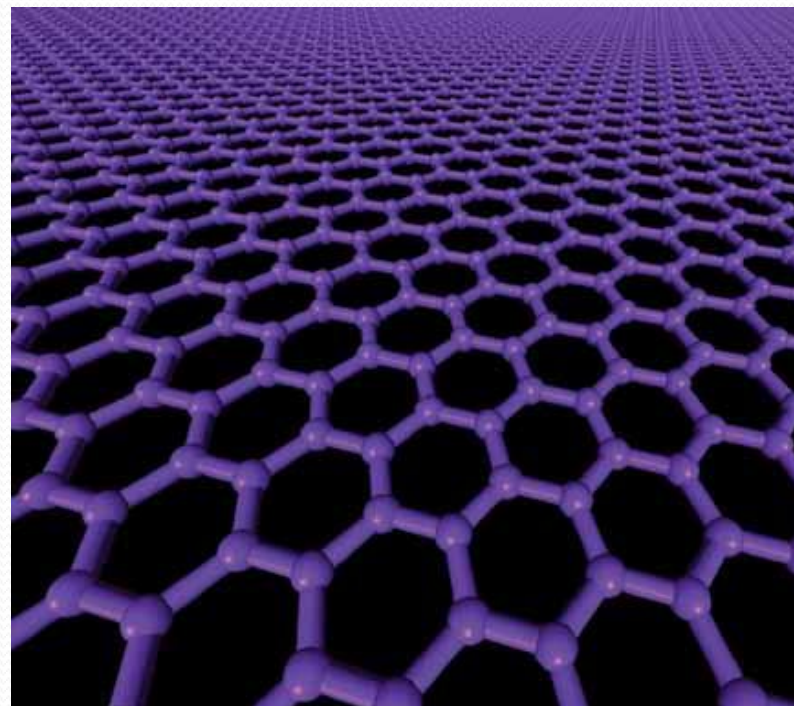
Graphene Superlatives

Thinnest imaginable material
Surface area = Activated Carbon x5
Very transparent
Most impermeable material

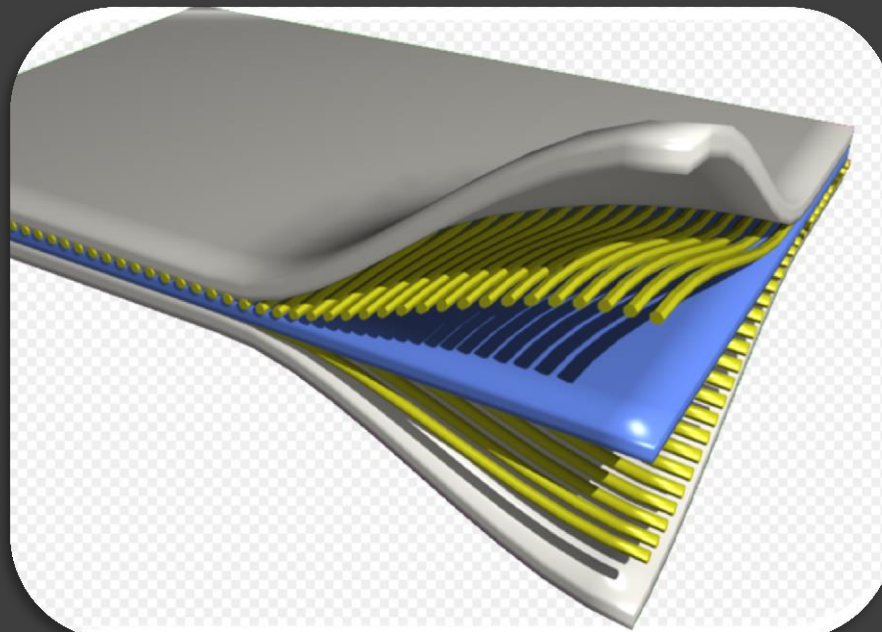
Strongest material
Stiffest known material
Most stretchable crystal

Easily functionalised
Processible
Record thermal conductivity
Highest current density

....



Introduction

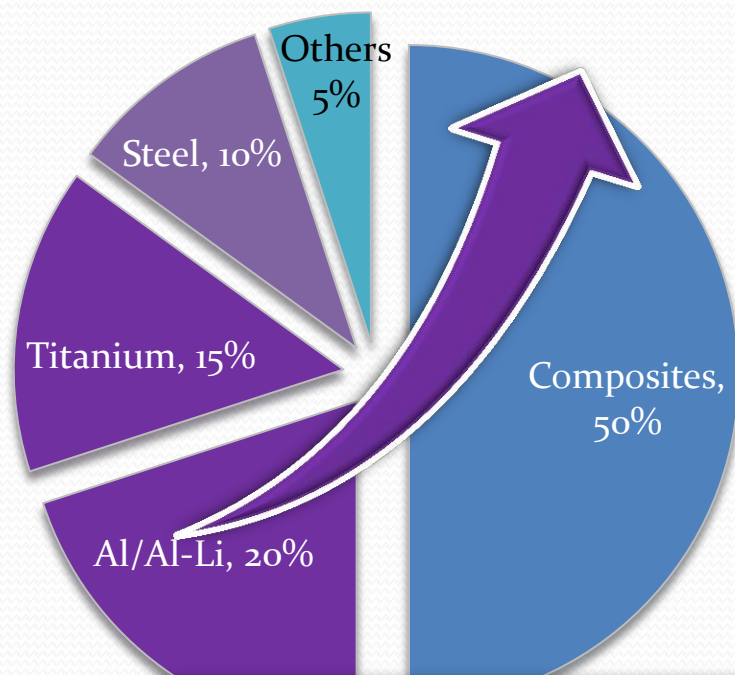
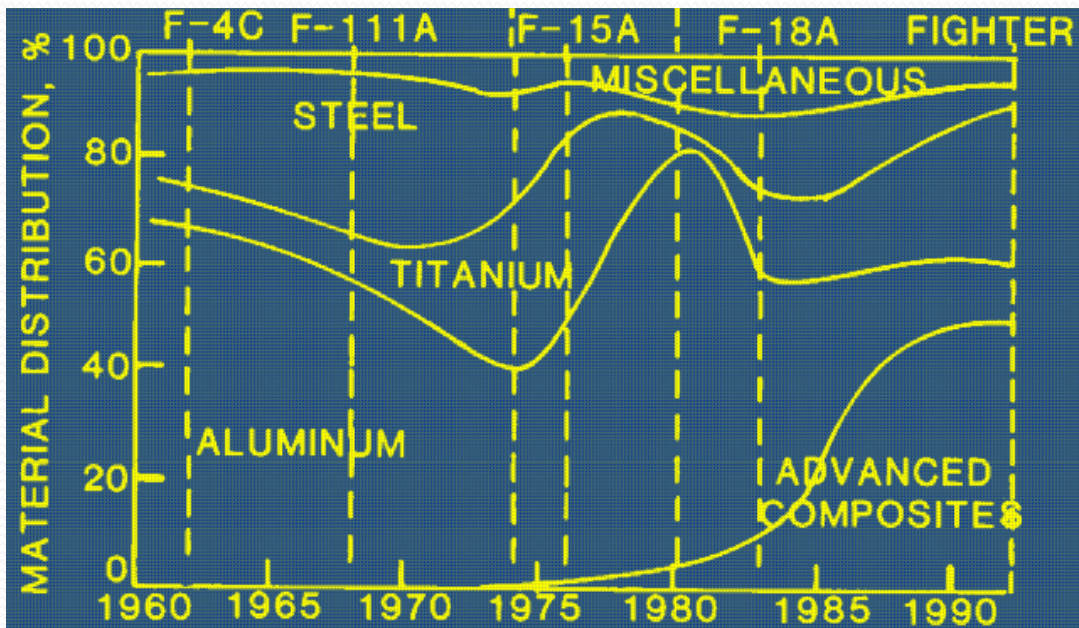


≥ 2 Components

Separate

Synergetical

Introduction



Only High-end ?

Introduction



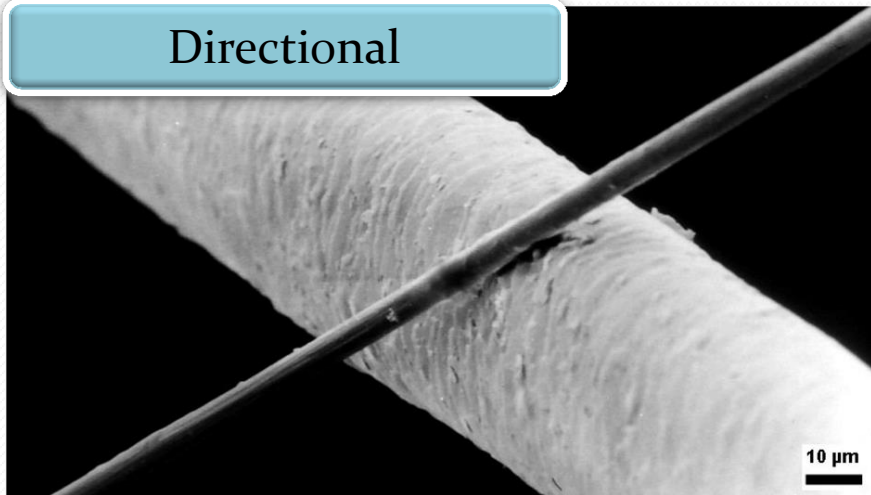
GRAPHENE™

<http://head.com/g/ew/graphene/>

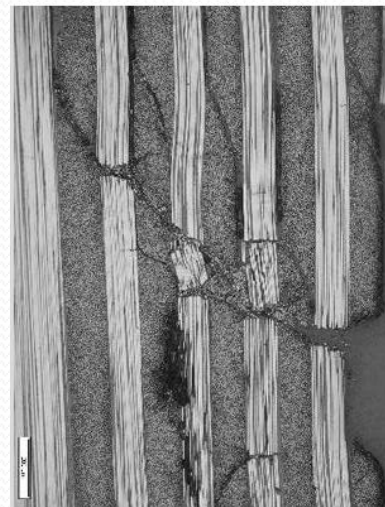
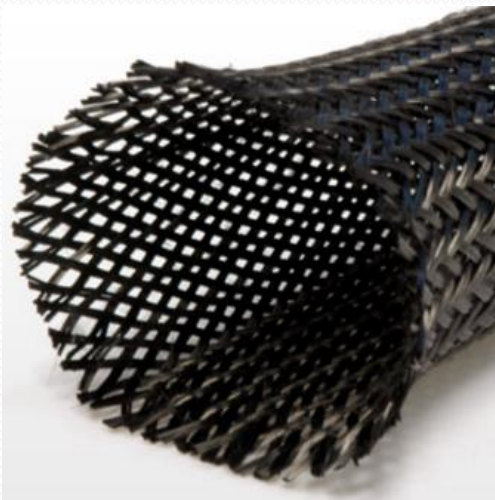


What's the Problem?

Directional



Delamination



<http://www.southampton.ac.uk/engineering/about/staff/rjw3.page>

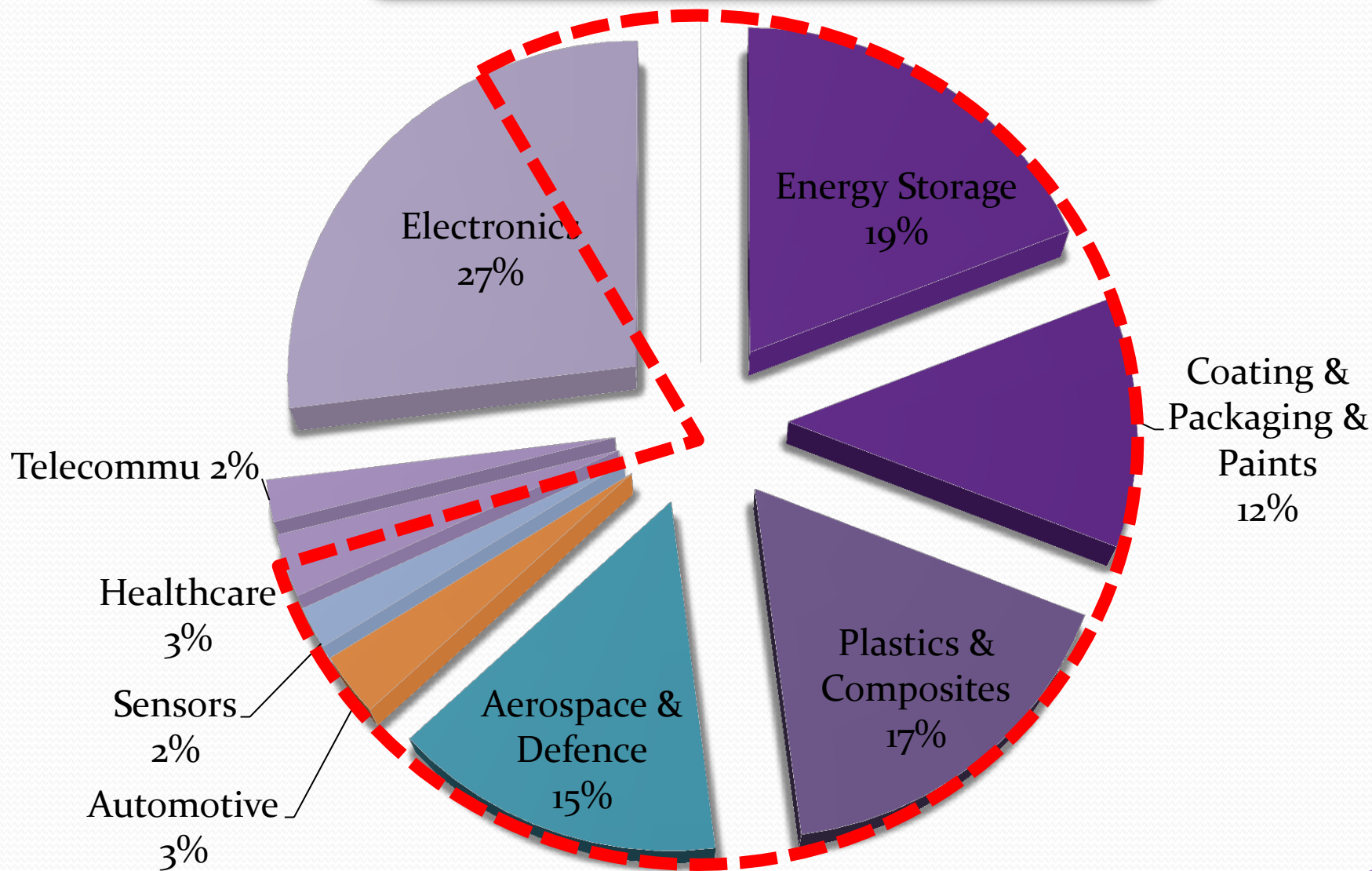
Partridge, Ik, *Philosophy Transactions of the Royal Society A*, 2016.

https://en.wikipedia.org/wiki/Carbon_fibers

www.easycomposites.co.uk

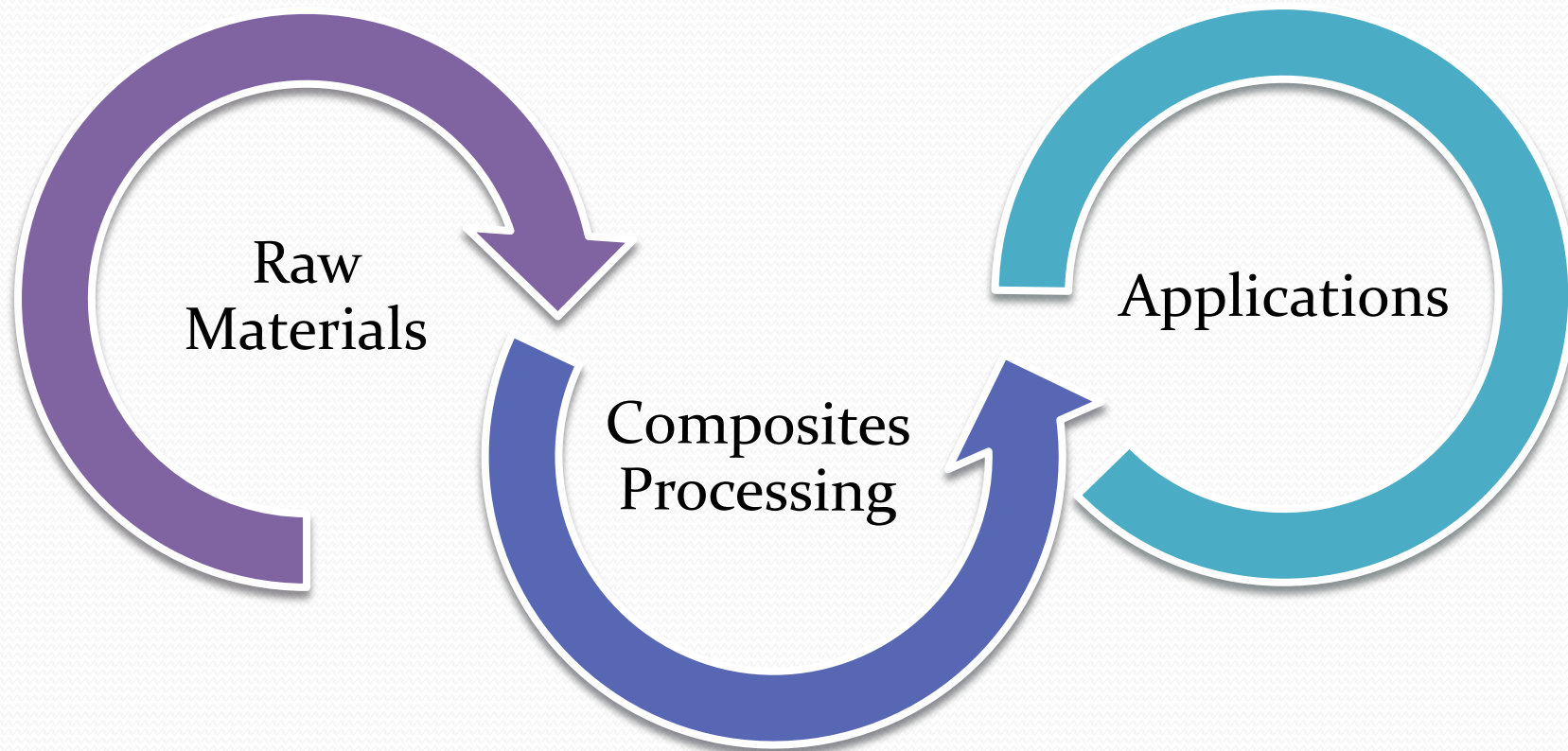
<http://imgur.com/gallery/domrd6P>

Graphene Composites

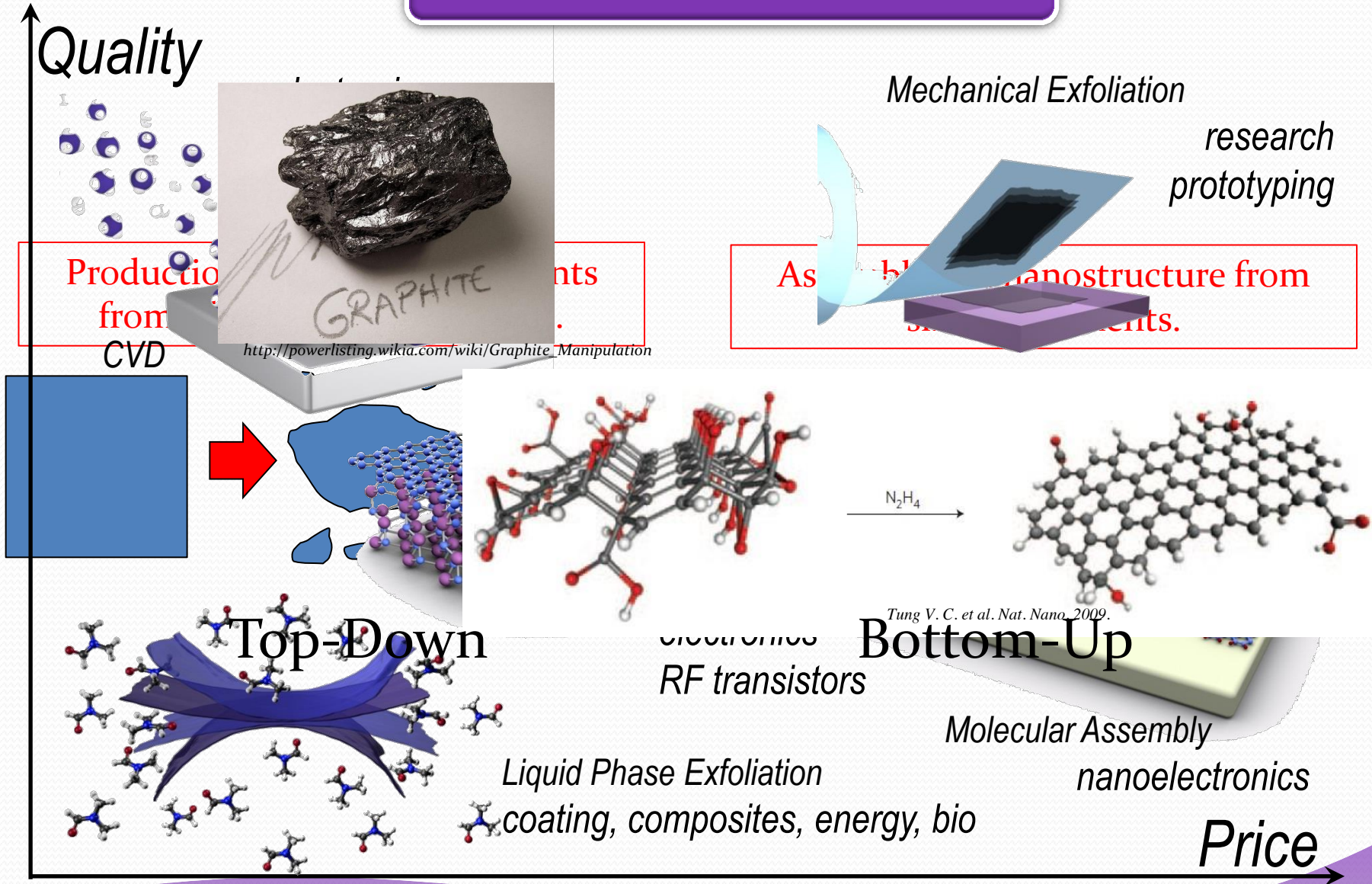


Source: Future Markets

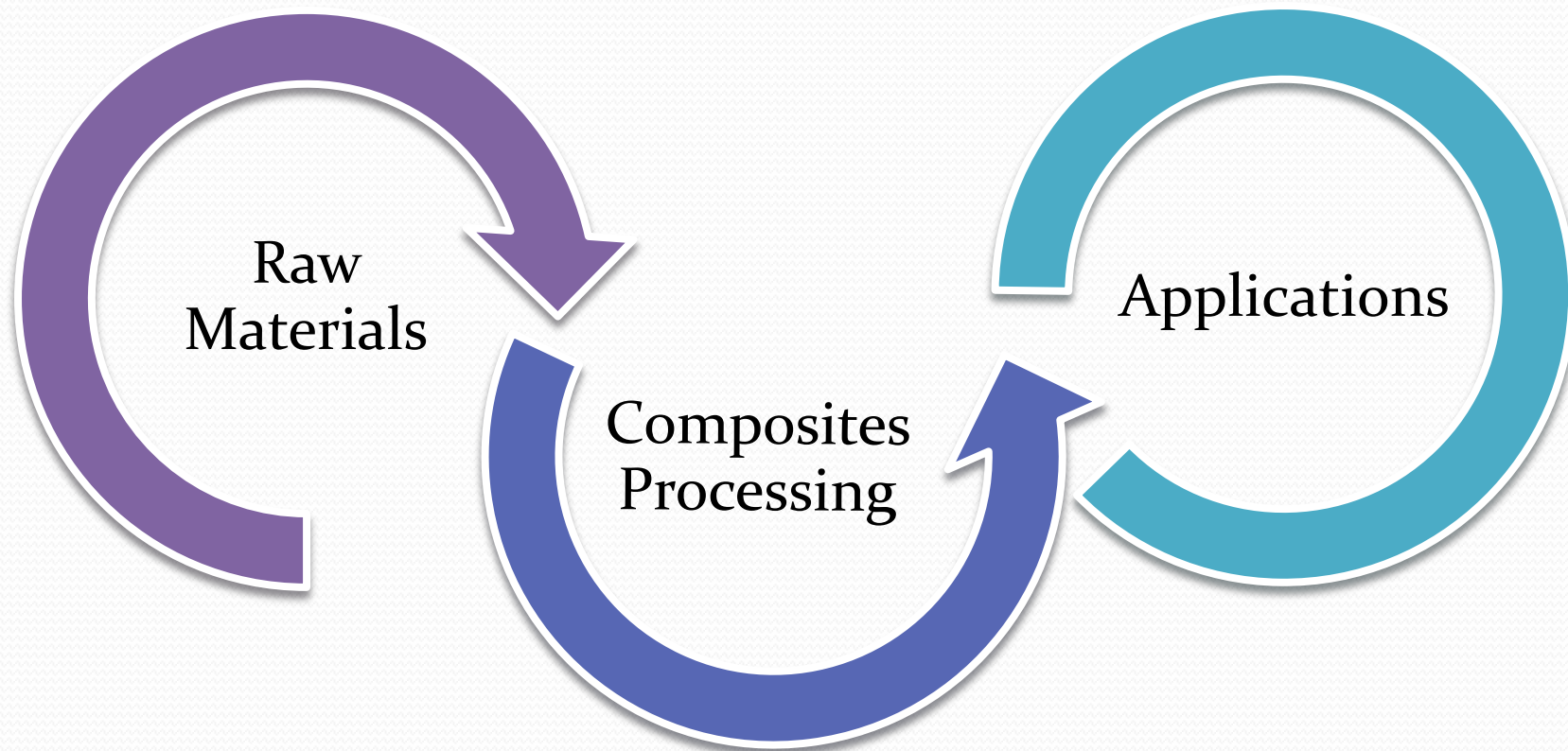
Graphene Composites



Raw Materials

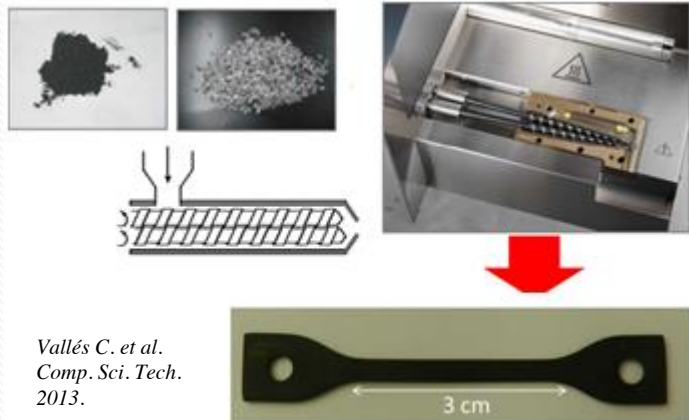


Graphene Composites

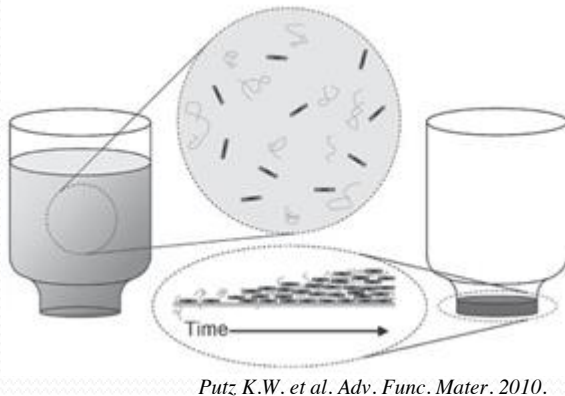


Composites Processing

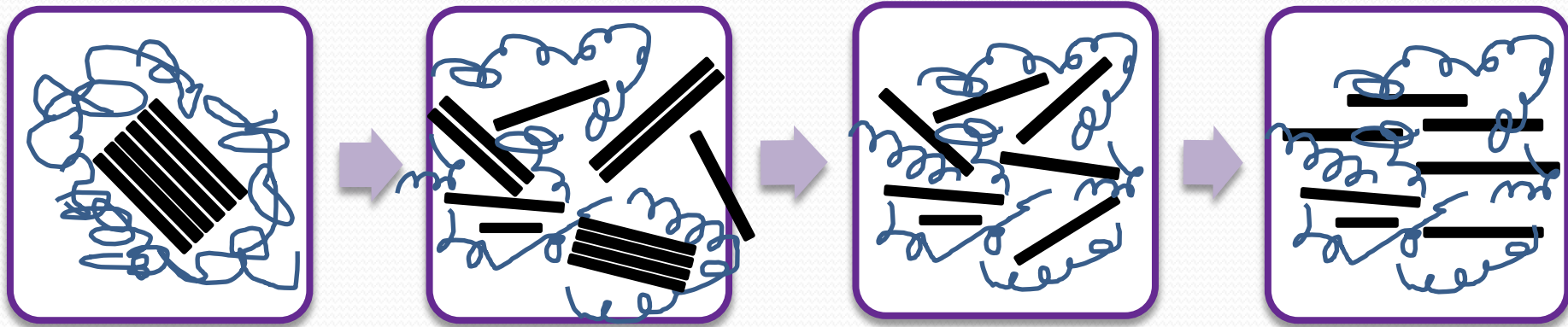
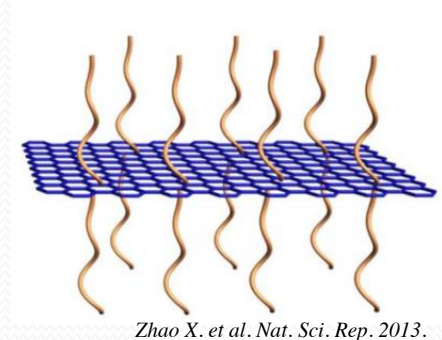
Melt Blending



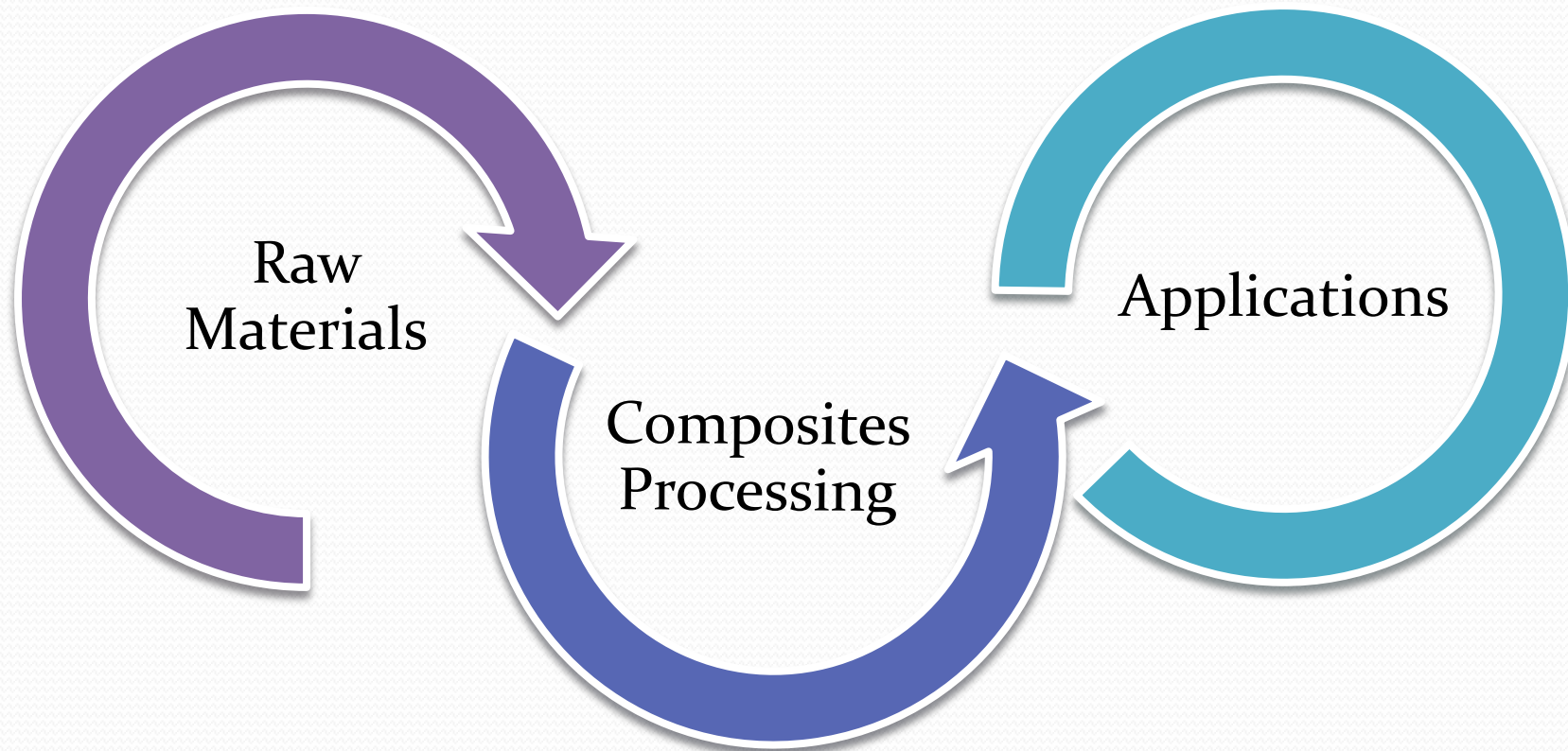
Solution Blending



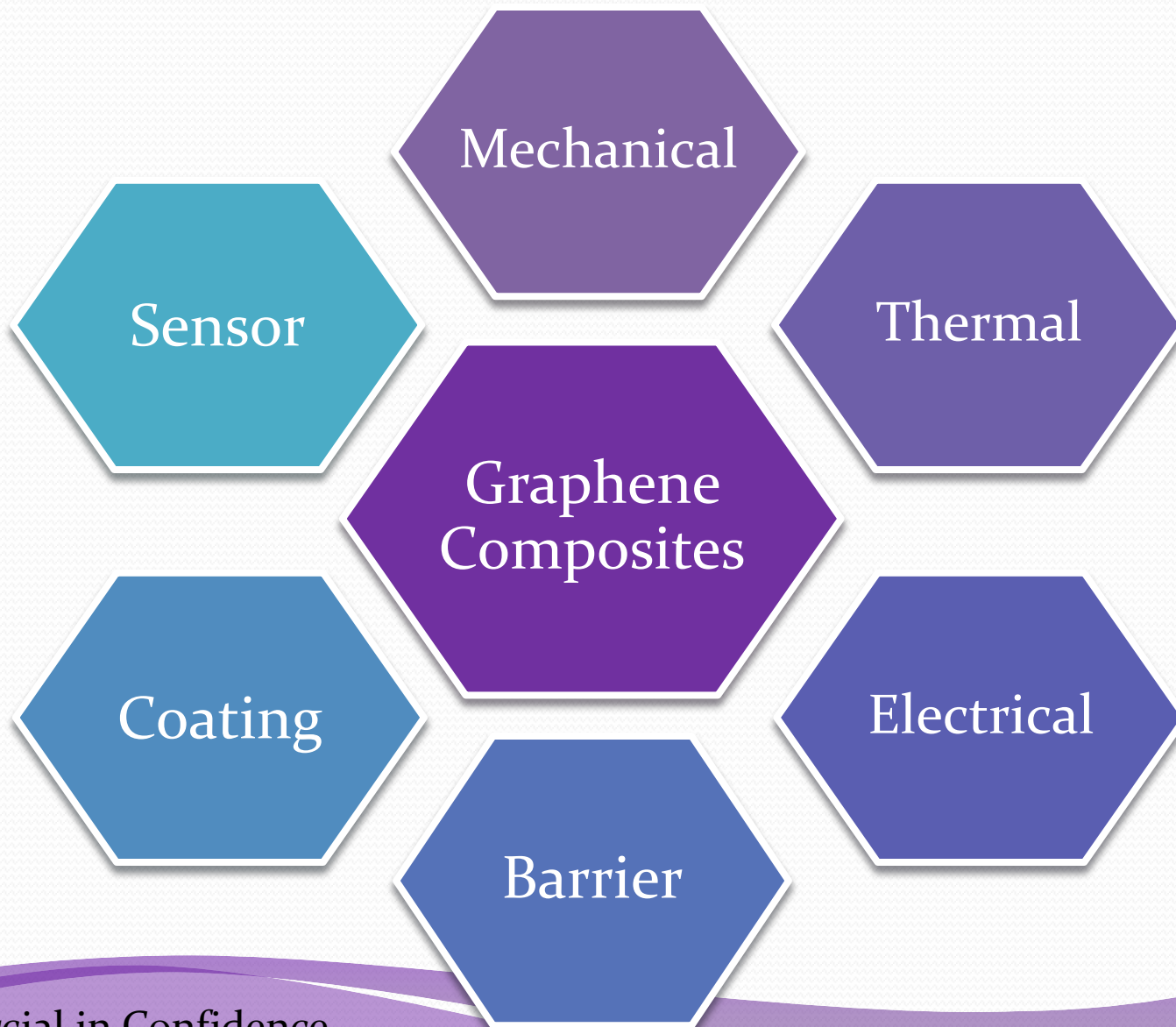
In-situ Polymerization



Graphene Composites

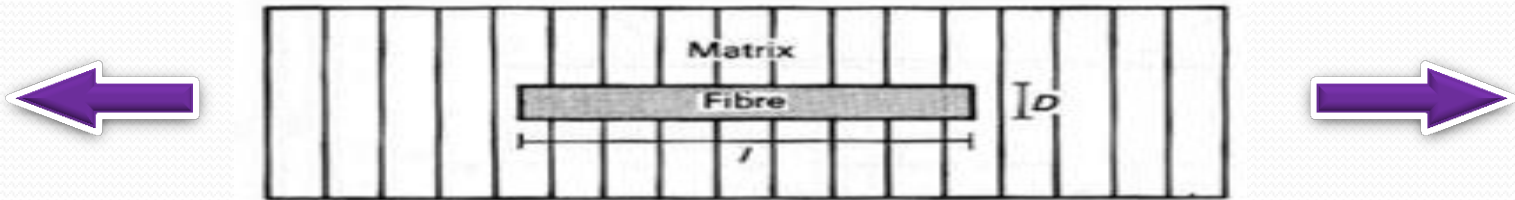


Application Map



Mechanical Reinforcement

Why Can Reinforce?



Surface Area Graphene Rigidity

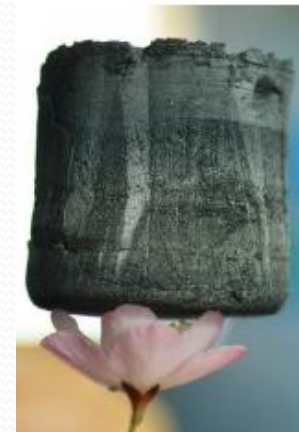


Activated Carbon x 5

Commercial in Confidence

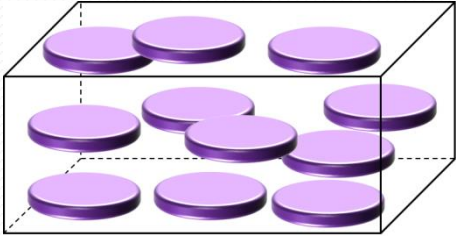


Outperforming Diamond
Most Stretchable Crystal

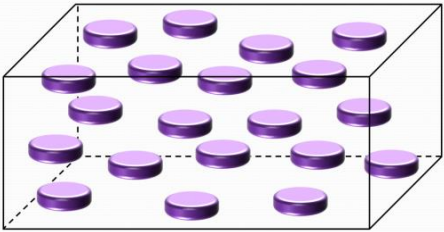


Mechanical Reinforcement

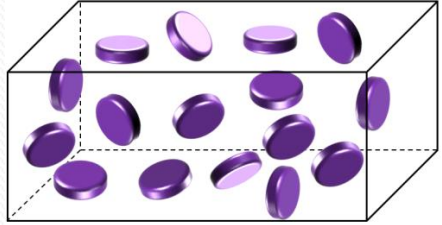
Stiffness



Large Size
Perfect Orientation



Small Size
Perfect Orientation



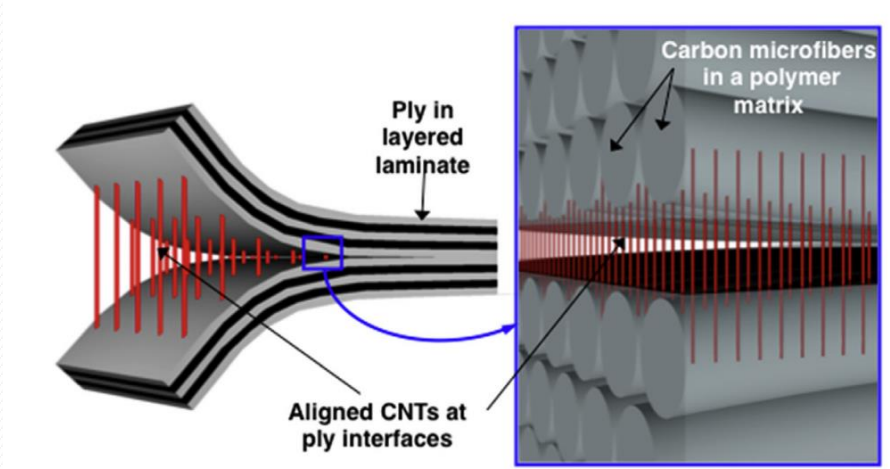
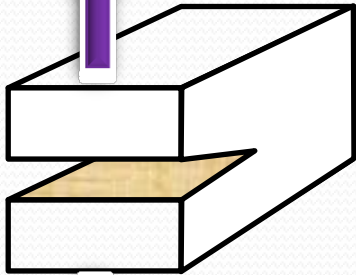
Small Size
No Orientation

Toughness

Stress

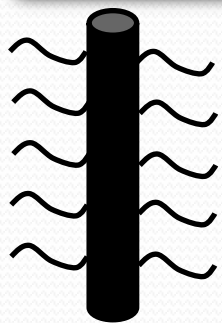


Crack Opening

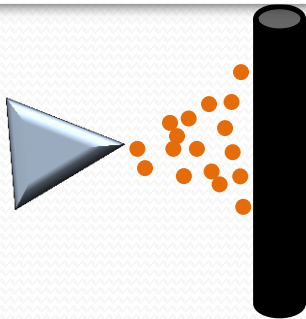


Mechanical Reinforcement

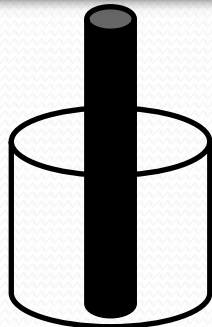
Carbon Fibre/Graphene Multiscale Composites



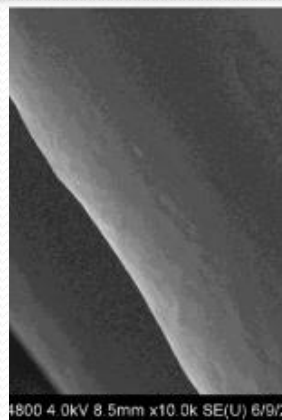
CVD



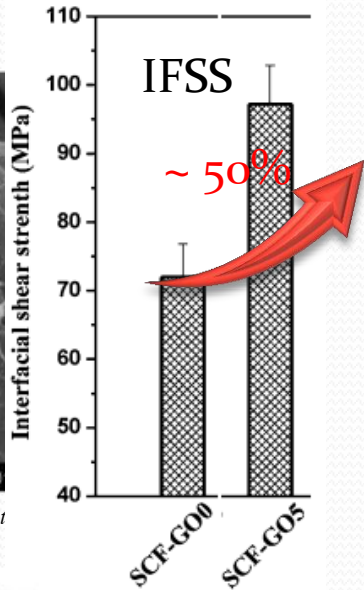
Spray Coating



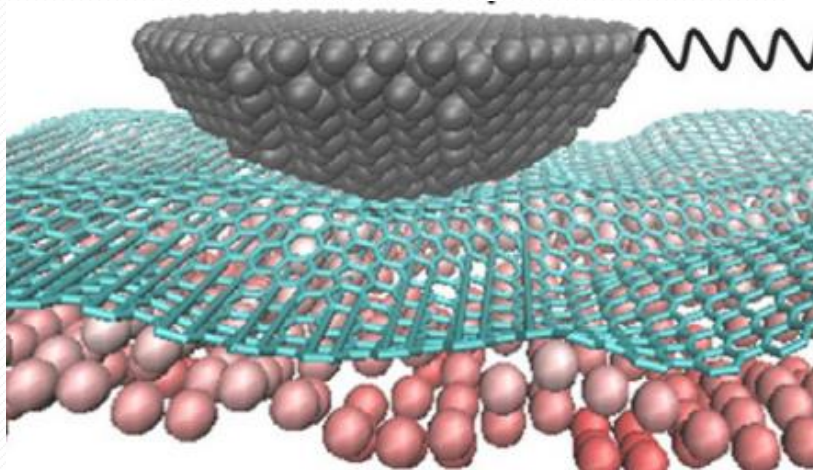
Dip Coating



Zhang, et al. ACS Appl. Mater. Int



Lubricant

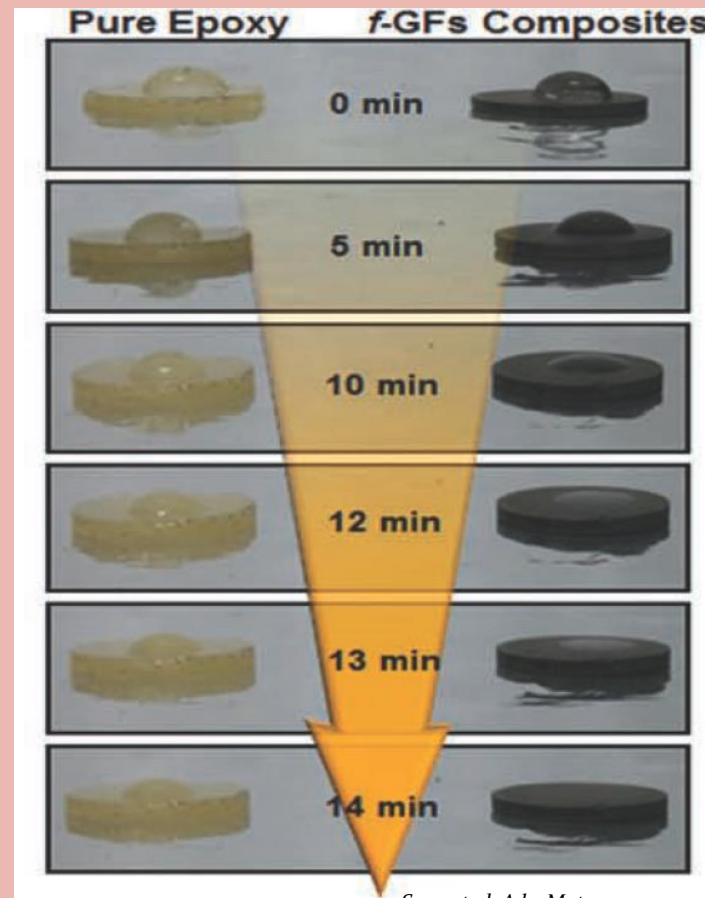
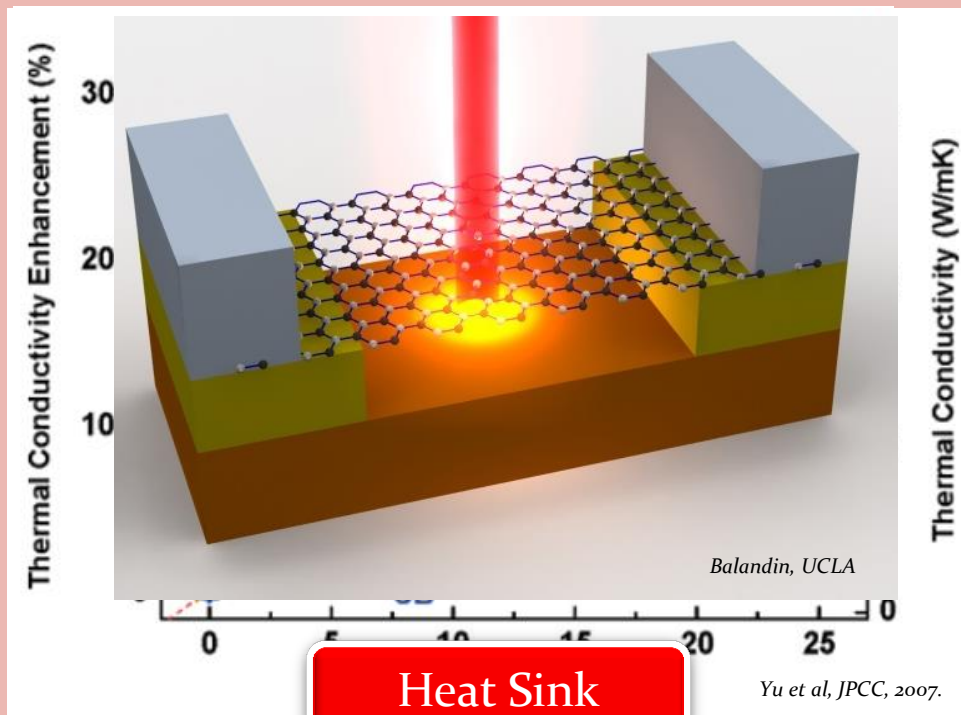


Rough Substrate

Functional Applications

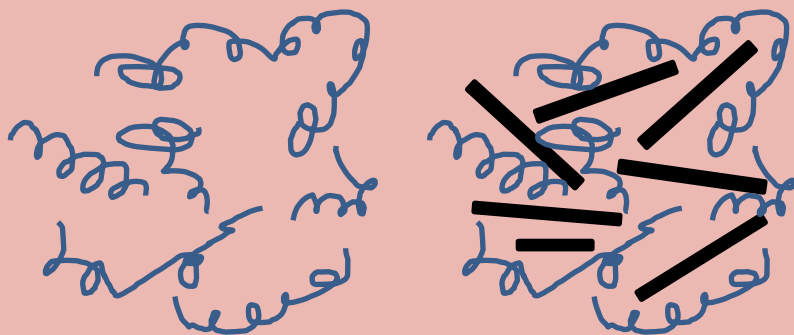
Thermal Conductivity

> Diamond at RT

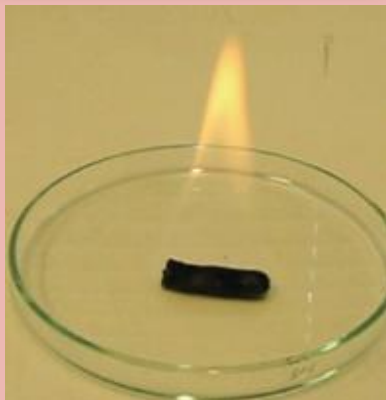


Functional Applications

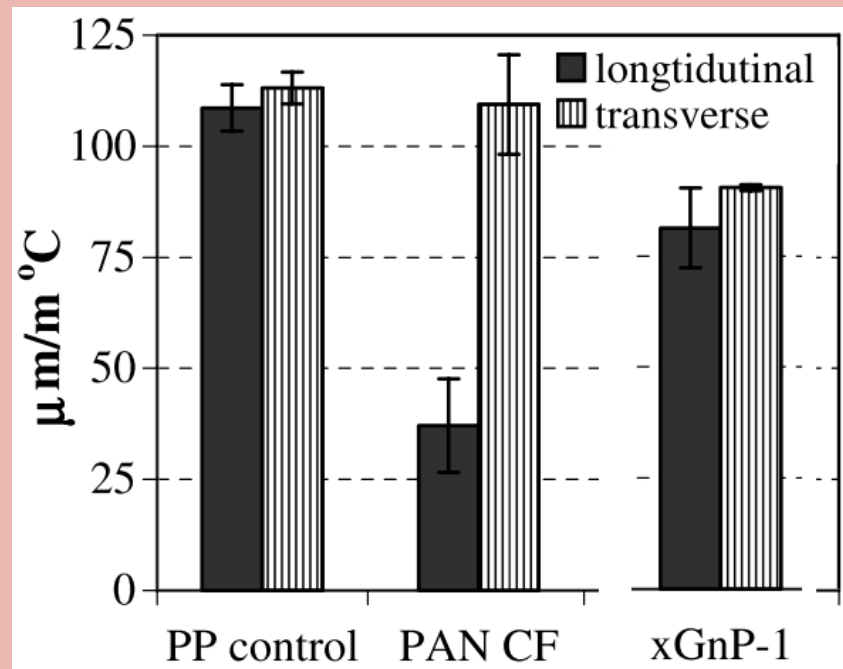
Thermal Stability



Fire-Retardant



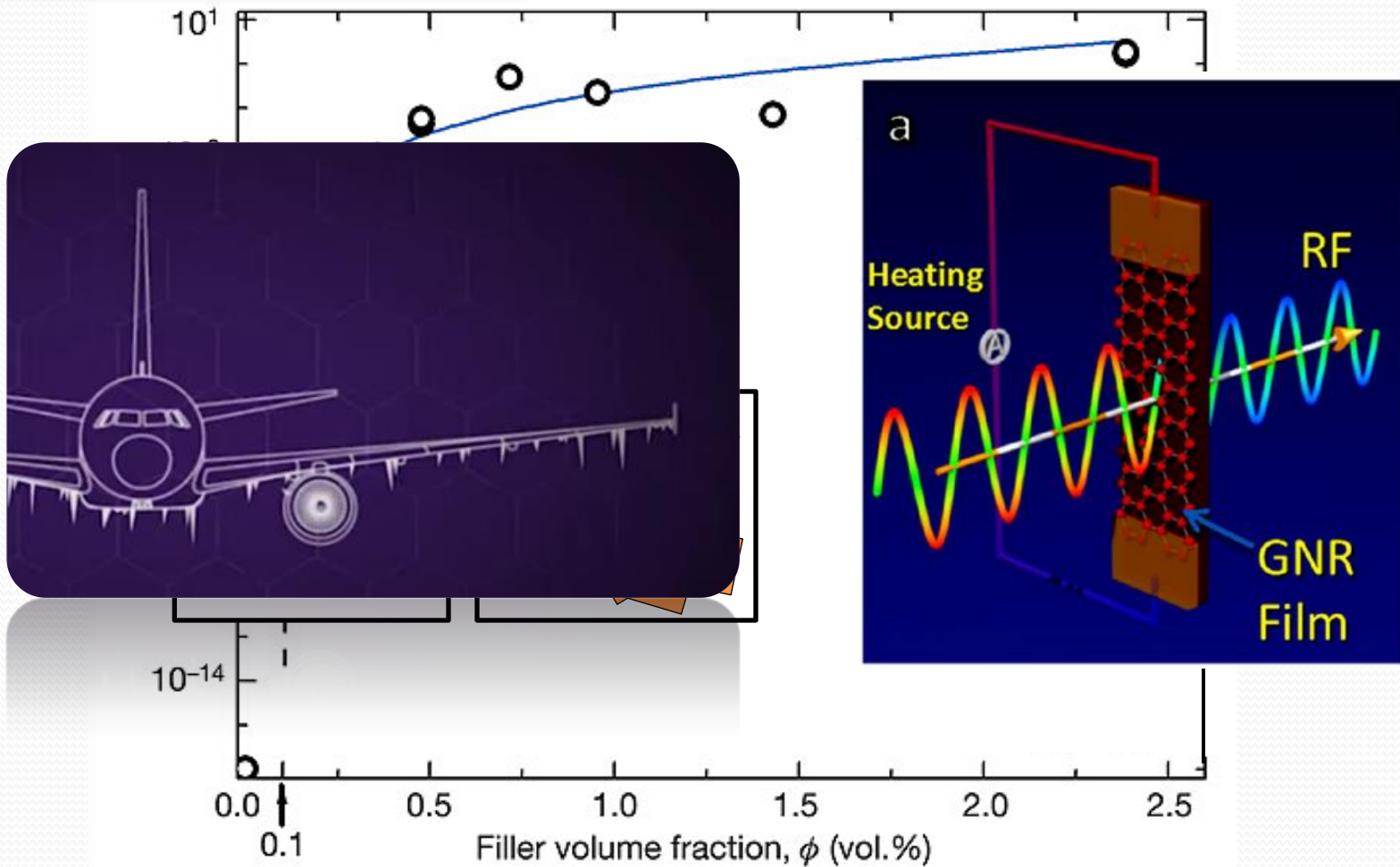
Wicklein et al. Nat Nano, 2015.



Kalaitzidou et al. Carbon, 2007.

Functional Applications

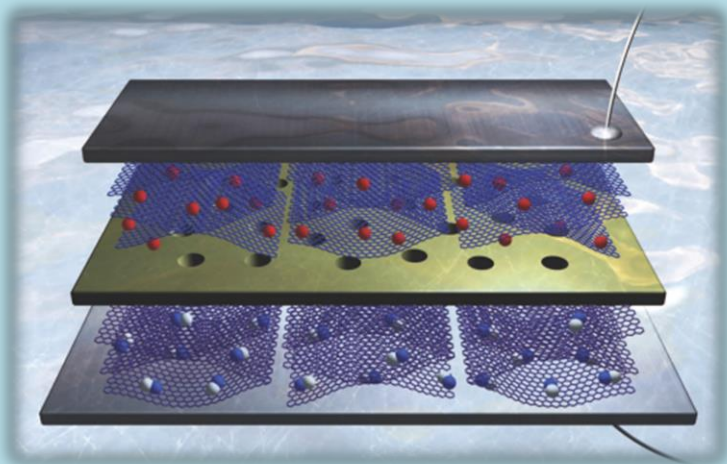
Electrical Conductivity



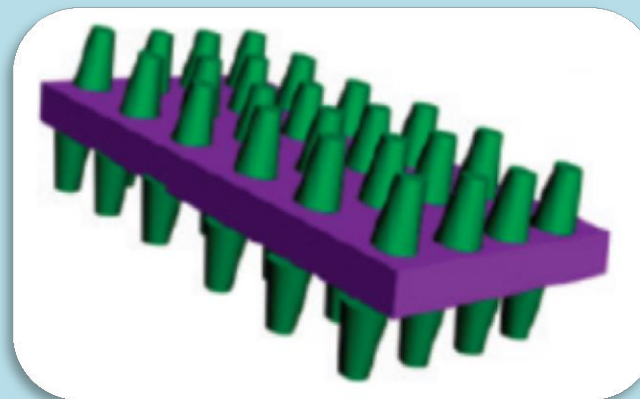
Stankovich et al, Nature, 2006.

Functional Applications

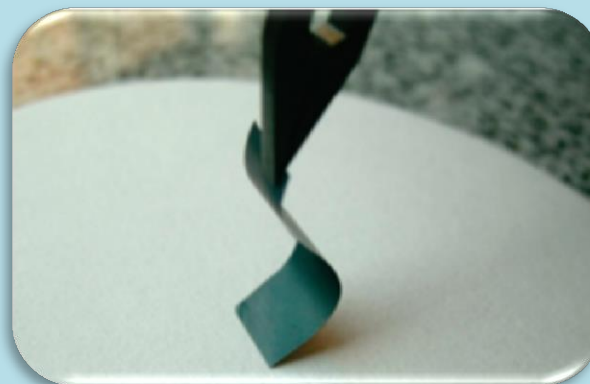
Energy Storage



Novoselov et al, Nature, 2012.



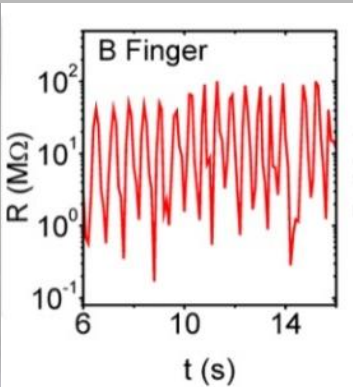
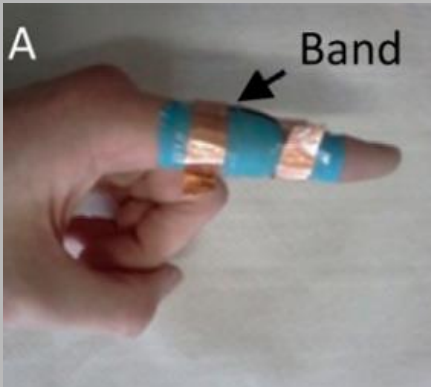
Xu et al. ACS Nano 2010.



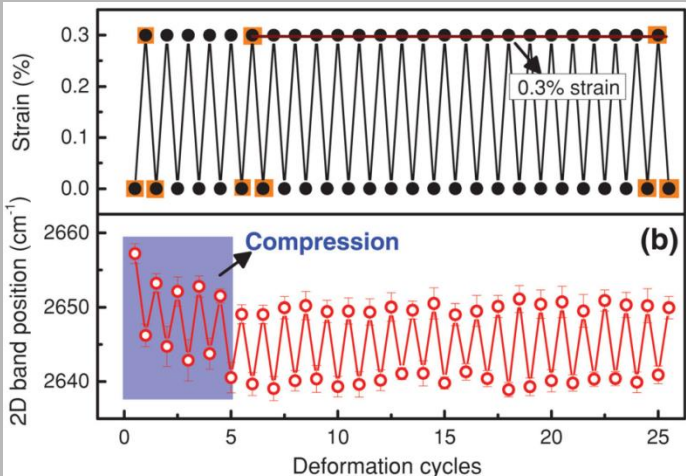
Supercapacitors Based on Flexible Graphene/Polyaniline Nanofiber Composite Films

Functional Applications

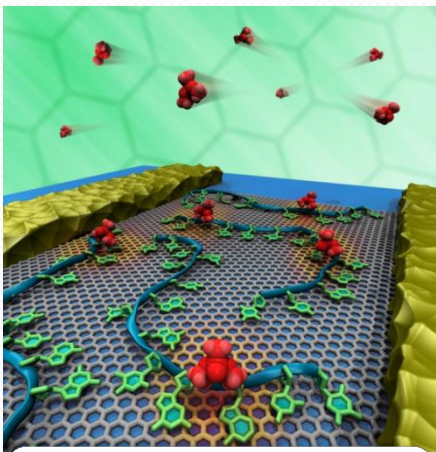
Strain Sensor



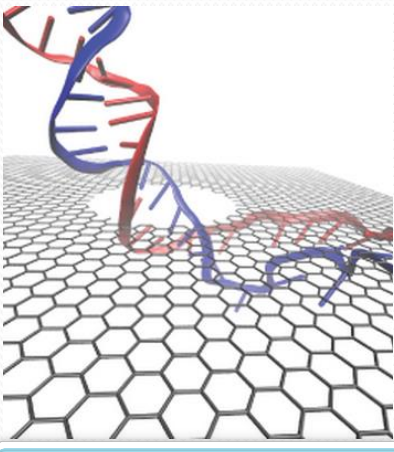
Boland et al, ACS Nano, 2014



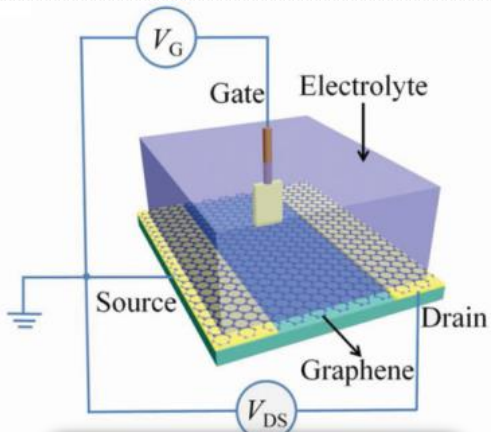
Raju et al. Adv. Func. Mater., 2014



Molecule/Ion



DNA Sequencing

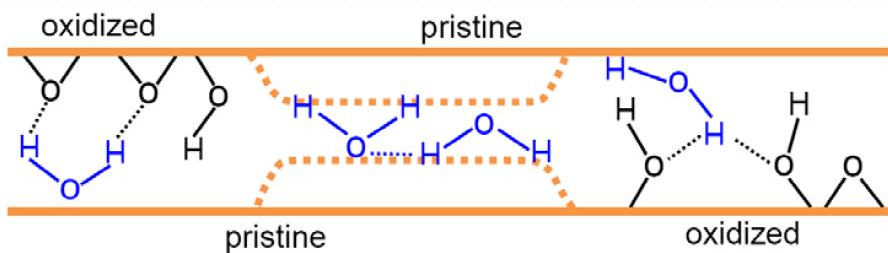
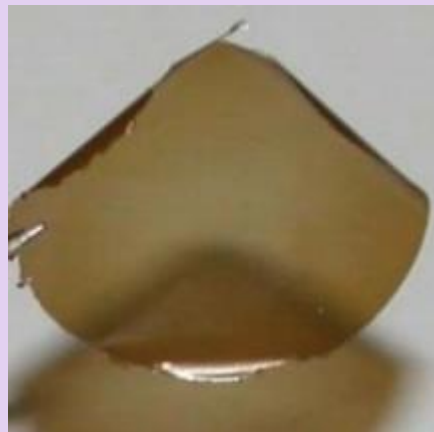
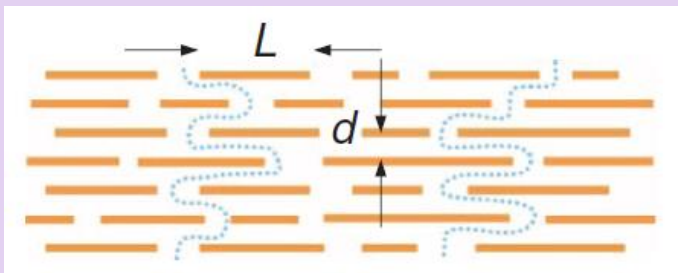


FET Sensor

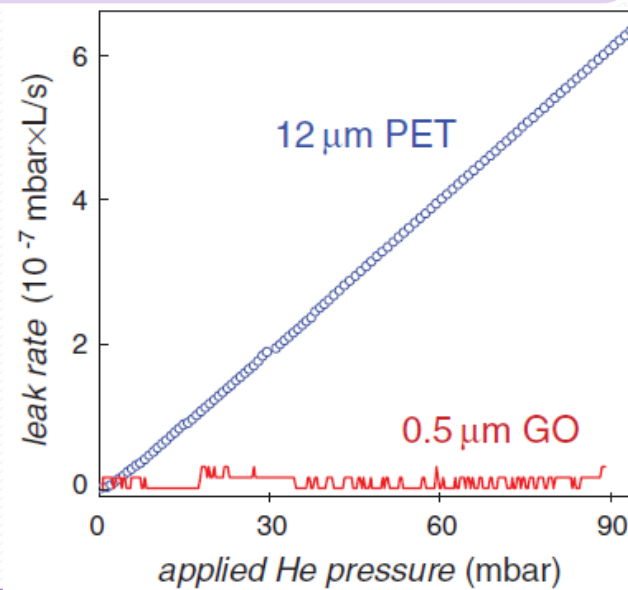
Functional Applications

Barrier

Most Impermeable
Helium atom can't squeeze

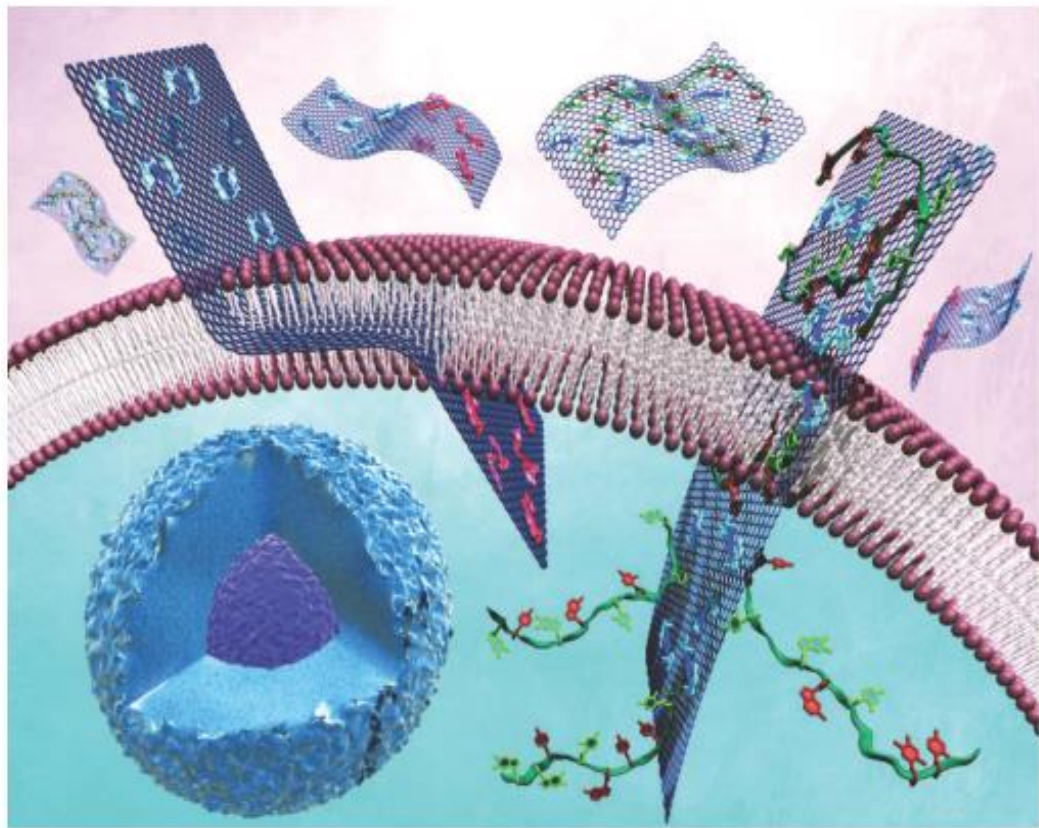
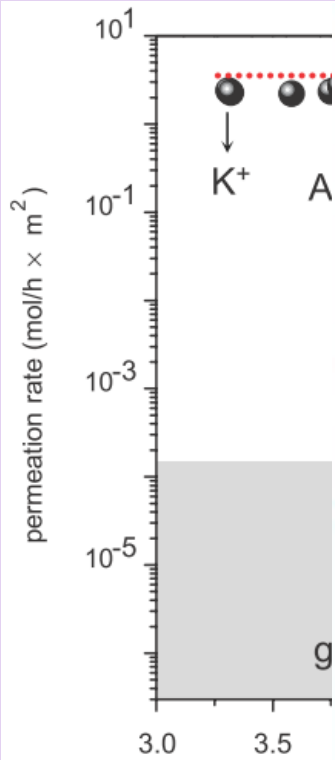


He Impermeability
H₂O Permeability



Functional Applications

Barrier



te



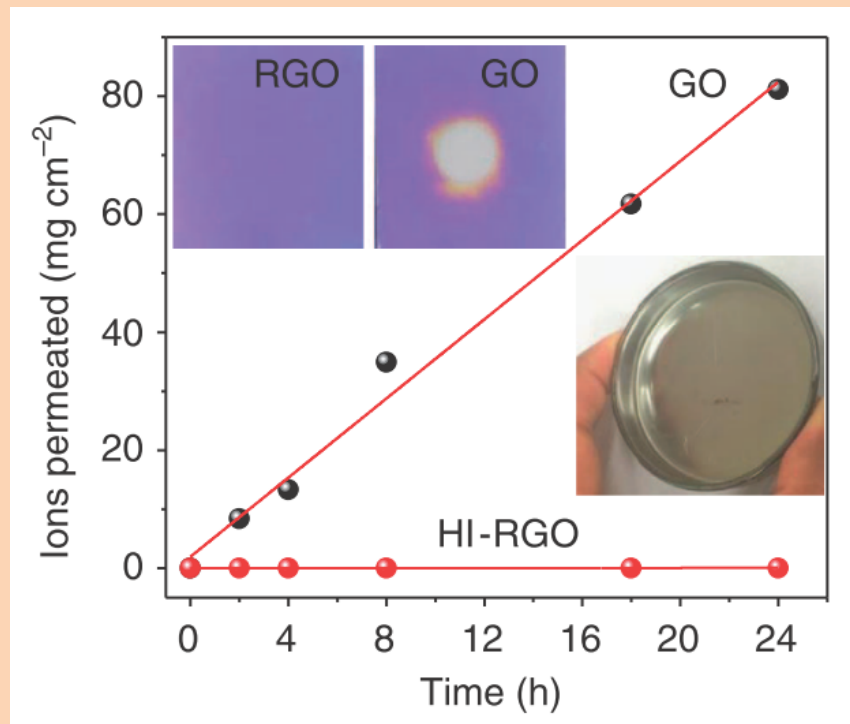
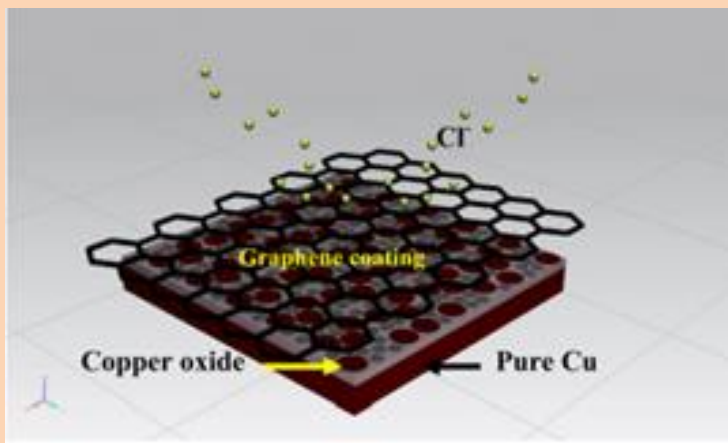
Novoselov et al, Nature, 2012.

Functional Applications

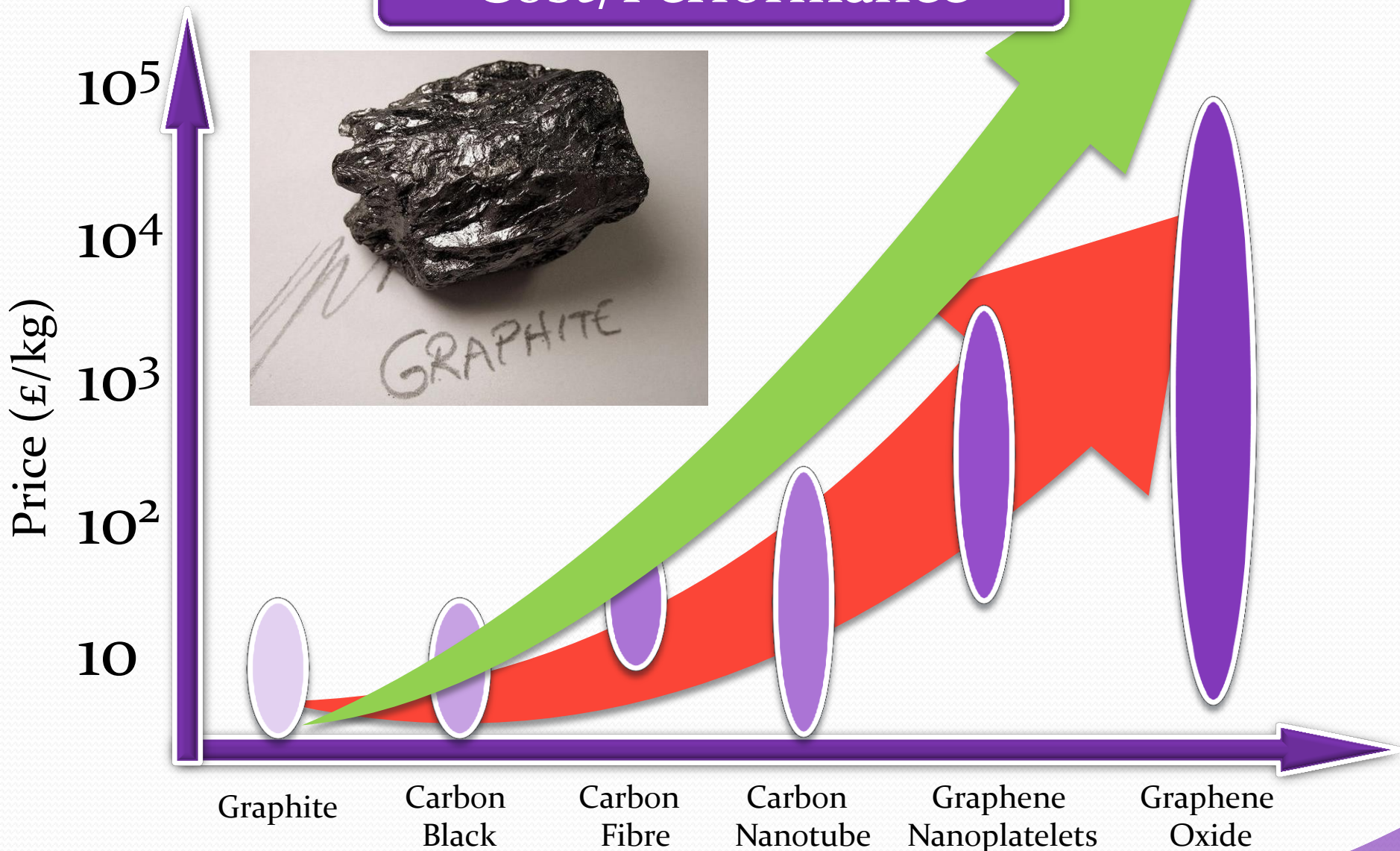
Coating



Water-proof!



Cost/Performance



Challenges

Chartered Graphene

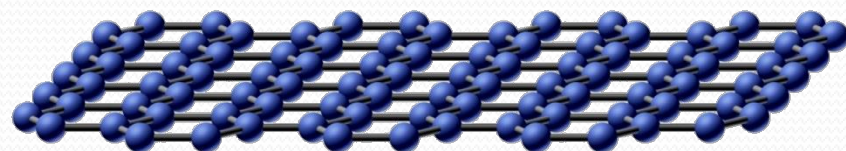
Standardization

£

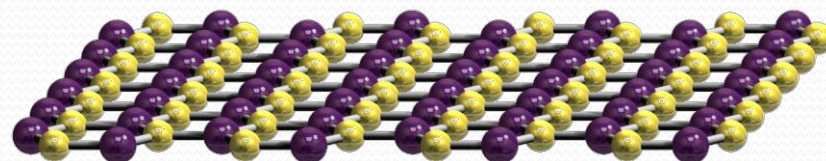
Cost

EHS
Environmental, Health & Safety

Environmental Health & Safety



Graphene

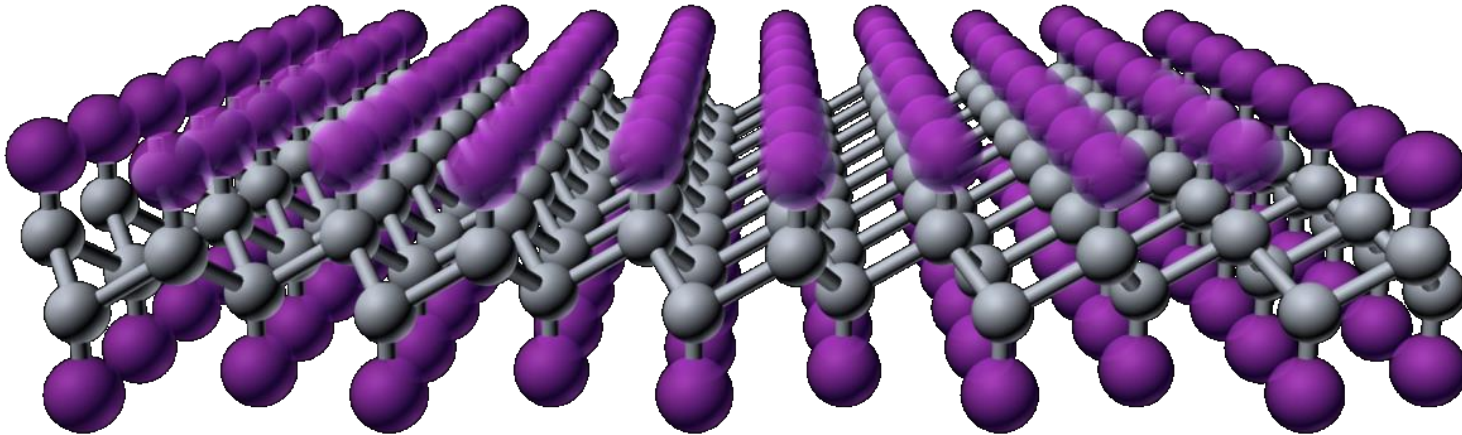


Boron Nitride

Flew in
Farnborough 2016



Graphene Nanocomposites



Dr Zheling Li (Bennie)

National Graphene Institute
School of Materials
The University of Manchester

zheling.li@manchester.ac.uk