"HVM Graphene+ 2014 Conference
Oxford, UK 15 May

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carbon technologies

The Worlds Largest producer of Functionalised Doped and Decorated Graphitic nano structures current capacity circa 100 tonnes per annum

Barriers to commercialisation

- Typically pristine graphene currently can only be produced bottom up via CVD growth on a substrate, The outputs are typically single or double layer flakes with relatively few defects.
- Barrier production is limited to grams per day, grain boundary's create issues for electron transport and thermal dissipation.
- Top down does not produce graphene it produces a material more akin to nano Graphite, (by the way nano graphite is a useful material) barrier expectations are elevated, consumers are disappointed.
- The average price of a gram of what is often a highly defected acid boiled graphite often referred to as graphene in 2013 was likely to be say £25 a gram. Barrier price and quality
- It is a fact that in 2013 the development of graphene and nano graphite remained trapped at the R&D stage worldwide. The market requires 100's or 1000's of tonnes. Barrier In 2014 Mass production will not been realised.
- **Most importantly Environmental impact, Lifecycle analysis and Nanotoxicology is underfunded and to an extent ignored.**
- If and after commercial production is realised the market could be enormous for both graphene and nano graphite.

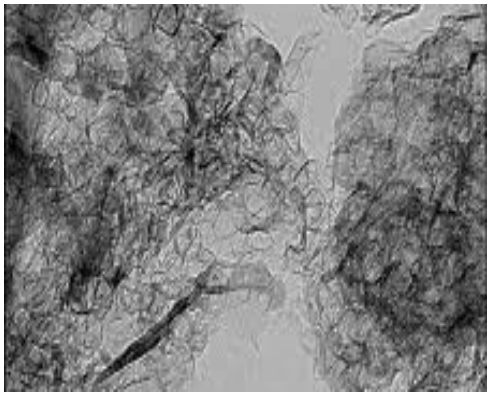
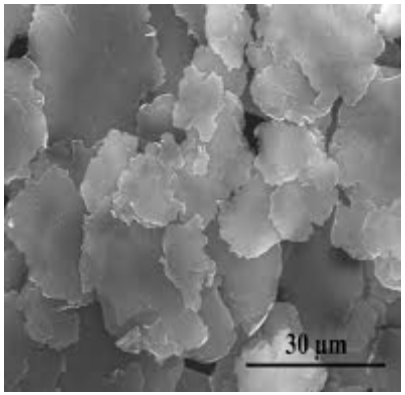
The Fledgling Graphene industry lacks credibility

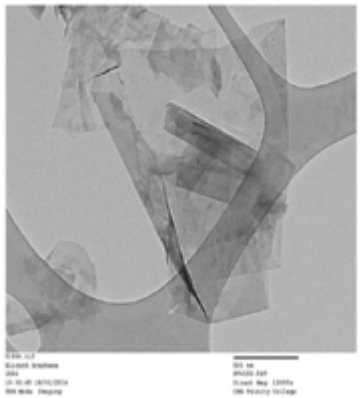
- Inaccurate and misleading claims from high profile company's in the graphene market space create havoc:
- “our ink is 100% graphene”, , it is impossible why claim it? “we can produce 20 tonnes per annum”
- X company sets the global standard for high-energy density graphene from a globally patented process. That process uniquely transforms raw, unprocessed graphite ore to affordable and scalable, high-purity, few layer graphene. There are no patents. Their sales revenues for the last 3 years zero
- 2014 Previously, the xxxxxxxxxxxxx Technologies’ scientists produced a new type of graphene paper called bucky paper. The thin sheet of carbon is still being experimented with, however, the scientists say it will revolutionize automobiles, aircraft, displays, electronics, batteries, medical treatments and more industries in years to come. CEO in Jail

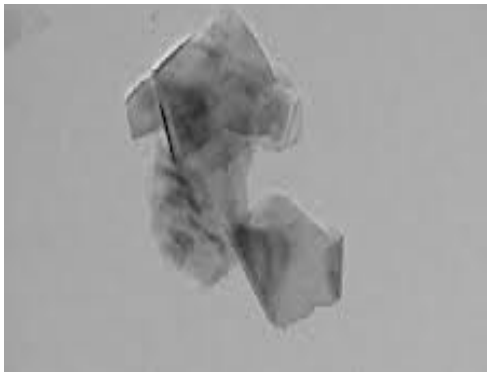
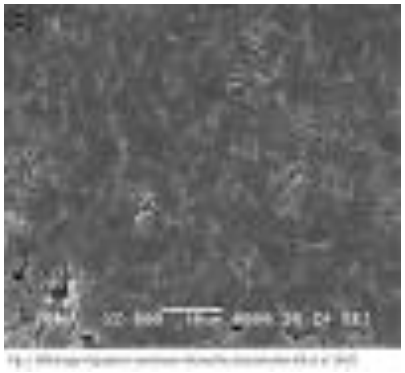
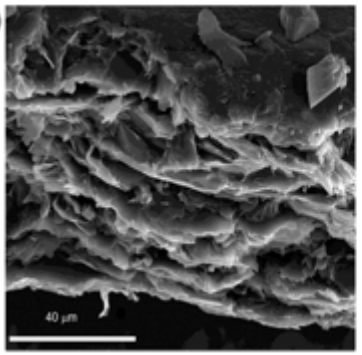
This hype has raised millions in investment. **The market is in danger of a loosing confidence**

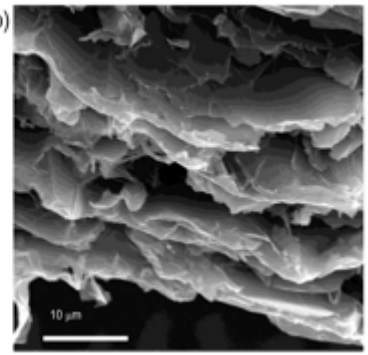
Graphene? industry offerings

Is this graphene? - ”a form of carbon consisting of planar sheets which are one atom thick, with the atoms arranged in a honeycomb-shaped lattice”.





Nano Graphites or GNPs and Nano Carbons are useful materials in their own right and have part to play but lets not pretend they have the same characteristic's as graphene

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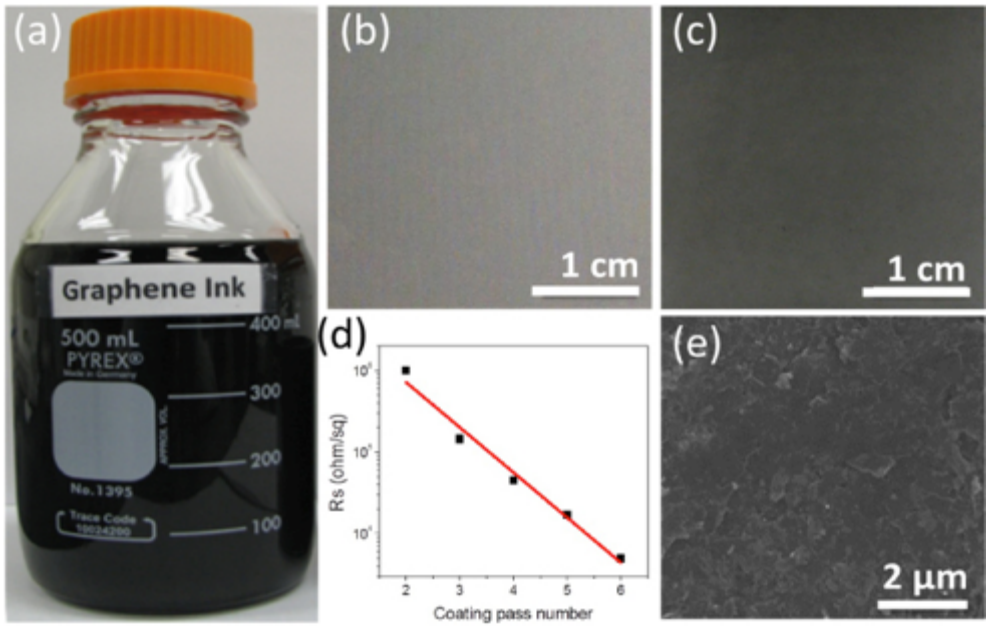
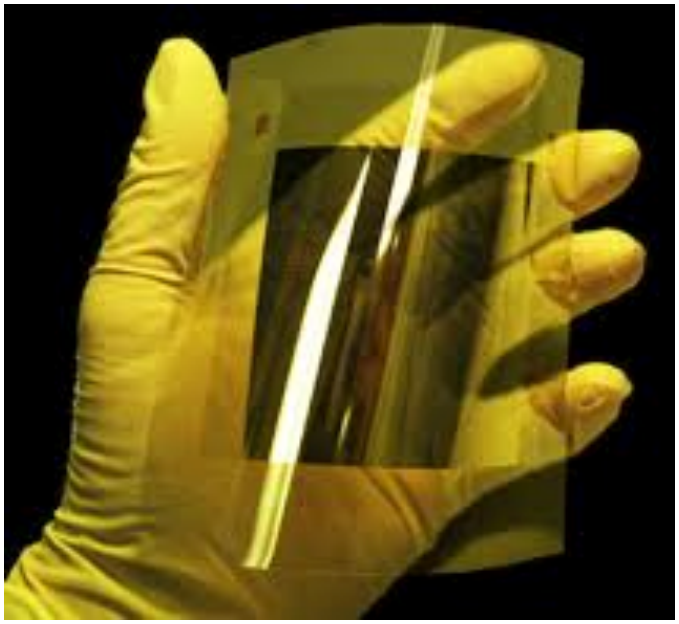
First product on the market graphene inks, but are they graphene inks?

2011 Leading UK University say they have made a giant leap forward because their printable graphene transistors are lighter, more conductive, more stable and cheaper to produce than anything seen before. Its now 2014 where are they?

Are there any commercial manufacturer's of “graphene inks” out there that do not include copious amounts of carbon and graphite to make them conductive?

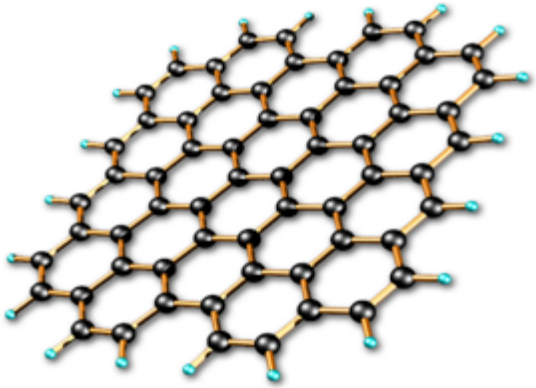




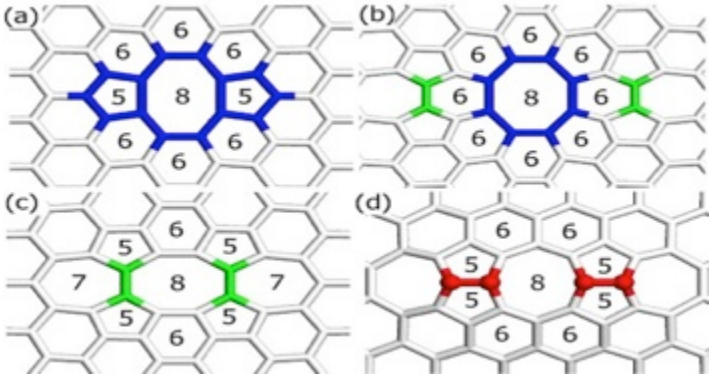
Inks that include small amounts of graphenes or GNPs enhance carbon inks- they process easier and promote adhesion so they are useful - however a sub ohm ink will never be produced from GNPs on their own they need help.

Reality of Structures that are currently referred to as graphene

Currently impossible to produce in infinitesimal widths and lengths



Vacancy's & Voids- defects are common in GNP's & present in CVD graphene



Typical defects in graphene type structures are caused by dislocations, grain boundaries and phase interfaces, often there are bloody big holes all have a negative effect on the electrical, thermal and mechanical properties of graphene.

If graphenes were really available in one atom thick structures at 2700 sq meters per gram packaging and handling would be impossible.

Flat graphene sheets/flakes are unstable if unsupported they cannot remain flat.

Transporting a tonne of graphene flakes would require x containers

Perpetuus method ? Is this more hype?

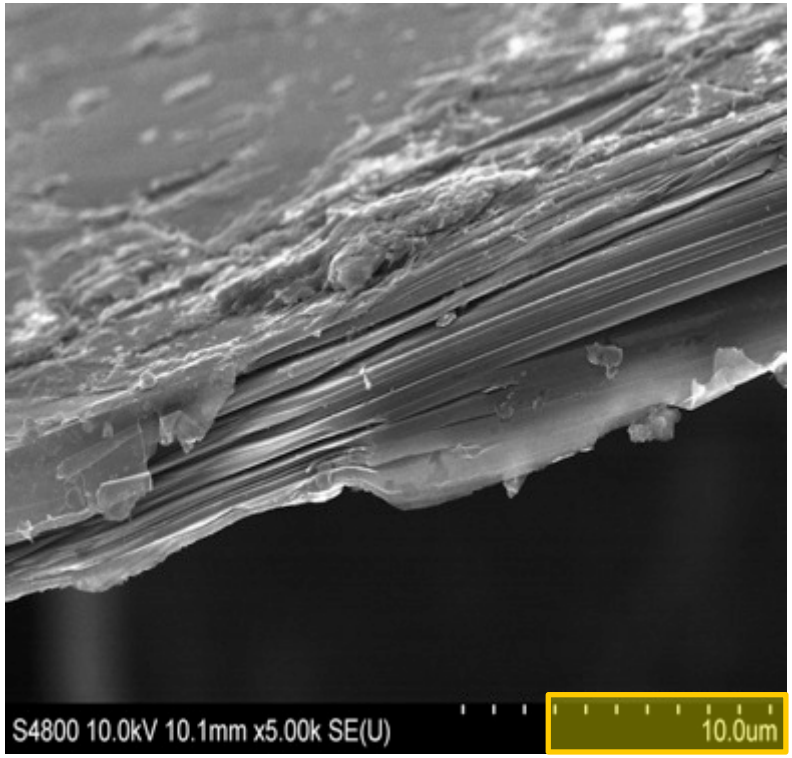
- Method - DBD or “plasma” within a unique purpose built reactor:
  - Purify and surface engineer . graphite, graphenes and carbon nanotubes.

  plus some others-molybdenum disulfide (MoS2), niobium diselenide (NbSe2) and boron nitride (BN)
    - Increase surface area by exfoliation
    - More often than not an unavoidable consequence of the process –we also generate defects
- By utilising solids and vapours to gasses in the process we surface engineer the material to repair defects enhance dispersion enhance conductivity and provide effective integration within the targeted matrix

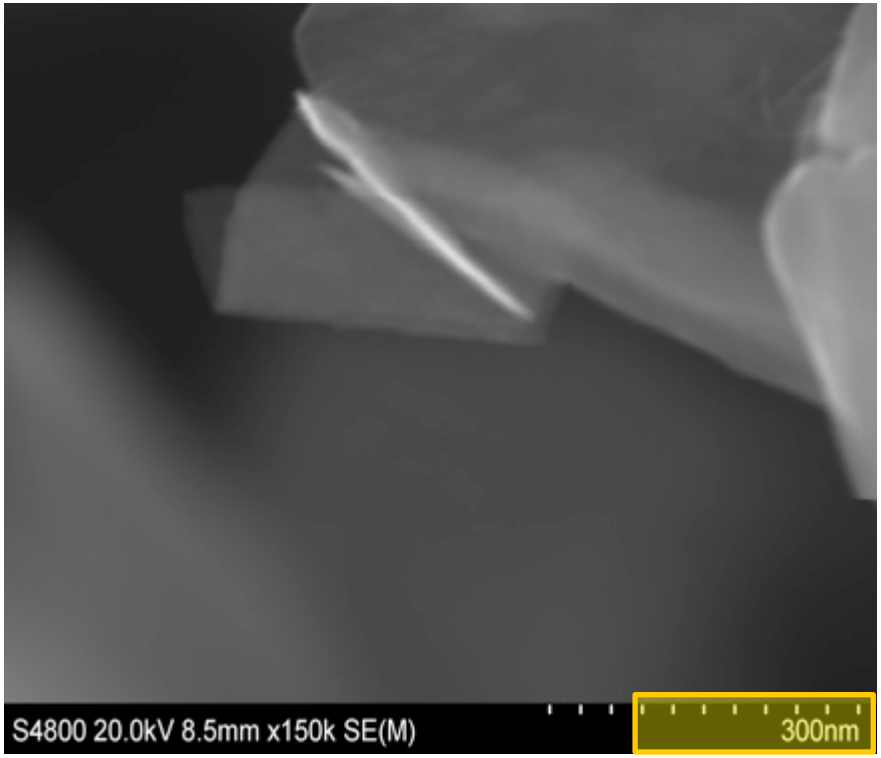
How we do it

- Computer controlled - Quality Control,
- Automatic,- “nanosafe load off load system”
- Multiple (more than 100) gas vapour diffusers for even plasma or ozone richness
- More than 1000 times pore powerful than any current known system.
- Multiple gas vapours inputs and mass flow controllers – precise decorates dopant functionality surface inhabitation control
- Current capacity 100 tonnes per annum with a single unit.

In
Mined Natural Graphite
Process Material



Out
Graphenes



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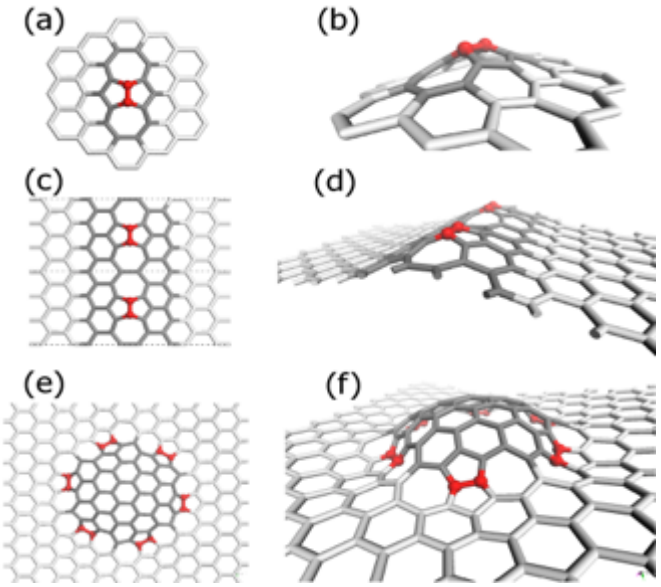
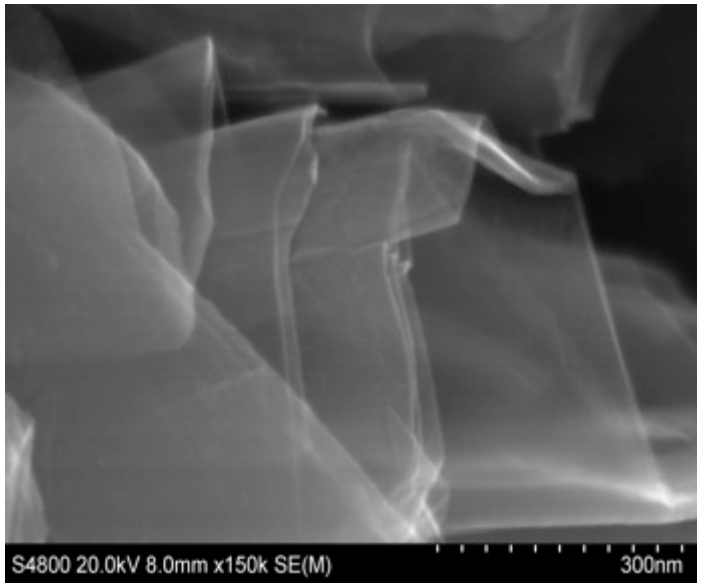
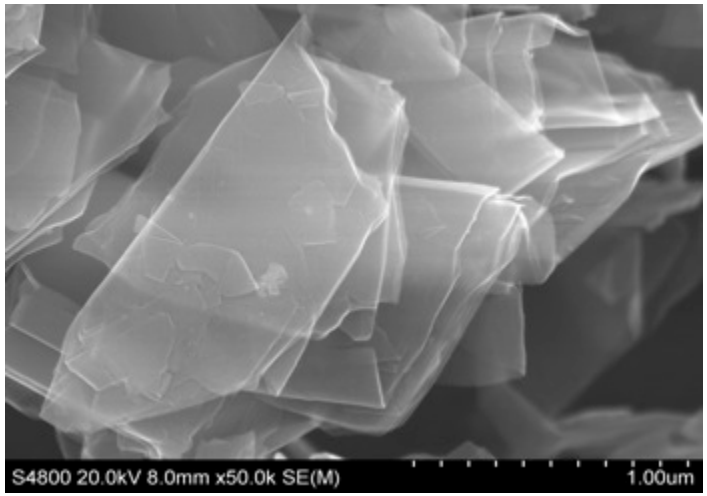
Liberating Graphene via Stone-Wales defects

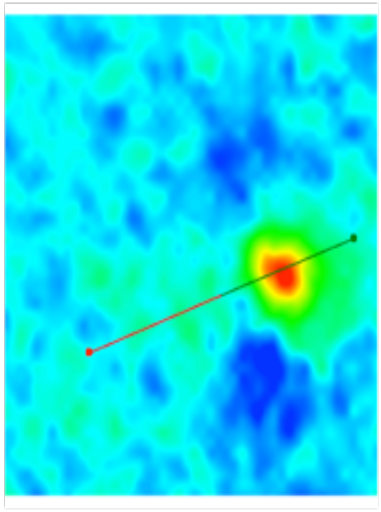
Doe to the π/2 (90°) rotation of a C–C bond. Six-membered rings are rearranged into pentagons and heptagons. The density of Stone–Wales defects is relatively small due to the high activation barrier of several eV for the bond rotation. However the defects in all probability facilitate partially or wholly the destruction of the Van Der Walls forces that hold that graphenes within the graphite.

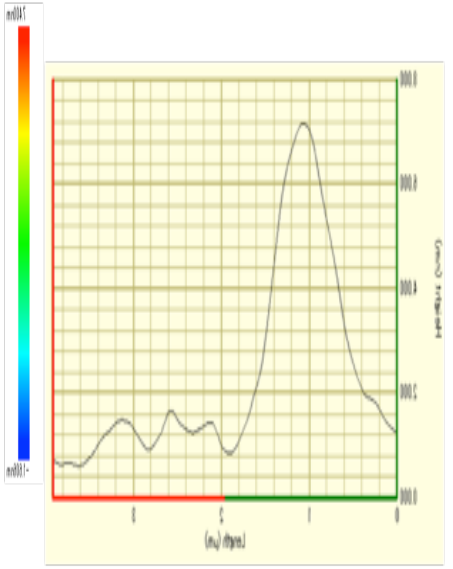




The outputs - friable graphene stacks







Designed to be “handle-able” and manageable typically the stack is made up of 2 to 3 layers of graphene with a gap followed by another two to three layers. The graphenes are realised when mixed using shear forces.

- Sample preparation stacks were placed on silicon wafer.
- “Topped Off” utilising a nitrogen gun
- Revealing ease of friability
- Residue left on silicone wafer analysed with Nikon BW-S50X 3D optical microscope clearly shows 3 layers of graphene
- The issue of dealing with grain boundaries and defects still remains

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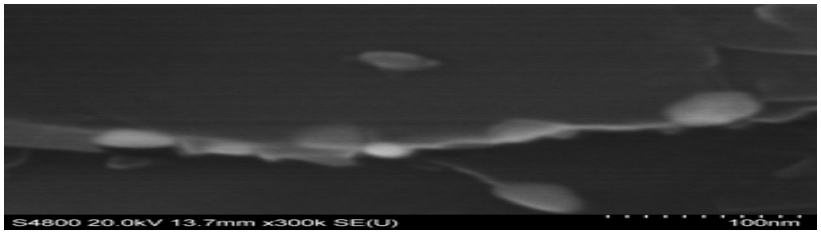
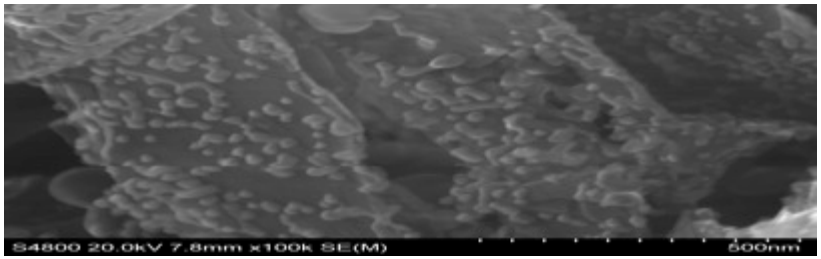
Other outputs doped decorated etc.

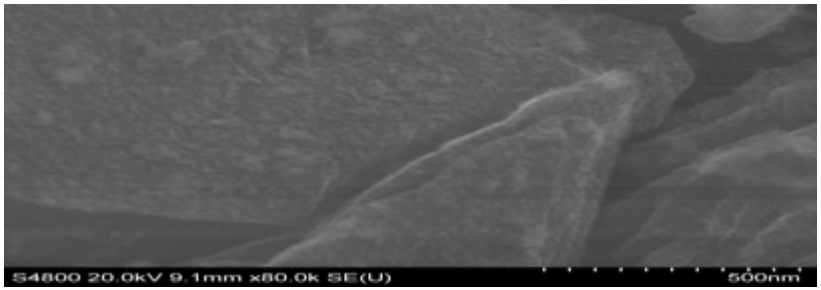
Precious metal doped decorated



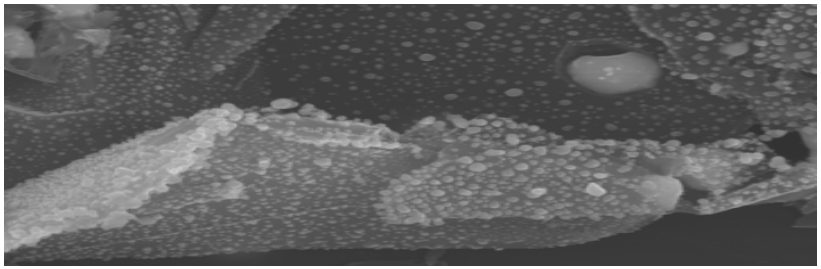
Silicone pods < 50 nm



Sulphur pods < 50 nm



Silver doped



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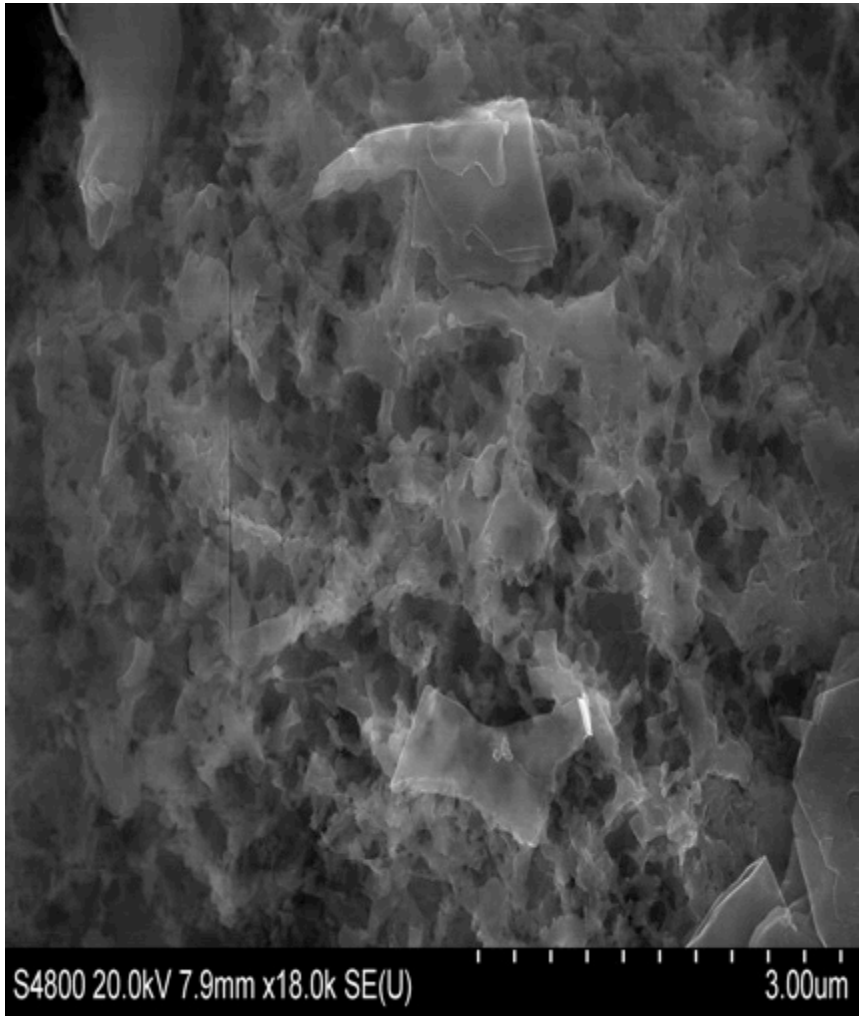
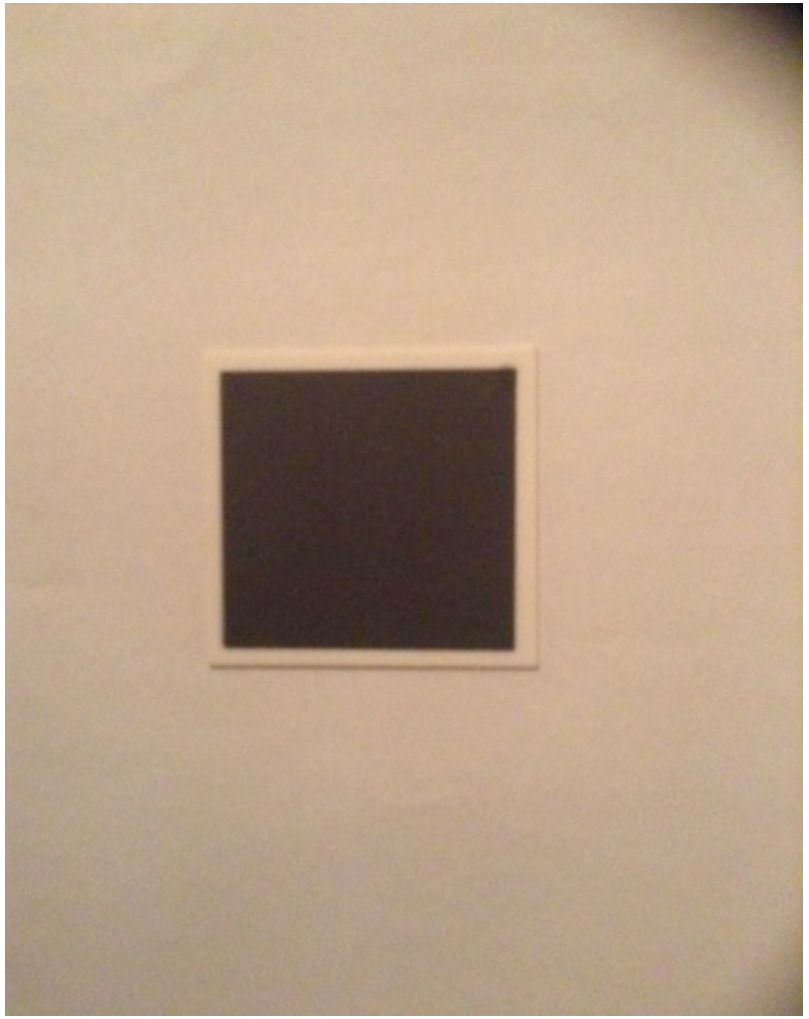
Intercalation Sulphur – Li-S battery





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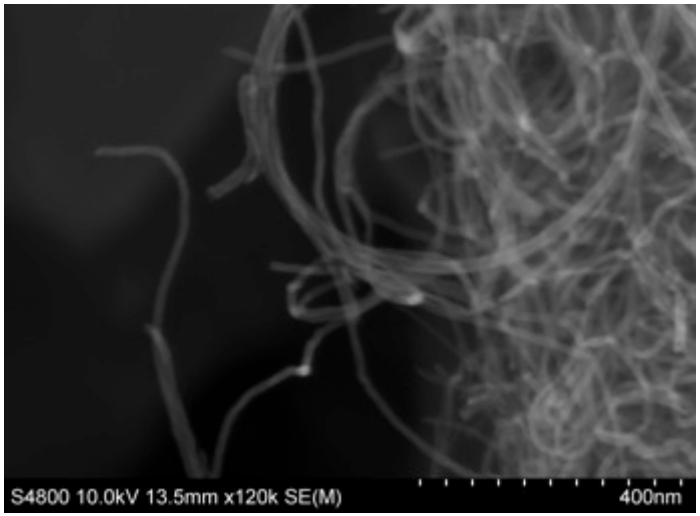
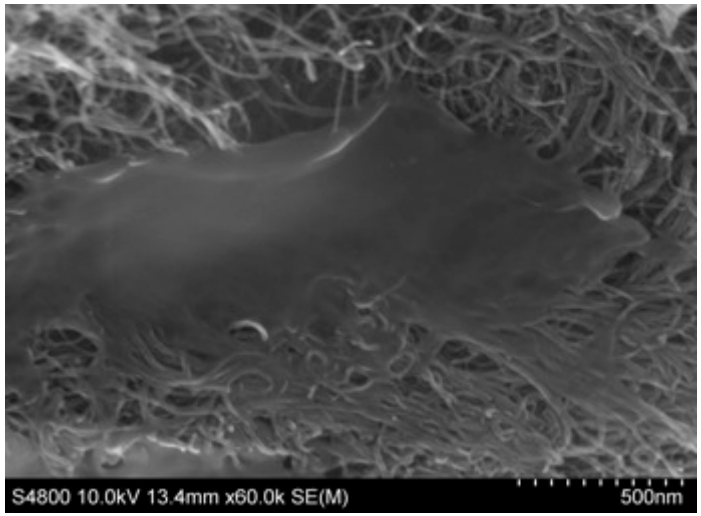
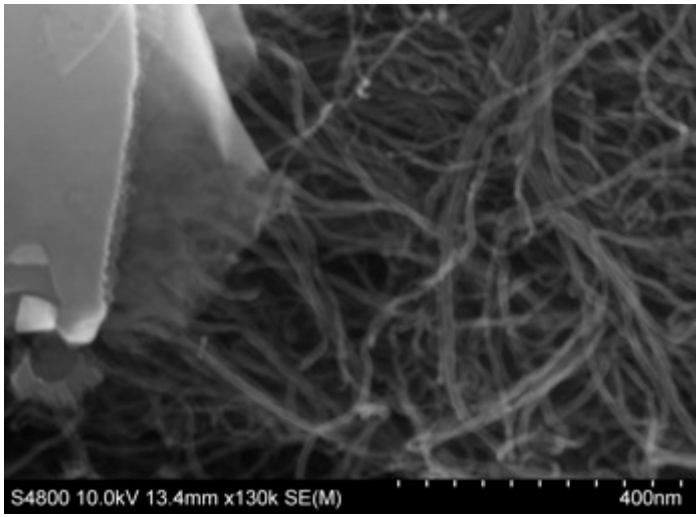
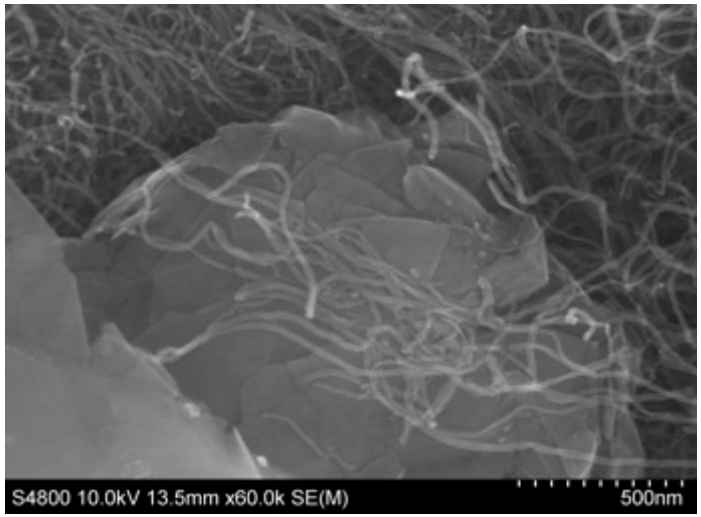
Carbon nano tubes grown on graphenes









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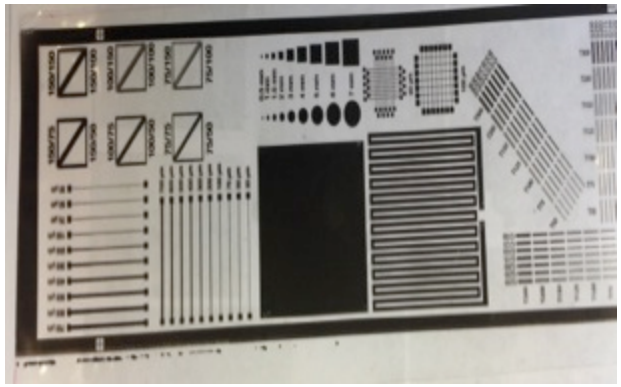
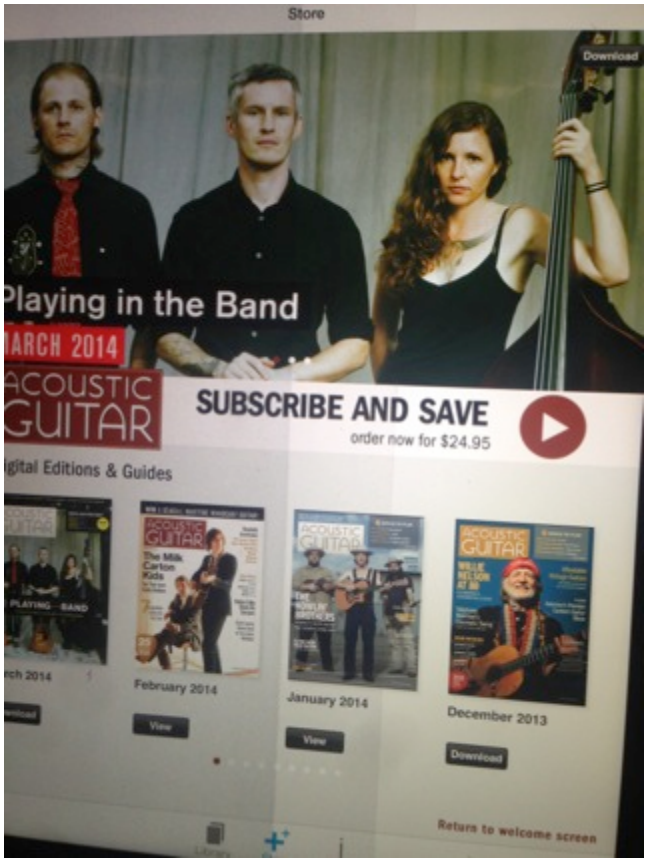
Applications to be disclosed at Manchester 12th June

Will contribute FOC 100 kilos of graphenes to academia to faciliate scaled up research





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Where does the graphene industry go from here?

- 2007 Lux and others offered optimistic projections of market size for graphitic nano materials based on the theoreticians perceived demand for nano-enabled devices components and materials. The projections have proven to be way off,. So lets ask the question? What is the point of such reports? Is it to sell 10,000 s of market reports at $10,000 a pop? Is it to provide data for business plans to justify funding applications for EU and UK development funds. Could this be abused for "buy me now" slogans offered by the kind of investment advisors who have historically pushed nanotechnology investments as get-rich-quick" schemes.
- UK and EU research institutions - employ professional form "filler inners" as an effective method of dipping their snouts into the cash rich graphene troughs provided by the EU/ UK - more than a Billion Euros in funding schemes to accelerate and promote research and development for graphene and related nano technology fields. The reality of this strategy is a grant exploitation industry has been created that provides an unhealthy and sometimes frenzied and perhaps even corrupt graphene gold rush with many company's being ready and willing serial participators but extremely limited deliverers of any commercial outputs from 2020 FP7 FP6 TSB and EPRC funding schemes.
- Perhaps we should consider that maybe the objective for some participants is to obtain funds to cover overheads and generate profits rather than achieving commercial exploitable graphene enabled deliverables . Is there evidence that the development fund participants have delivered any commercially exploitable graphene or CNT process/product breakthroughs evidenced by sales. If this revenue stream were withdrawn would the serial grant applicants cease trading if exposed to the commercial realities of the make it and sell it global nano technology market.
- A further consequence could be that R&D risk adversity by the major players is at an all time high. If its R&D they may wait for a TSB scheme to come along and cover the risk even to the extent that industry may be gearing its R&D programmes to comply with funding calls rather than responding quickly to the needs they have identified due to their intimate knowledge of the market. The hype surrounding graphene is irritating, sensationalist and an unfortunate way of communicating that sooner or later 2D and indeed 3D nano materials will have a deeply transformative impact on all aspects of our lives.