

Graphene-Based Materials

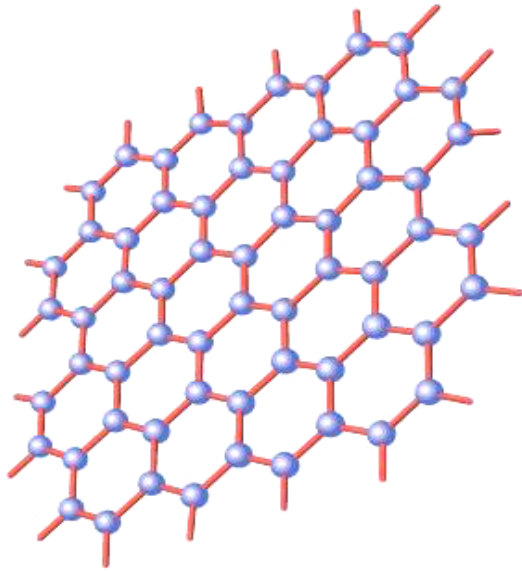
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Outline

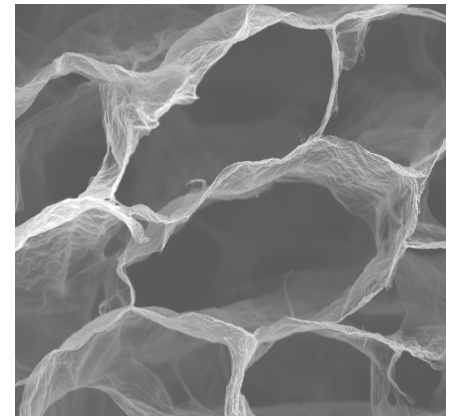
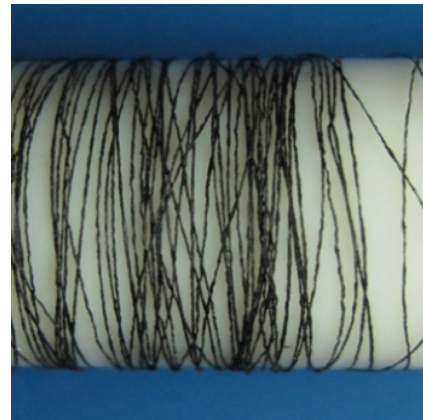
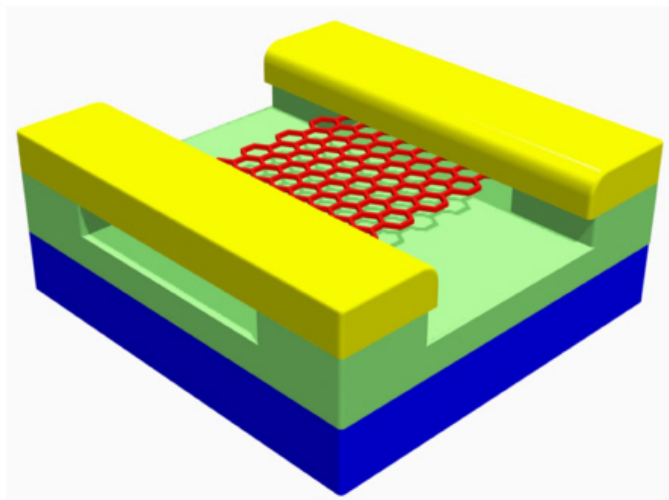
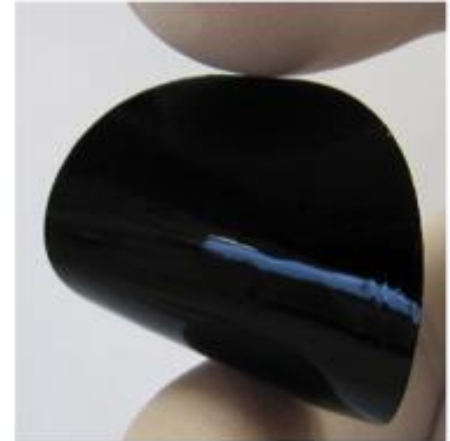
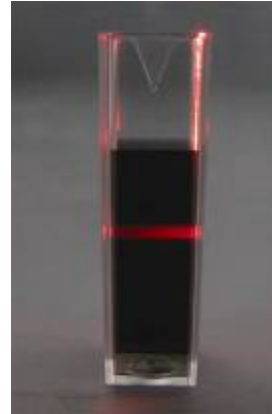
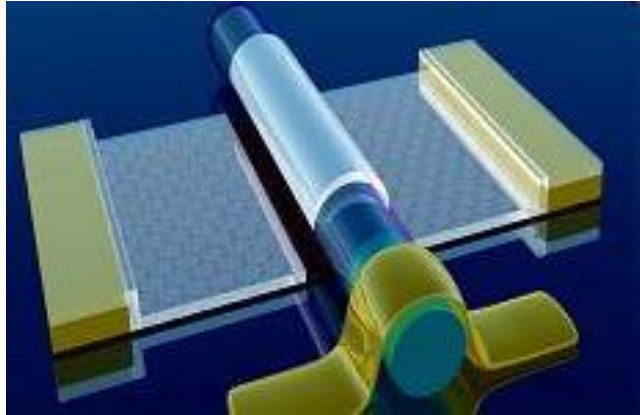
- Briefing on graphene industrialisation
- Key design principles for extraordinary graphene-based materials
- Our research capabilities

What makes graphene attractive?



- Electronic/optical properties
- Mechanically strong
- Electrically conductive
- Thermally conductive and stable
- High aspect ratio
- Chemically stable
- **Lightweight**
- **Chemically tuneable**
- **Processability and scalability**

Versatility of graphene-based materials



Pictures adopted from Internet

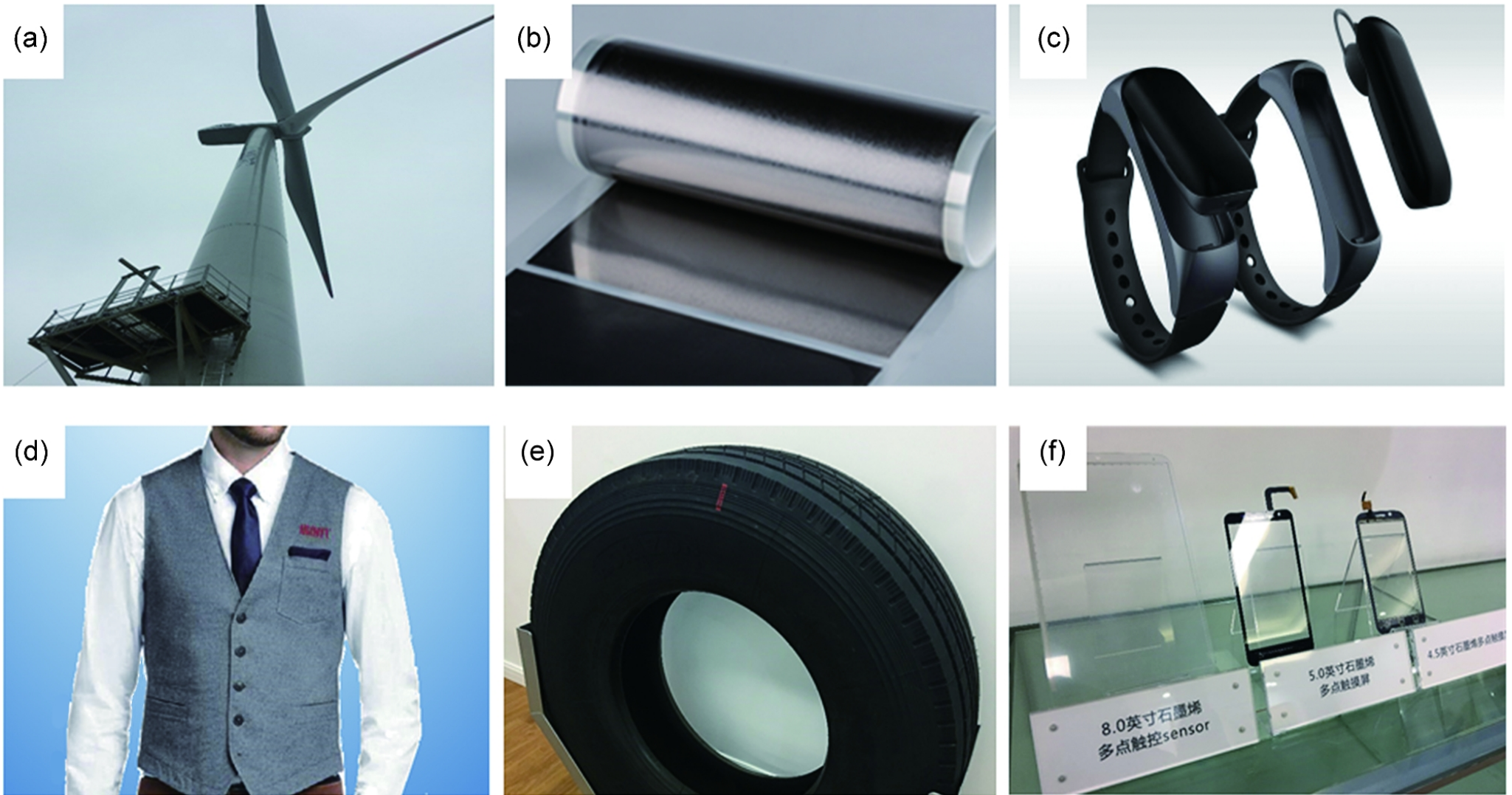
Current industrial production capability



>10, 000 tons/year

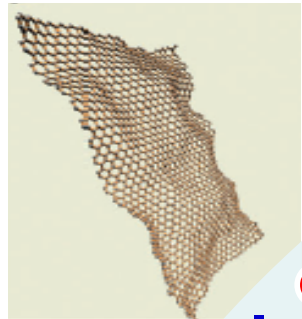
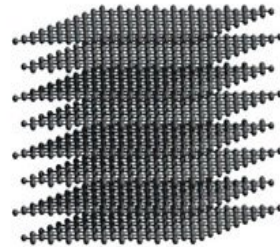
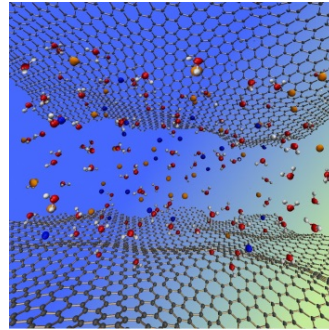
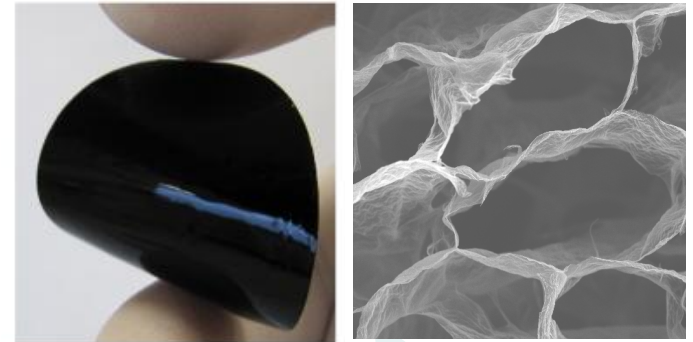
Zhu, Ji, Cheng & Ruoff., *National Science Review*, doi: 10.1093/nsr/nwx055 (2017)

Examples of graphene-based products



Zhu, Ji, Cheng & Ruoff., *National Science Review*, doi: 10.1093/nsr/nwx055 (2017)

Key to unique graphene-based materials: Architectural design

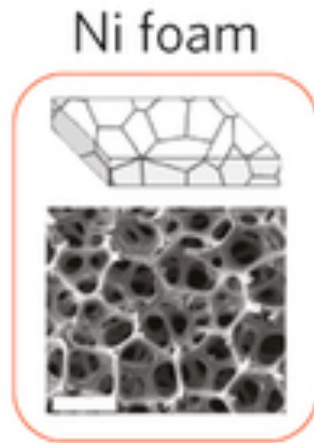


**Individual
graphene
sheets**

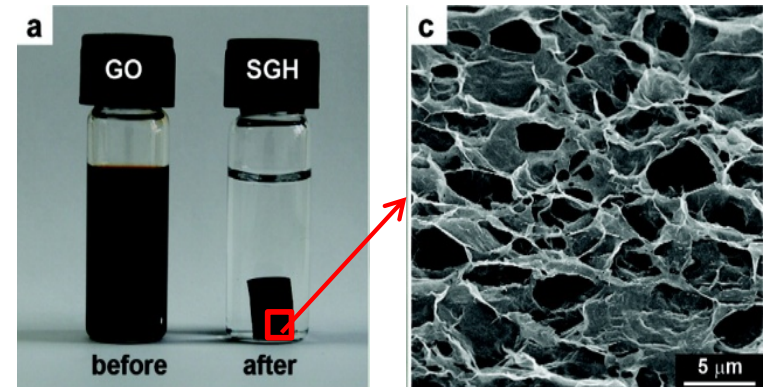
**Inter-sheet
interactions**

**Architecture
of assembly**

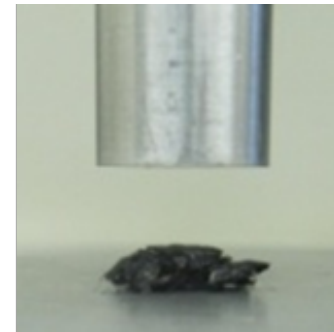
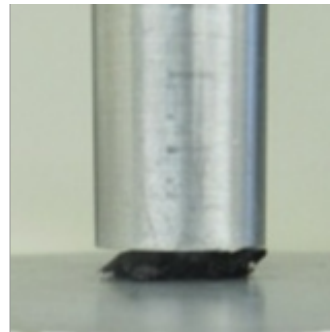
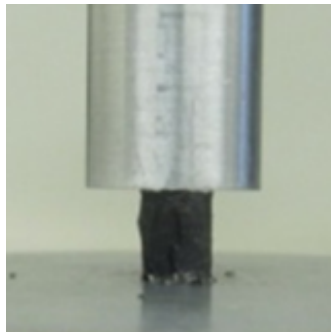
Graphene-based cellular/porous materials



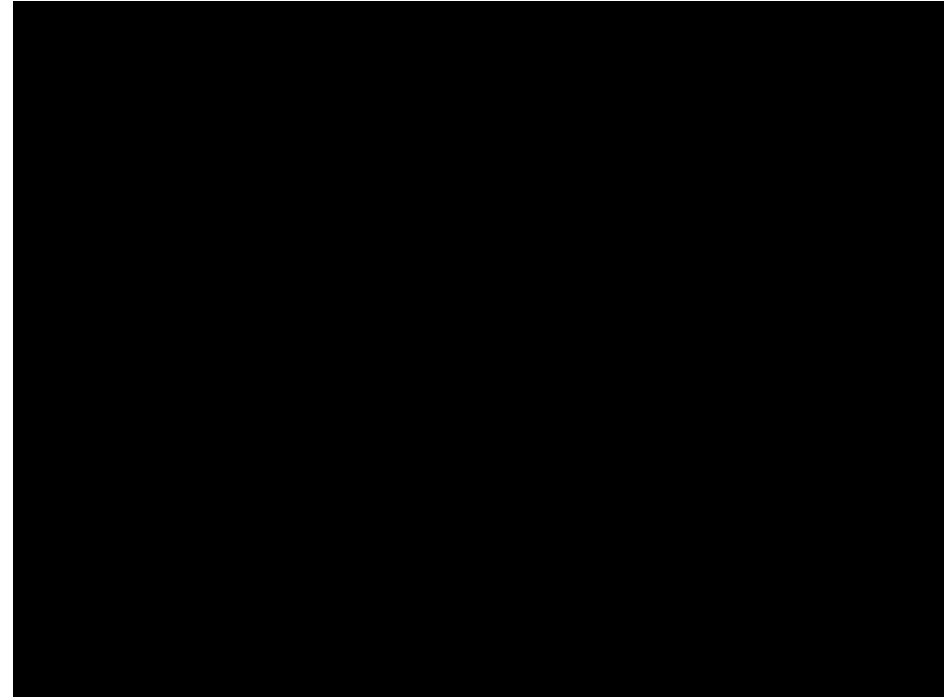
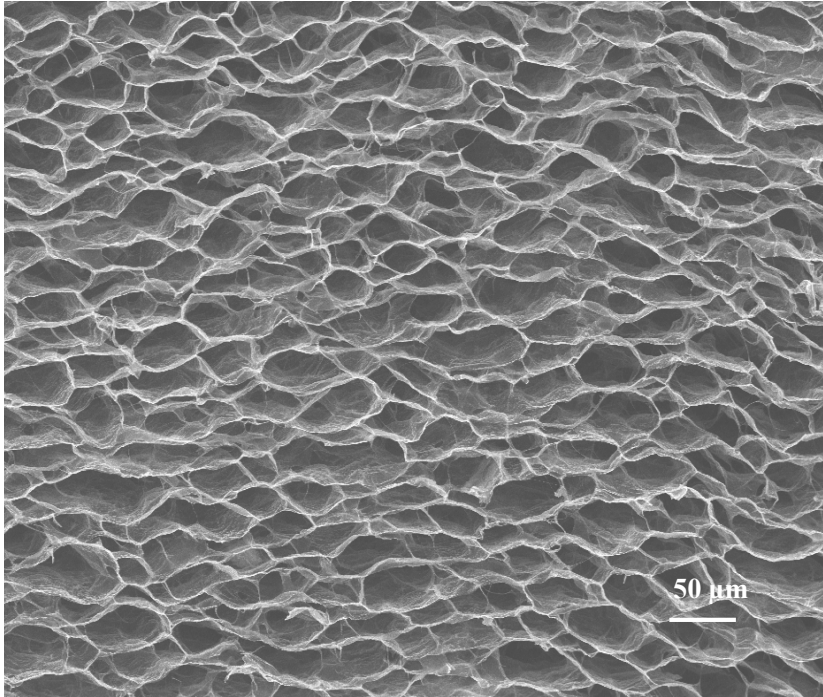
Cheng, et al. *Nature Mater.* 10, 424 (2011)



Xu, et al. *ACS Nano*, 4, 4324 (2010)



Cork-like graphene-based cellular foam

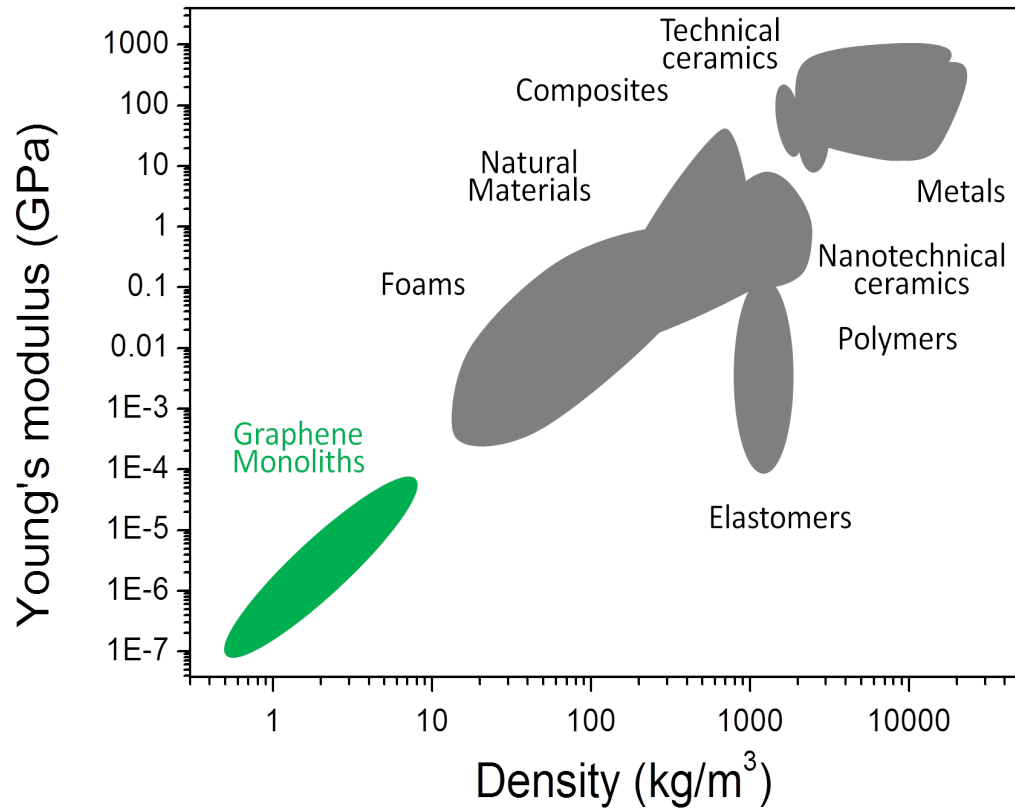


- Can recover from large deformation (>98% strain)
- Fast recovery rate
- Can support over 50,000 times of its own weight
- Excellent cycle performance

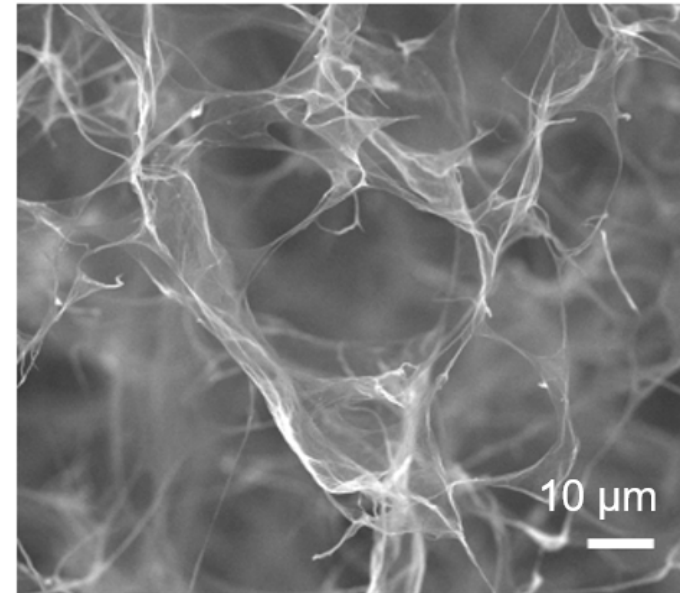
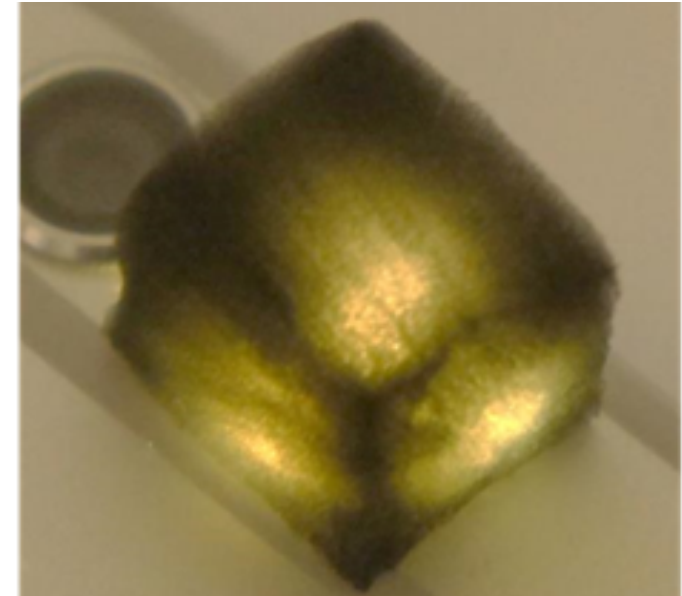
Qiu, Liu, Chang, Wu & Li, ***Nature Communications*** 3, 1241 (2012).

Extremely-low-density cellular material

The most lightweight compressible material: **0.18 mg/cm³** (Air: 1.2 mg/cm³)



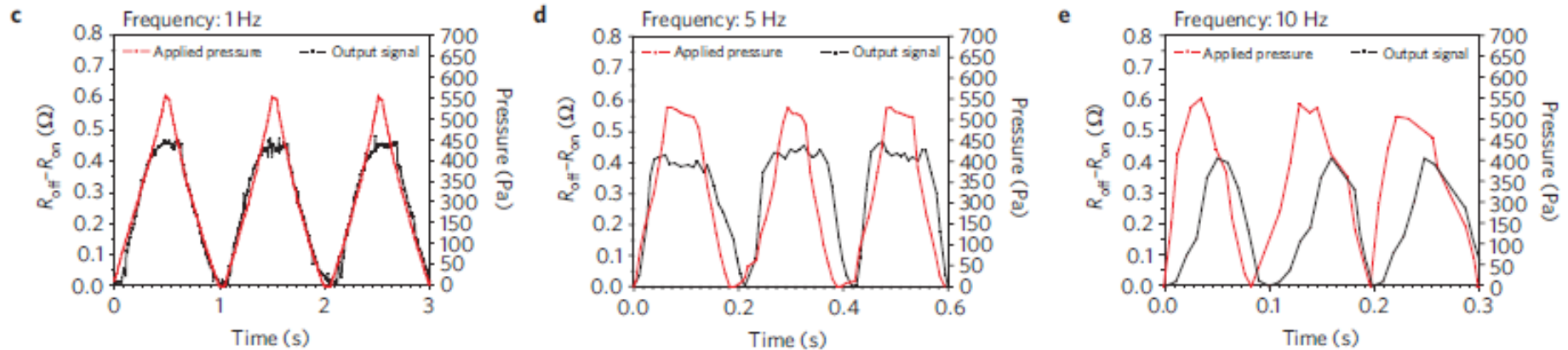
Adv. Mater. 29, 1701553 (2017)



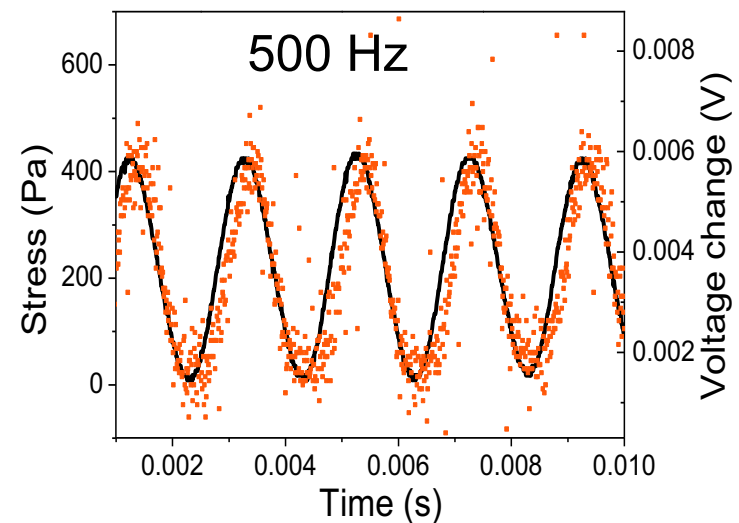
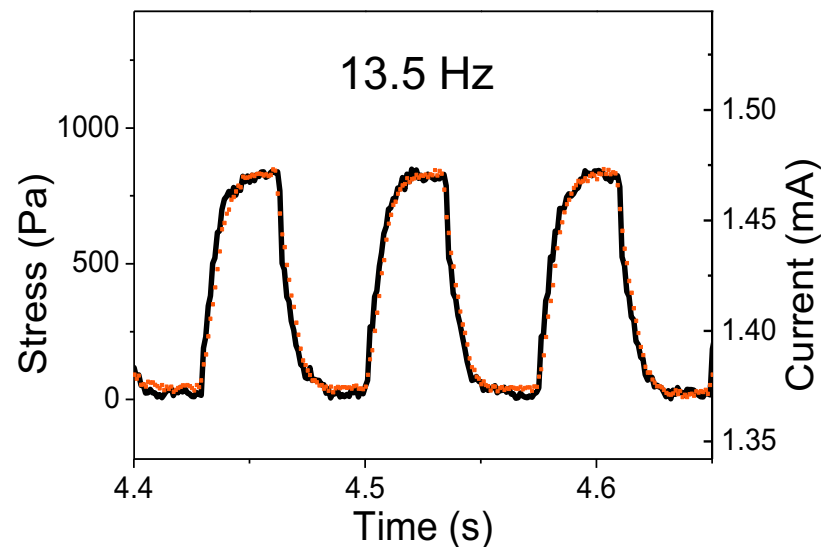
Extraordinary dynamic response: exceeding the skin

Conductive polymer-based

Nature Materials 11, 795–801 (2012)

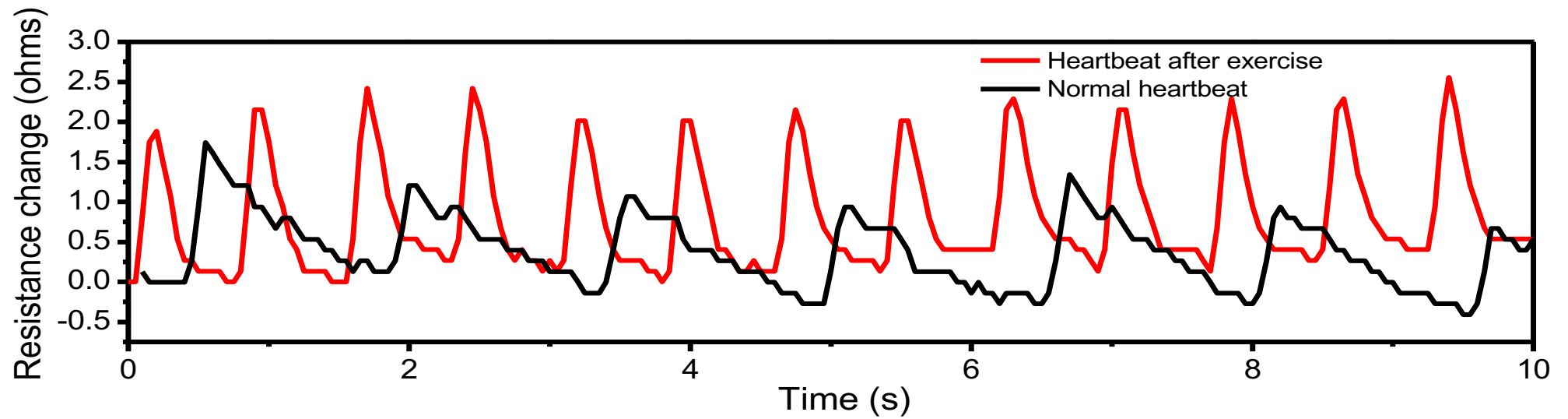
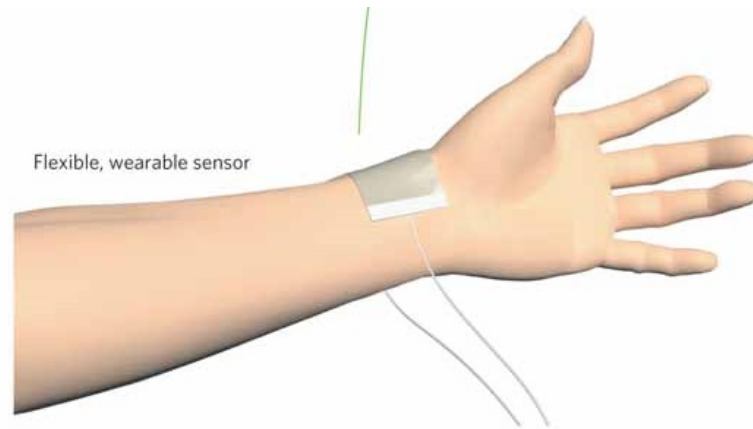


Graphene sponge

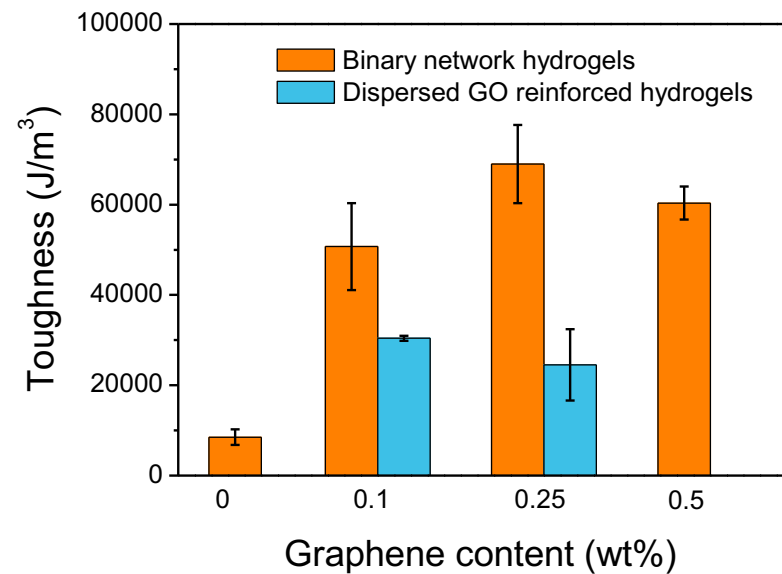
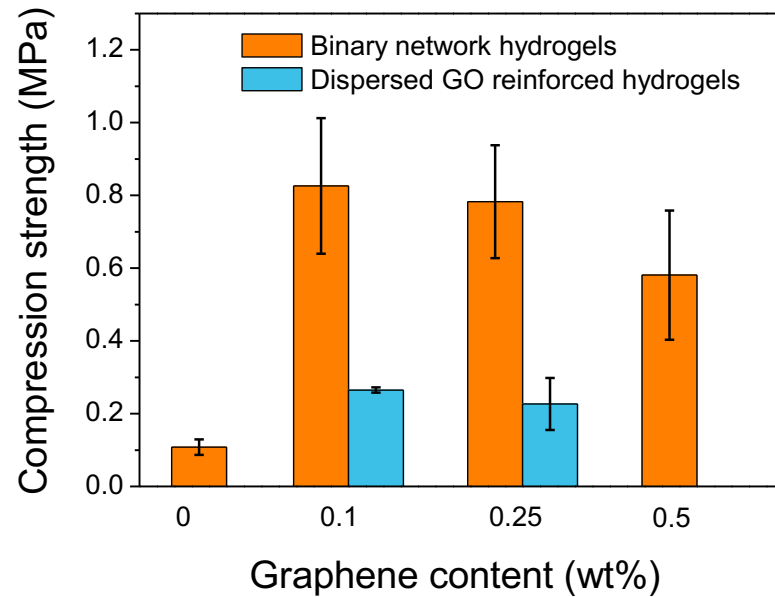
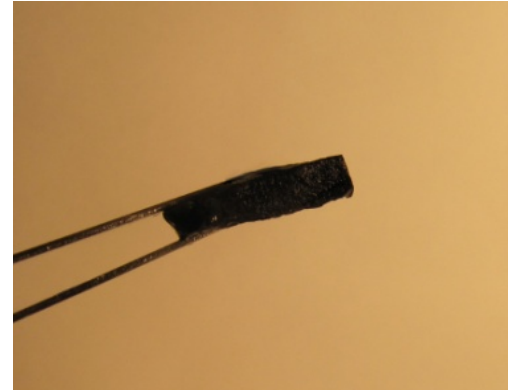
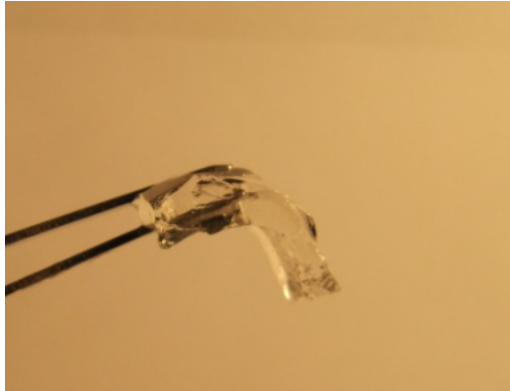


Qiu, Coskun, Tang, Liu, Alan, Ding, Truong & Li, *Adv. Mater.* DOI: 10.1002/adma201503957 (2016)

Graphene elastomer-based pulse sensors

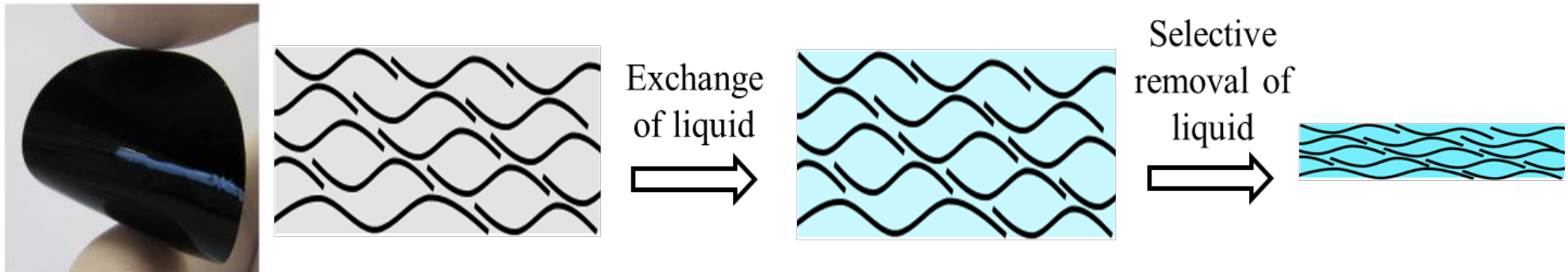


Mechanical enforcement of polymers

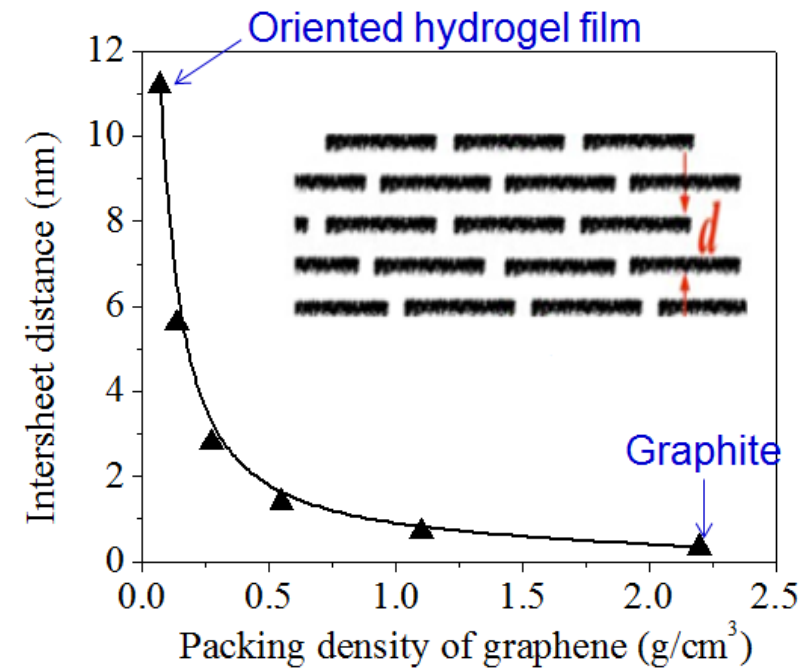
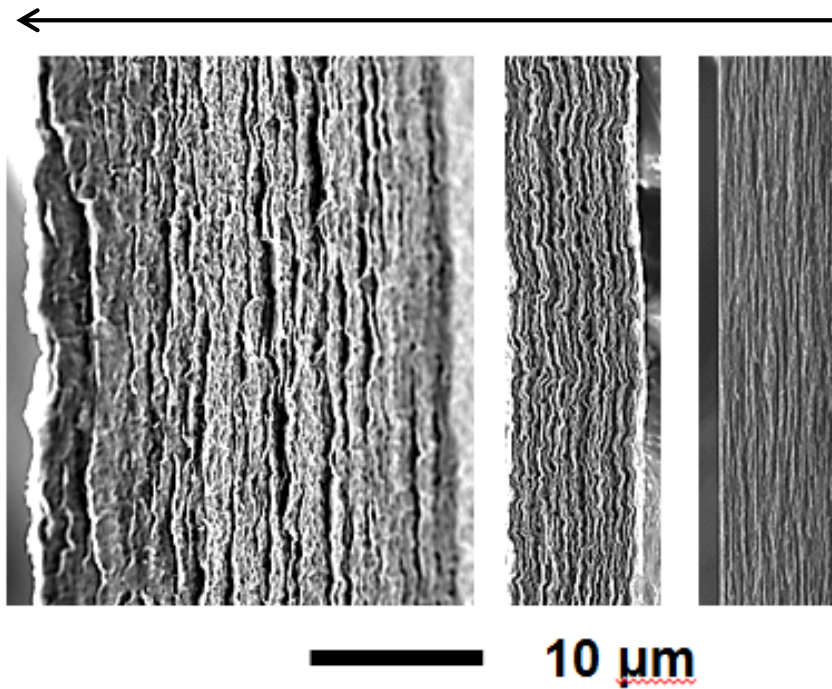


Adv. Mater. DOI: 10.1002/adma.201305359 (2014)

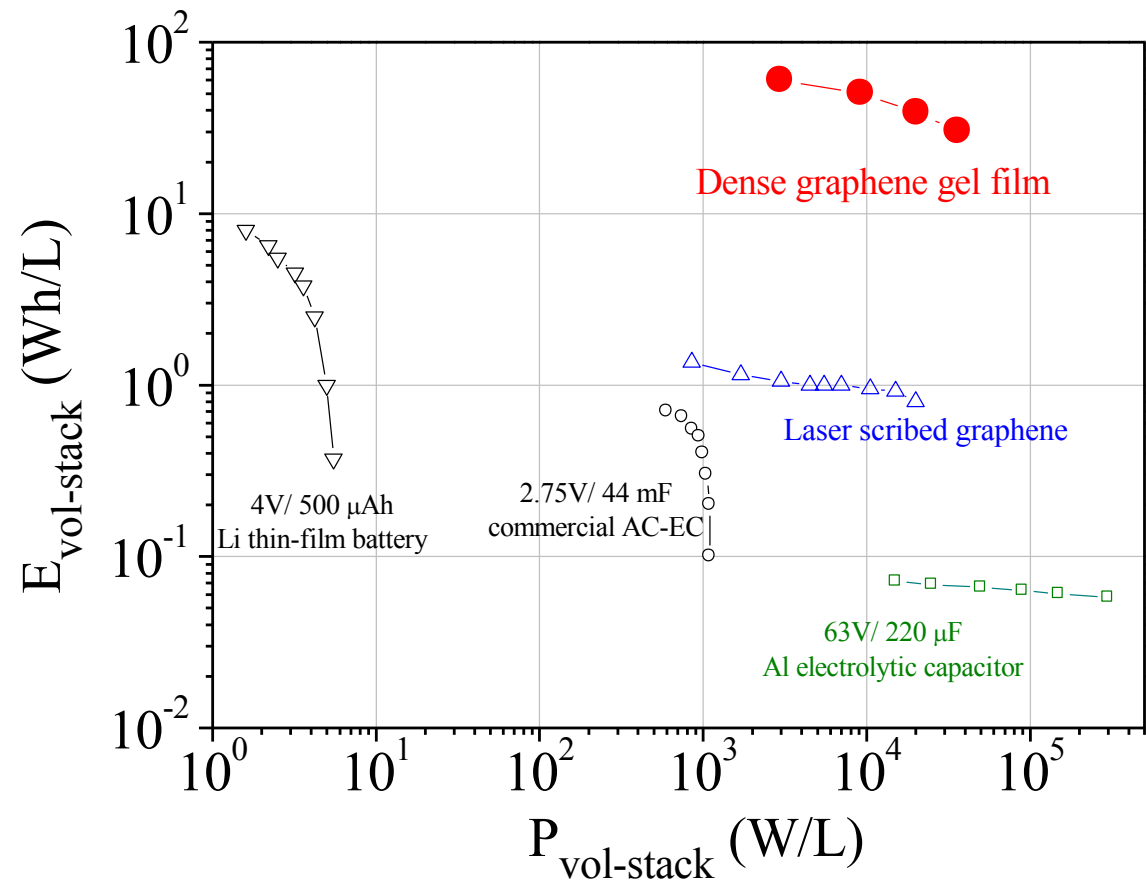
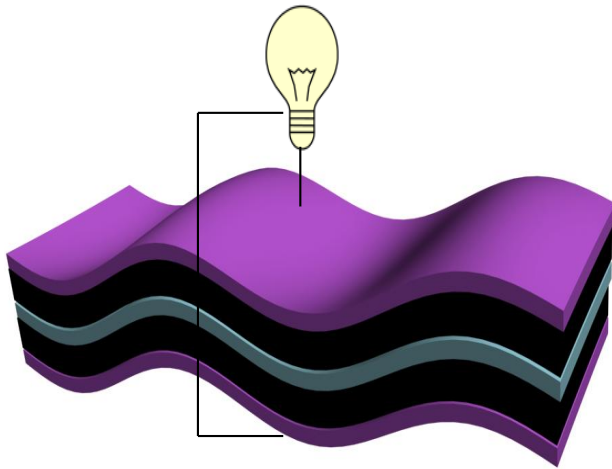
Extremely porous yet dense carbon materials



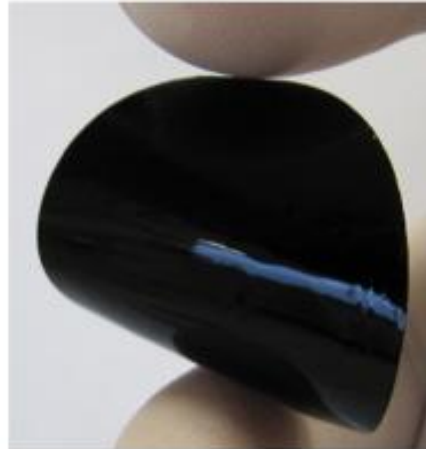
Ratio of non-volatile liquid (electrolyte)



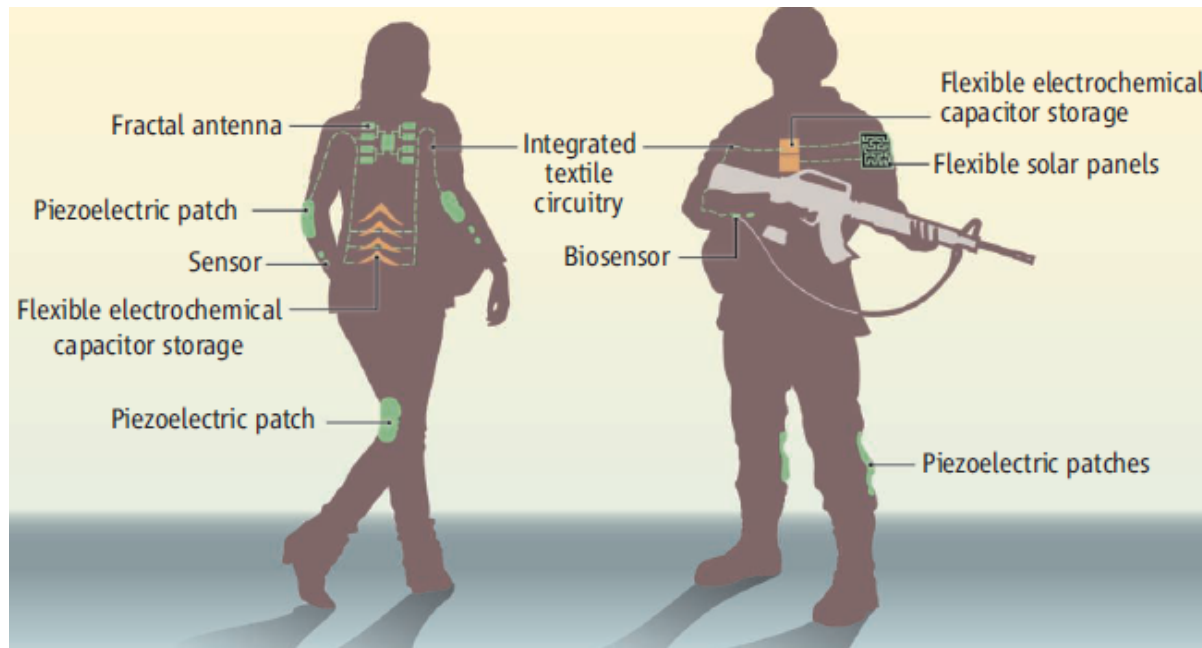
Compact supercapacitors



Graphene-based dense membranes: multifunctional



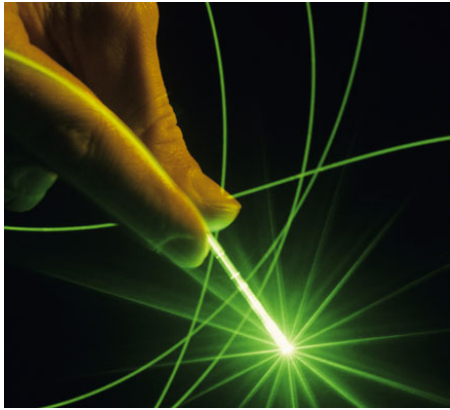
- High capacity of energy storage
- Fast charge/discharge
- Mechanical strong
- Lightweight
- Flexible



Miller., *Science*, 335, 1312 (2012)

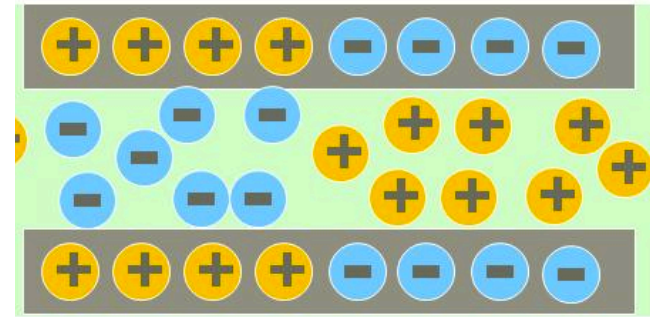
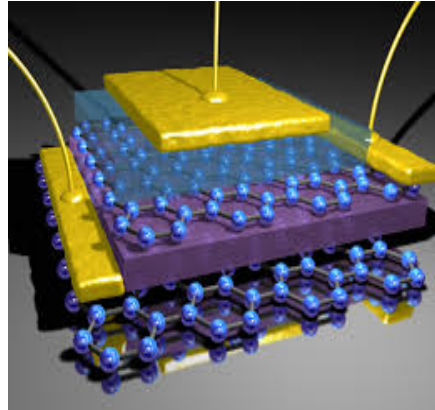
Enabling new sciences using graphene materials: Case of nanoionics

Electrons and photons in nano-confinement



Nanoelectronics

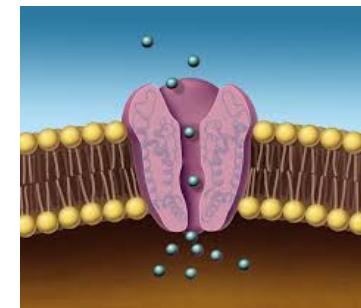
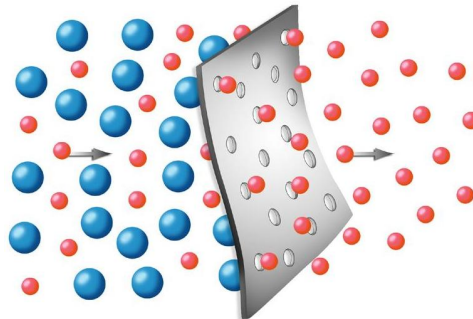
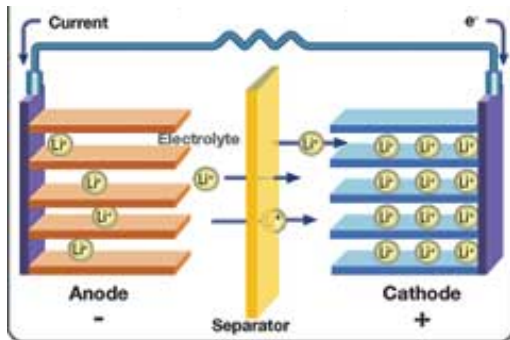
Nanophotonics



**New nanoionic (fluidic)
phenomena/applications?**

Nanoionics is an emerging discipline involving the study and application of properties, phenomena, and mechanisms of ion transport and storage in nanoscale systems including nanopores/nanochannels.

Technologies with nanoionics as the core science



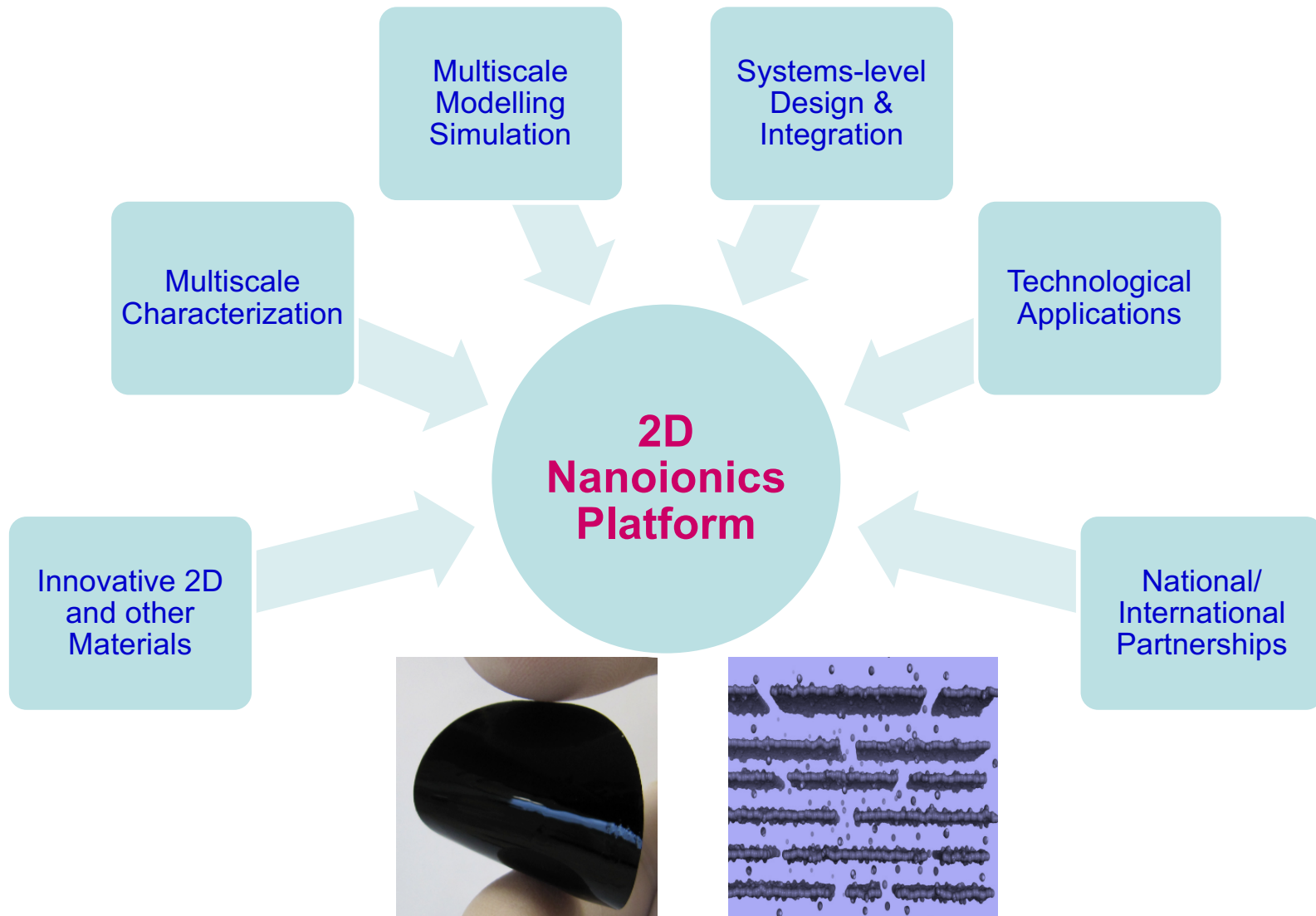
Energy storage

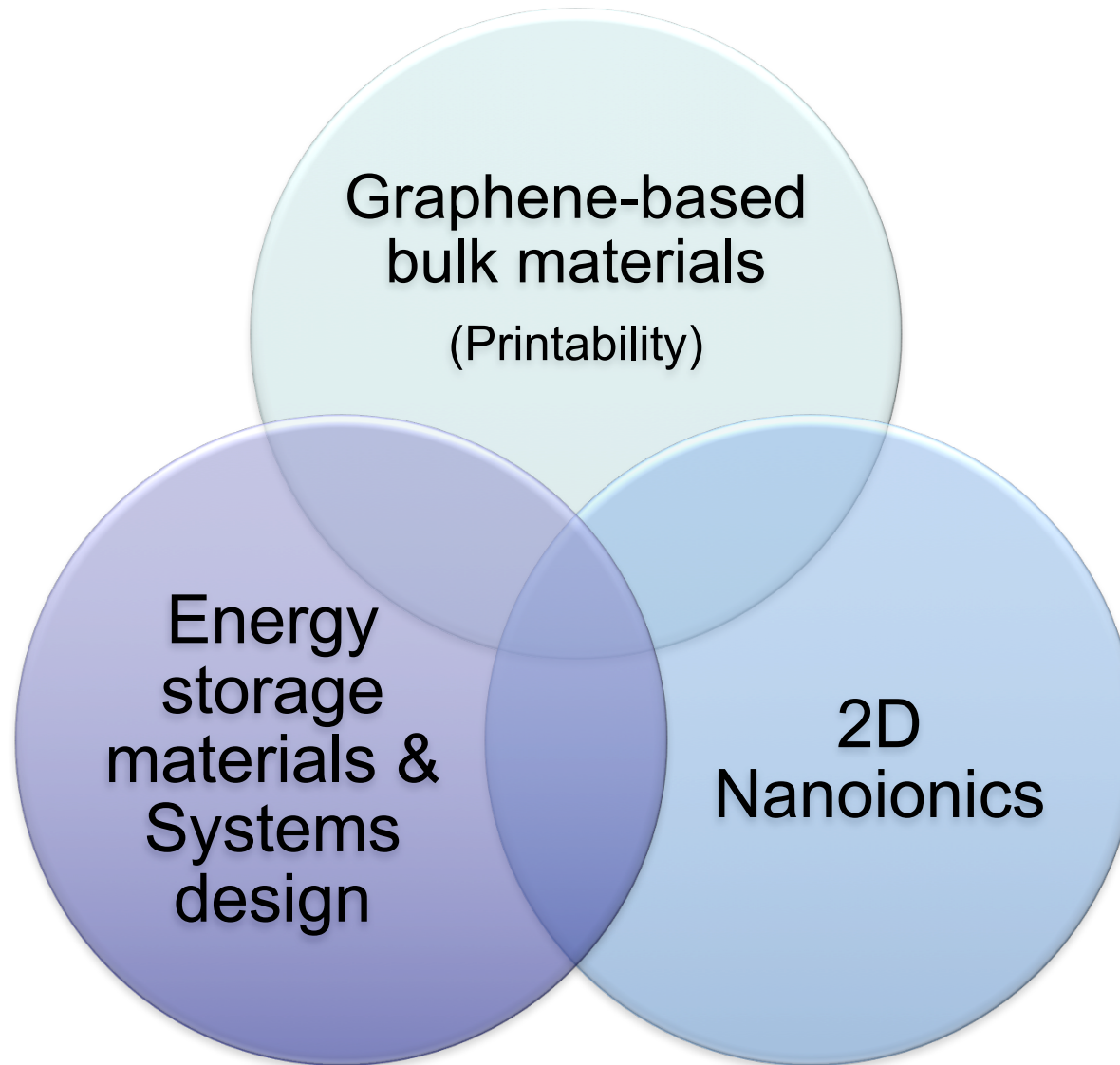
Water/environment/mining

Biomedicine

**Images from Google resource*

Building a 2D materials-based nanoionics platform





Thank you!

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University of Melbourne

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