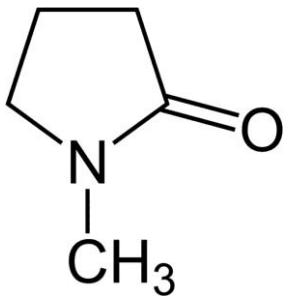


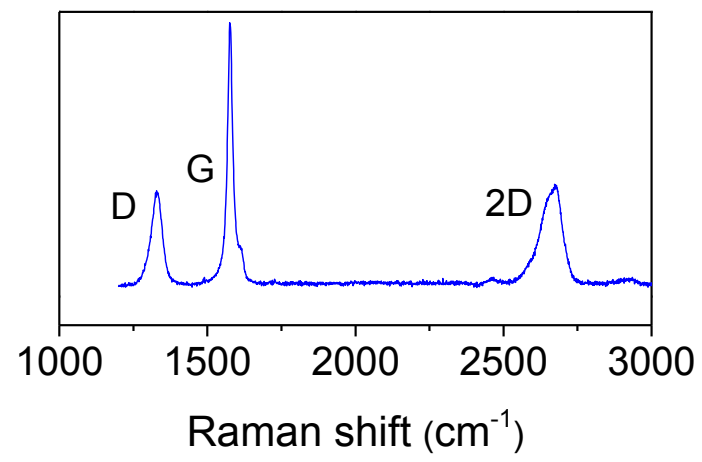
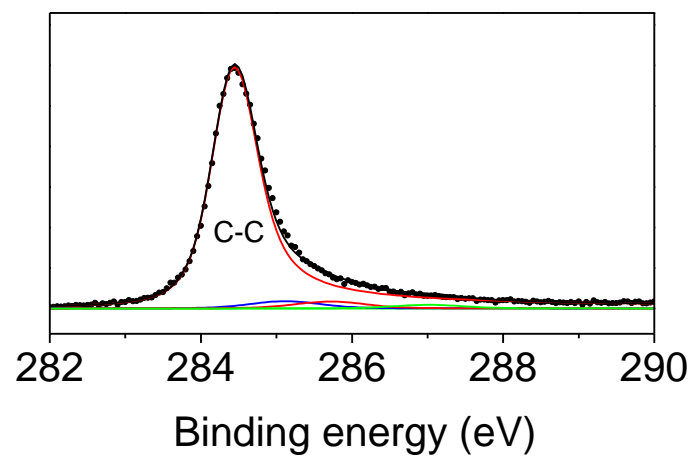
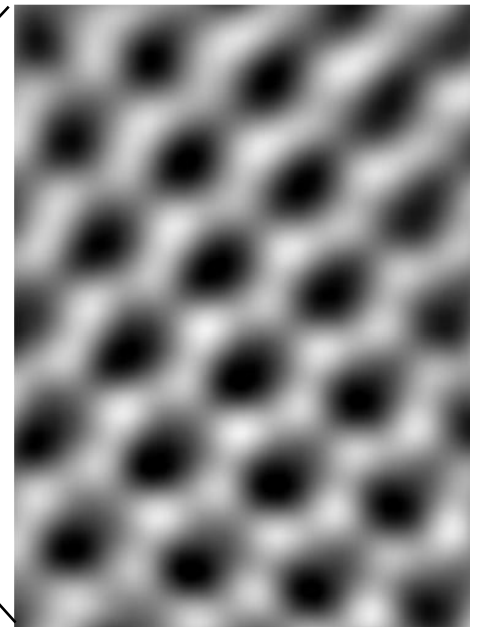
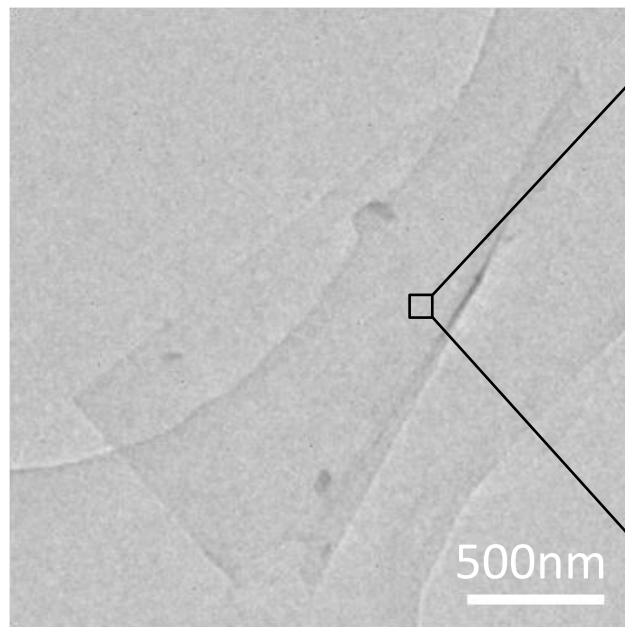
Layered materials: from tiny things to advanced applications

Prof Jonathan Coleman
School of Physics & CRANN,
Trinity College Dublin

Liquid exfoliation of graphene

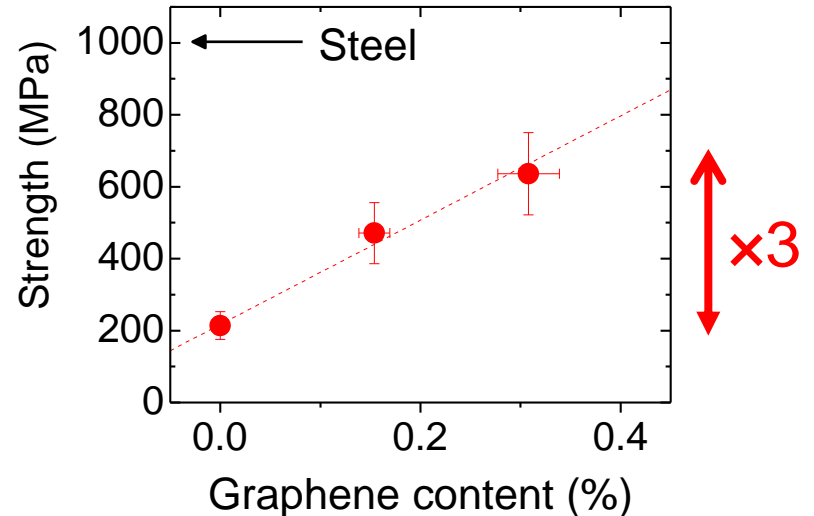
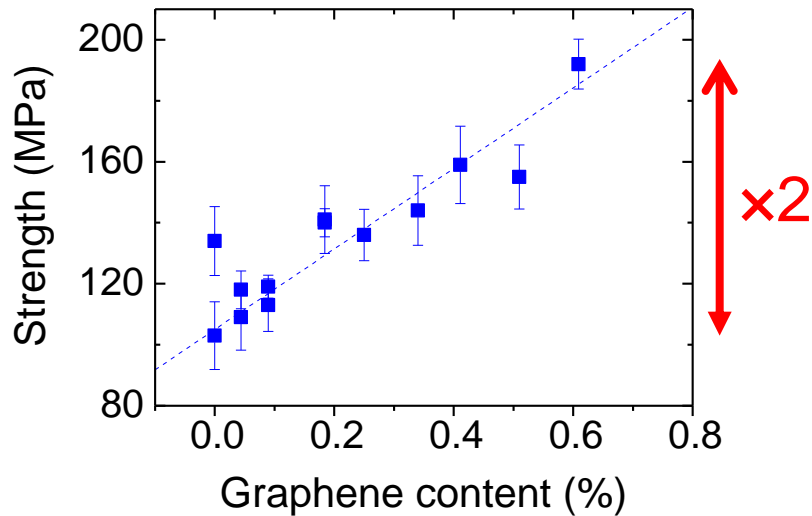
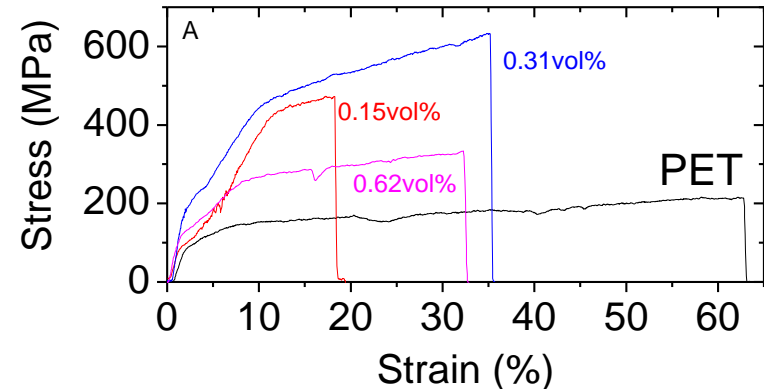
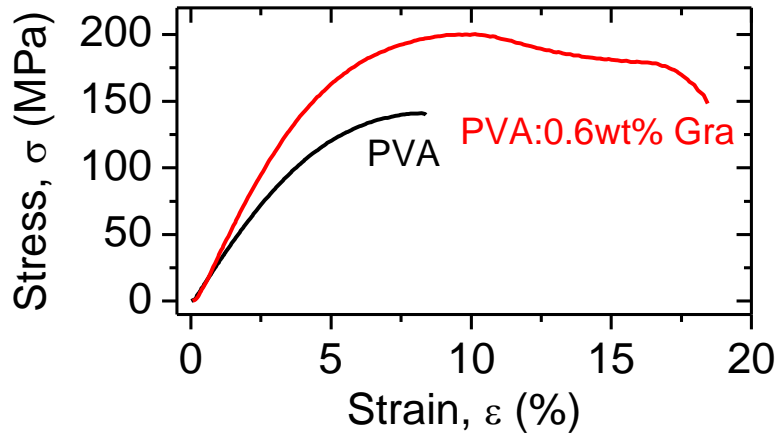
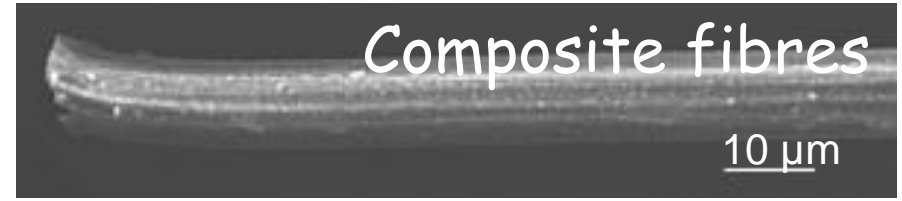
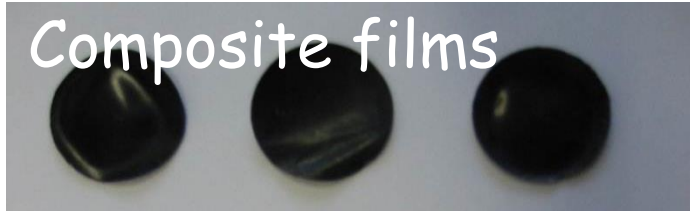


NMP



Small but *no defects, no oxides*

Use exfoliated graphene to reinforce composites



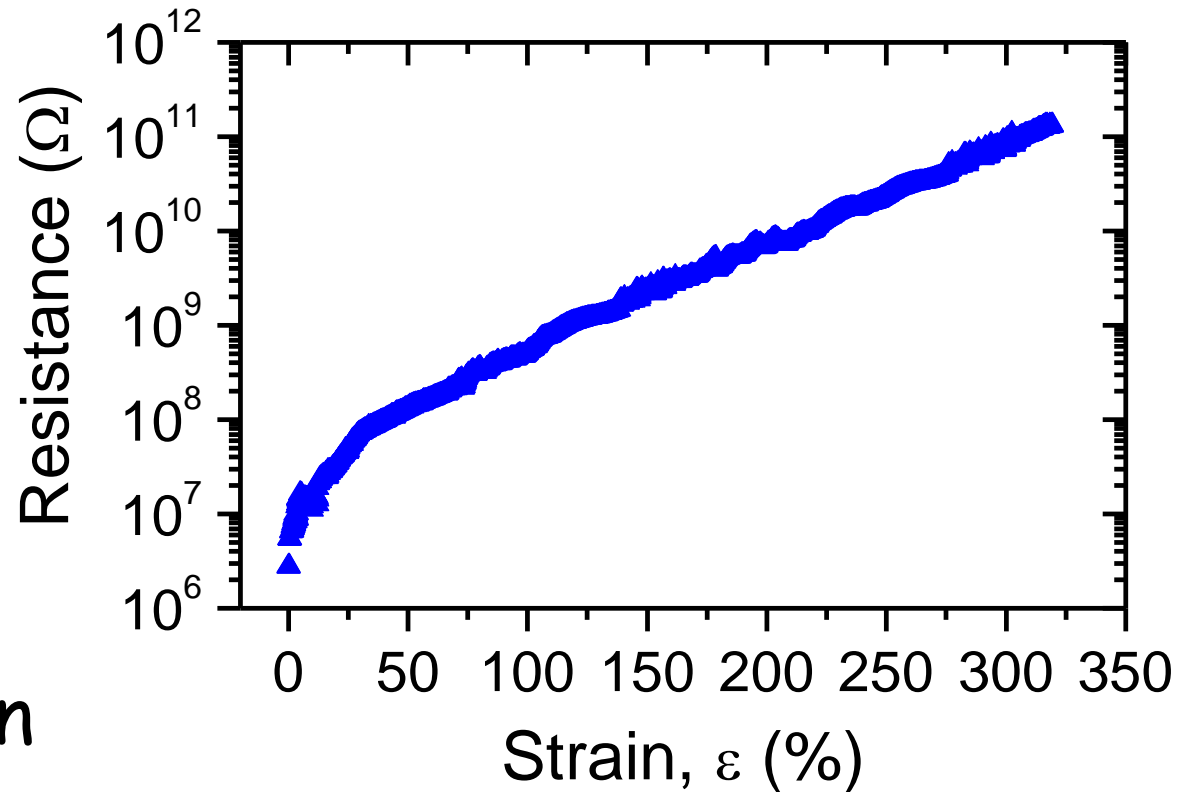
Applications: Composite strain sensors

Graphene +
rubber =



→ Electrically
conductive

Strain
dependent
resistance

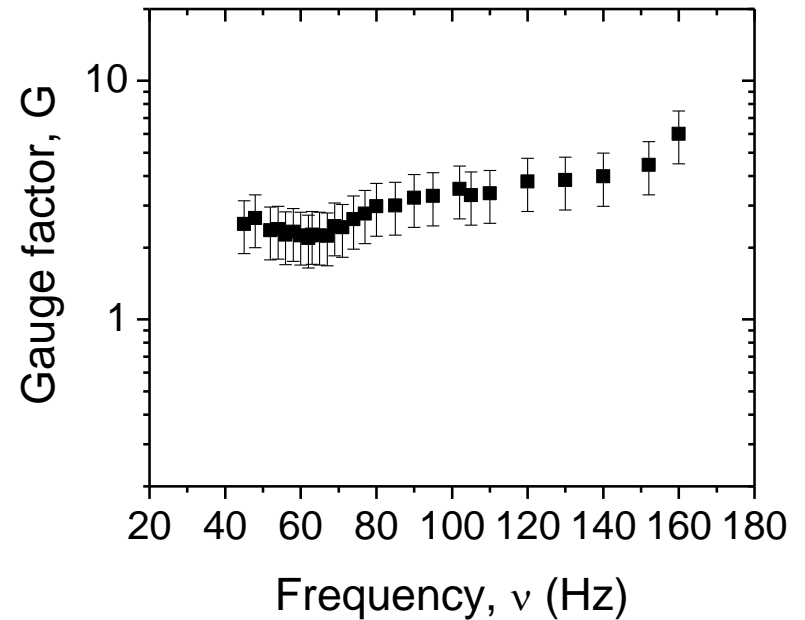


High-strain,
high rate strain
sensors

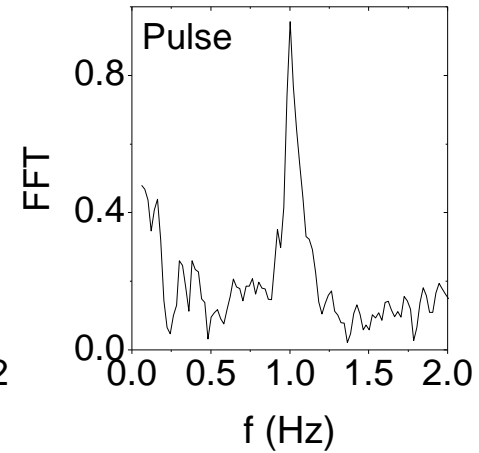
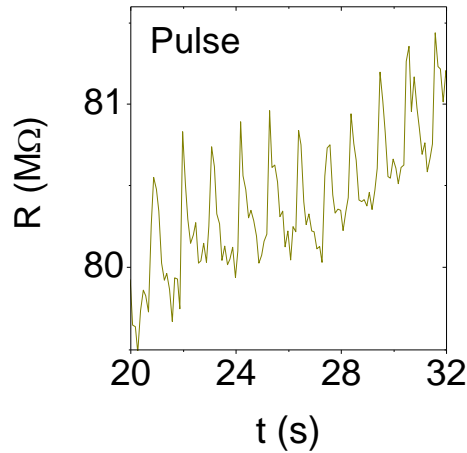
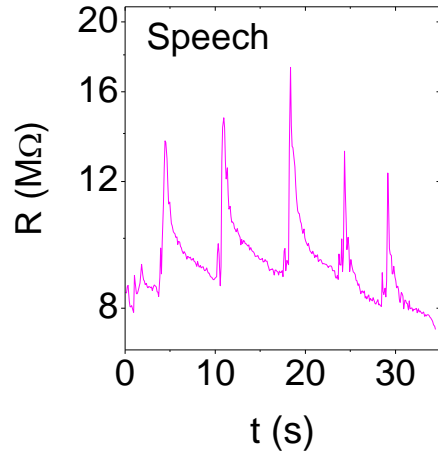
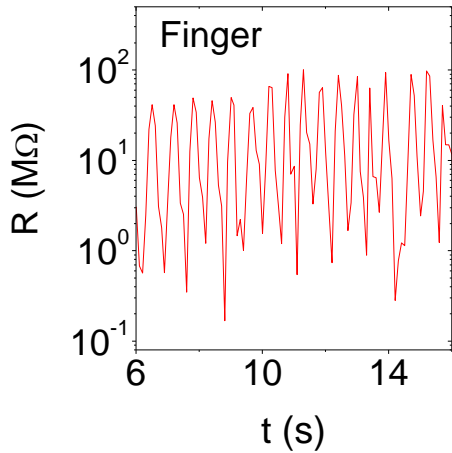
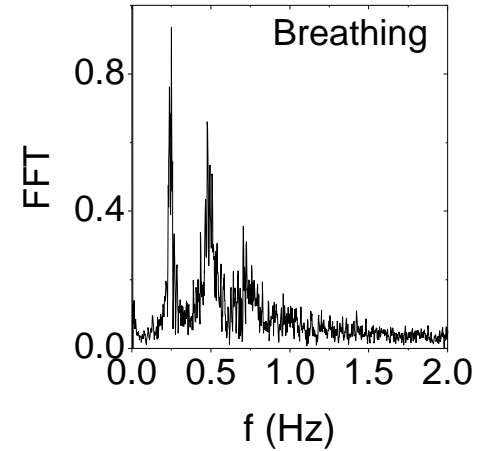
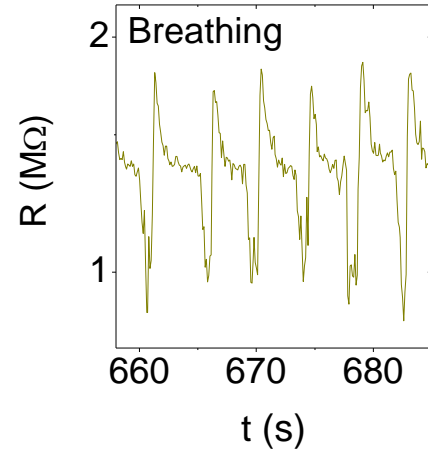
Dynamic strain sensing



High
rate
sensing



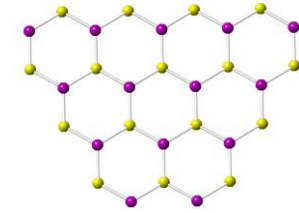
Bio-mechanical motion sensing



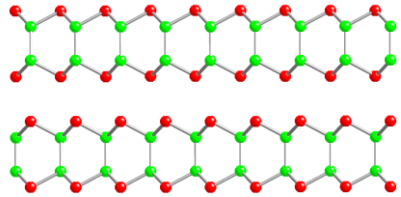
Simple, cheap and very effective

Exfoliation of inorganic layered compounds

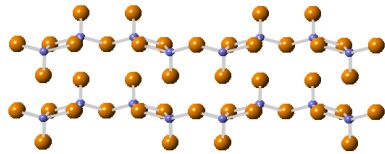
There are ~500 layered materials with all different properties



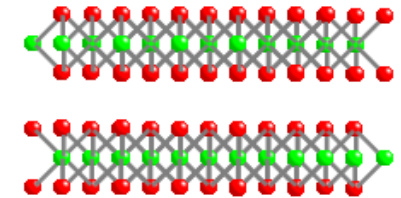
Boron nitride



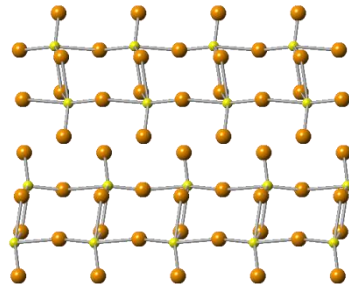
GaS, GaSe etc



V_2O_5



MoS_2 , WS_2 etc



MoO_3

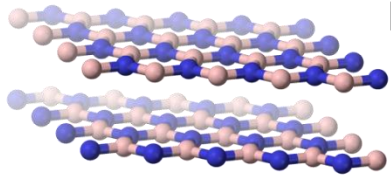
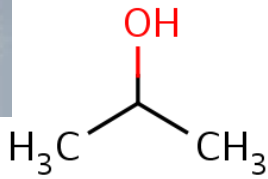
Metals
Semiconductors
Insulators
Electro-chemically active
Luminescent
Mechanically strong
Photo-sensitive
Superconductors
Charge density waves
Etc etc

Liquid phase exfoliation?

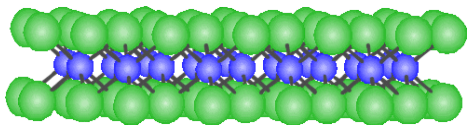
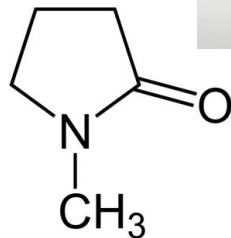
Can we extend to layered compounds?



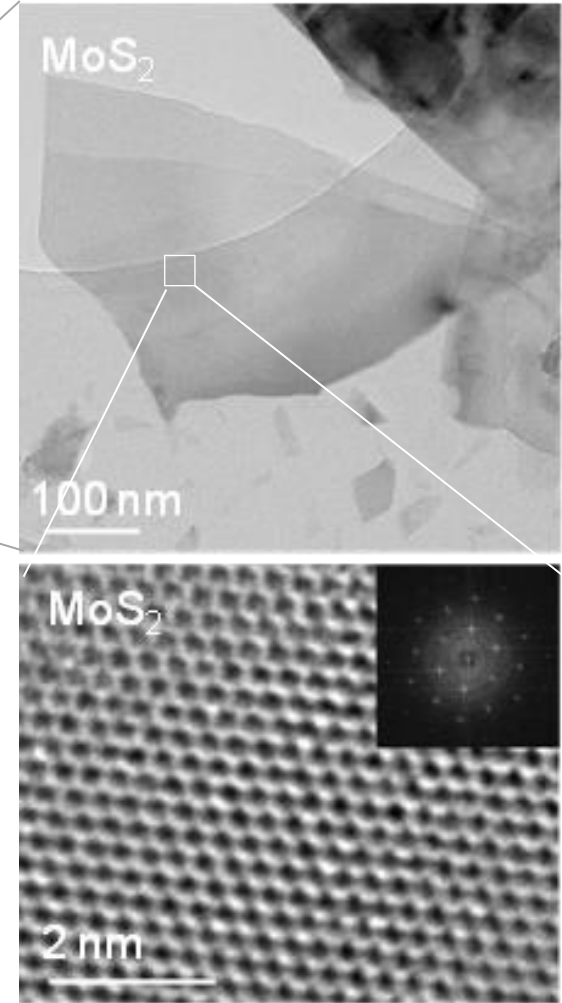
+



+



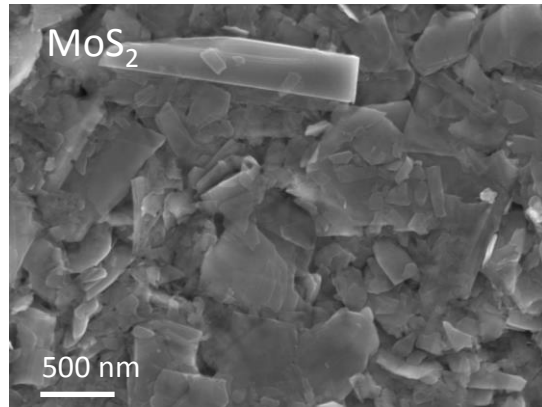
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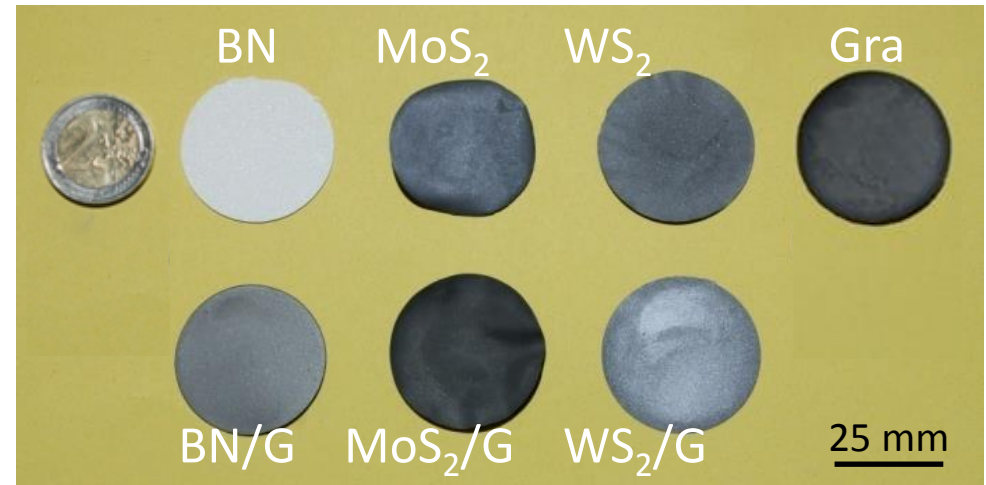
Science, 331, 568 &
Adv Mat 23, 3944

Also works for WS_2 , $TaSe_2$, $MoTe_2$, $MoSe_2$,
 $NiTe_2$, $NbSe_2$, TiS_2 , TaS_2 , MnO_2 , RuO_2 , TiO_2 ,
 Bi_2Te_3 , Bi_2Se_3 , Sb_2Te_3 , Sb_2Se_3 , MoO_3 , $GaS...$

Prepare films...



From 10s of nm thick to freestanding



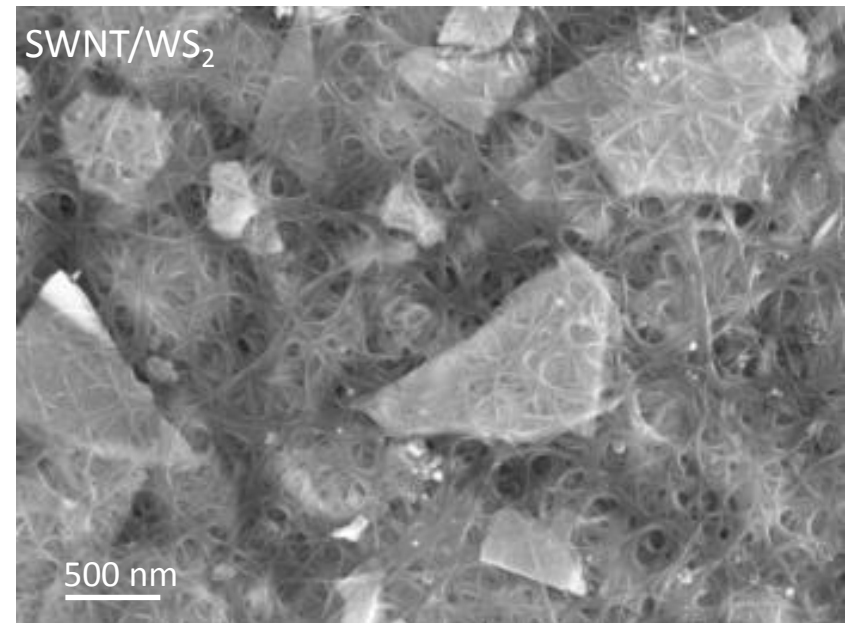
.....and composites

Many possibilities

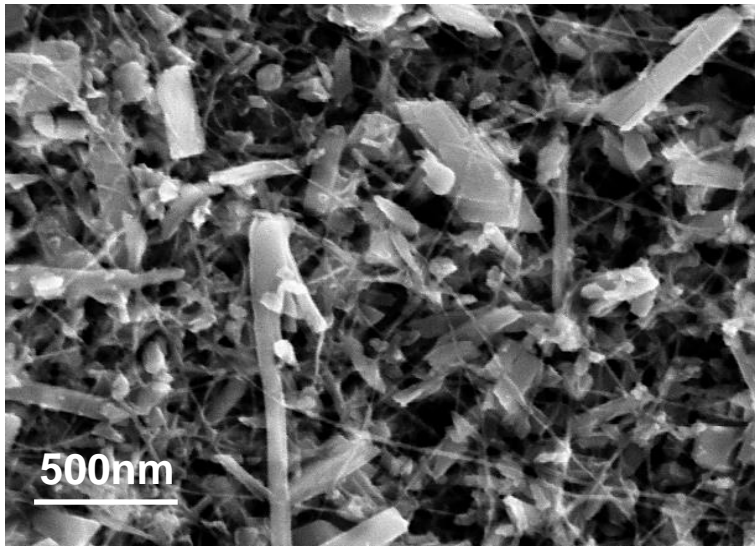
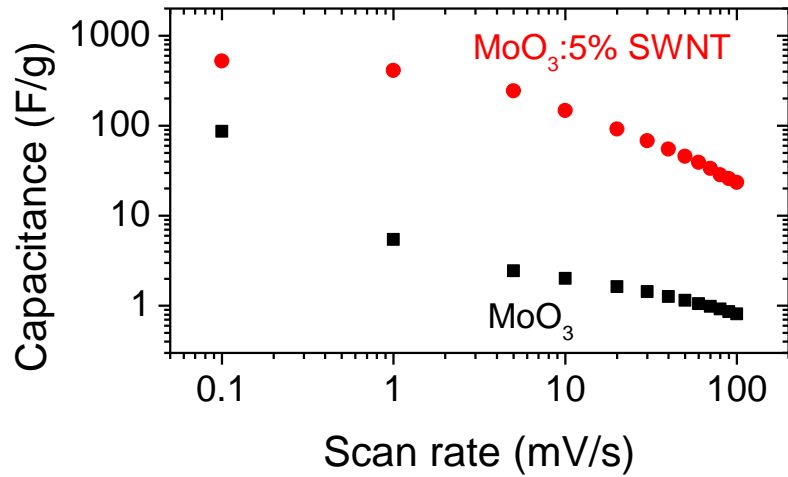
e.g.

2D:1D

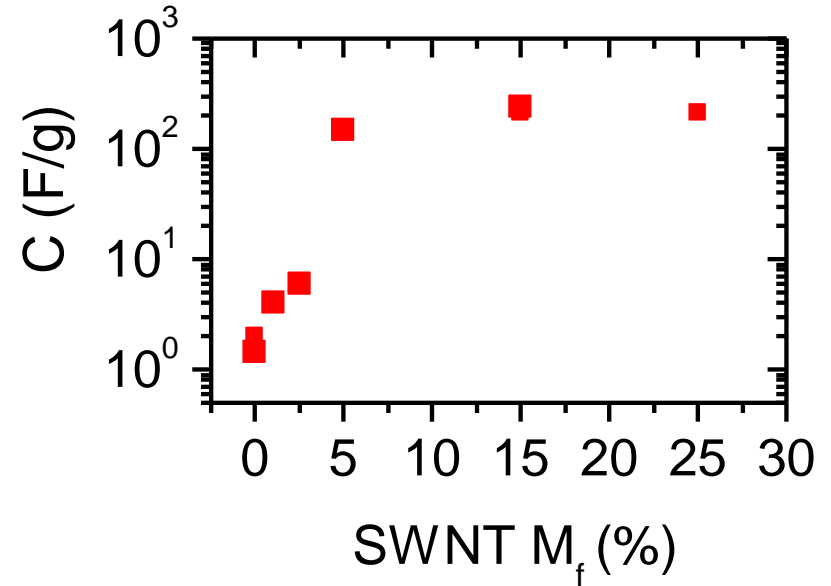
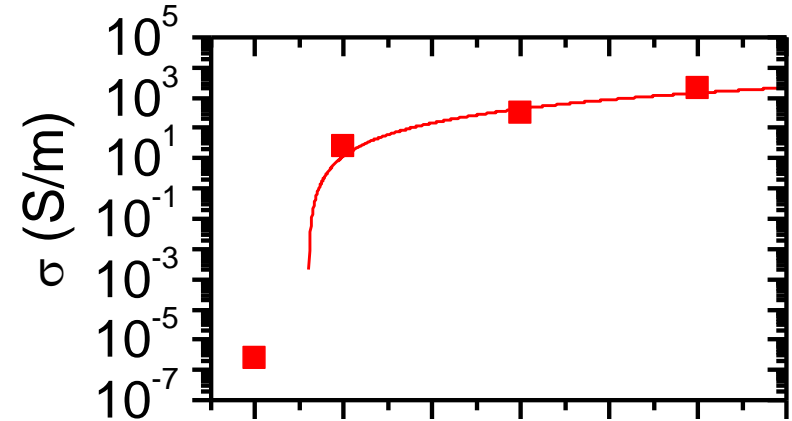
WS₂:SWNT



Applications: MoO₃ Supercapacitors



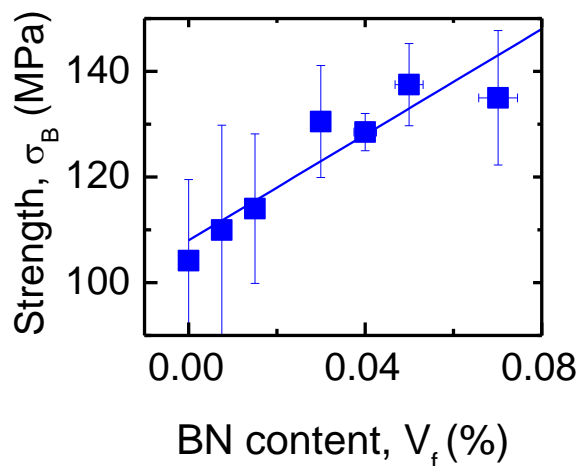
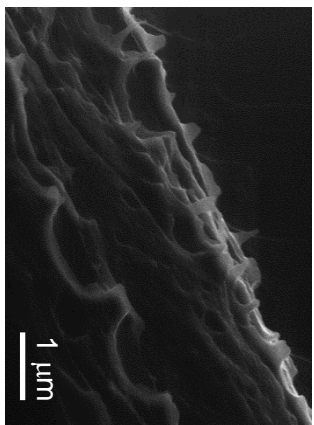
2 electrode cell
1M LiClO₄ in propylene carbonate



100-fold increase with 5% SWNT

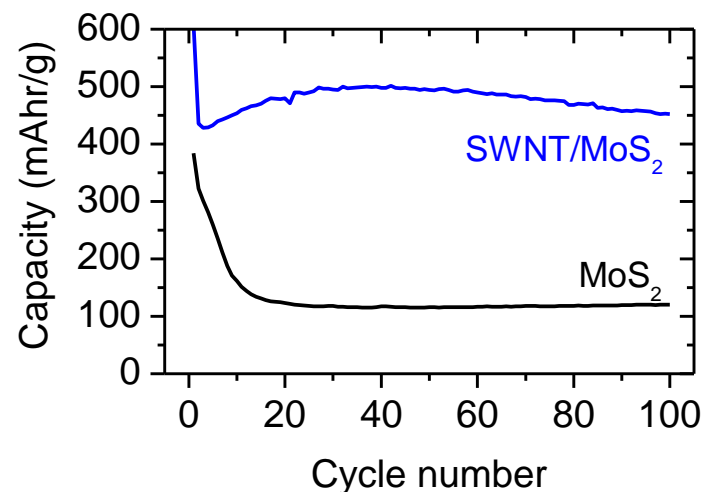
Up to 500 F/g at low rates

Reinforced composites: BN



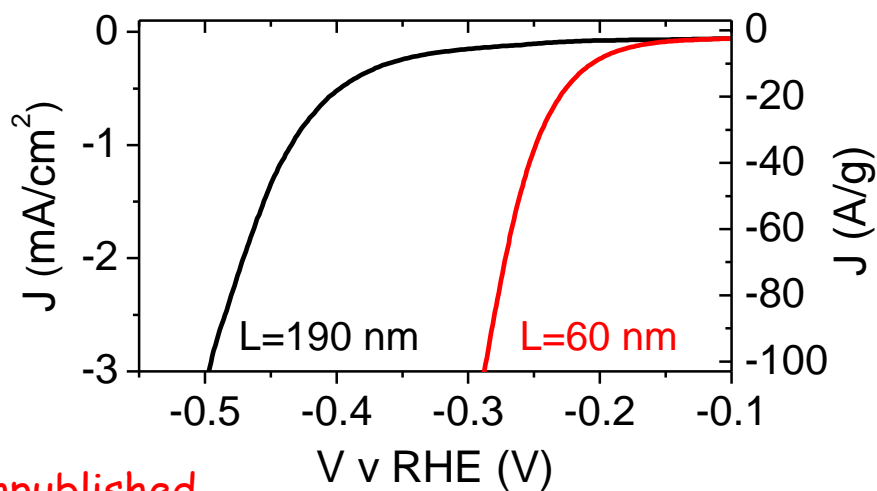
Nanoscale, 5, 581

Stable high capacity Li ion batteries: MoS₂



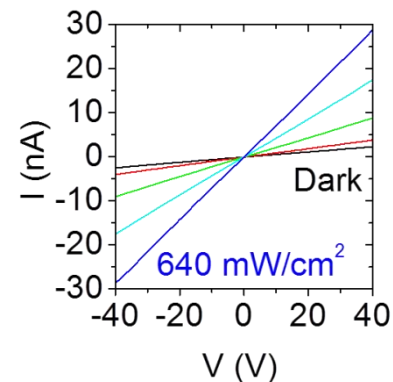
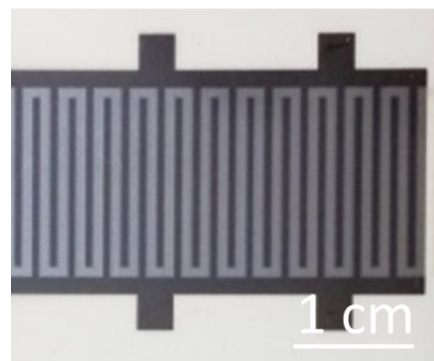
Adv Energy Mater, 3, 798-805

H₂ evolution at lower potential for smaller flakes: MoS₂



unpublished

Inkjet-printed photodetectors: Graphene/MoS₂



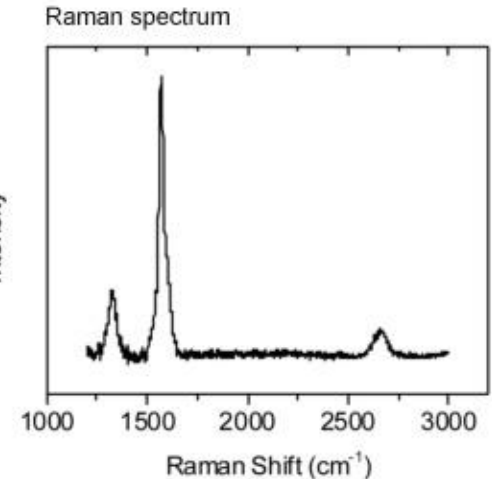
J Mater Chem C,

Production process
scaled up for graphene
and other 2Ds

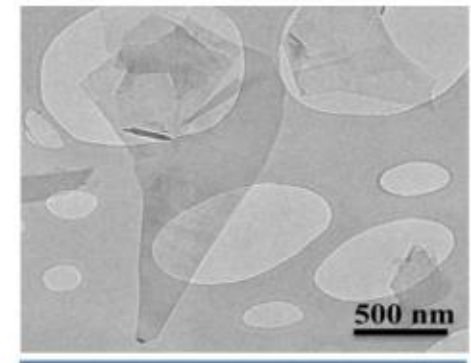


Elicarb[®] Graphene Products

- Solvent exfoliation as a route to non-oxidised, conductive, Graphene Nanoplatelets.
- Developed in association with Prof. J. Coleman at CRANN, Trinity College Dublin.
- Potential applications include:
 - Transparent conductive materials
 - Flexible and printed electronics
 - Super-capacitors and batteries
 - Thermal management materials
 - Mechanical reinforcement
- CRANN process is currently being transferred to Thomas Swan, Consett, UK.



TEM analysis



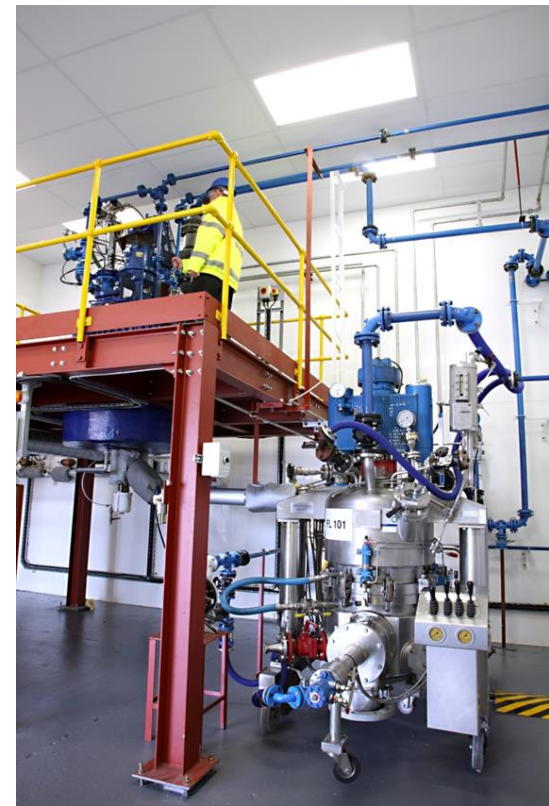
CRANN-Thomas Swan Graphene

- Testing at Thomas Swan confirms that the solvent exfoliated graphene is substantially non-oxidised with good conductivity.
- Exfoliation pilot scale is now established at Thomas Swan and commissioning is in progress.
- Design of a full scale exfoliation plant is underway.
- Elicarb® Graphene will be available at gram scale for customer evaluations early in 2014.
- Thomas Swan welcomes customer enquiries for application development opportunities.

For enquiries contact:

agoodwin@thomas-swan.co.uk

Thomas Swan....proven ability to scale carbon nanomaterials



Elicarb SW Low Residue 500kg production plant – recently commissioned.

Thanks to:

Group

Dr Shane Bergin
Dr Sukanta De
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Mustafa Lotya
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Prof V Nicolosi

Wollongong
Various.....



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Fondúireacht Eolaíochta Éireann
Science Foundation Ireland