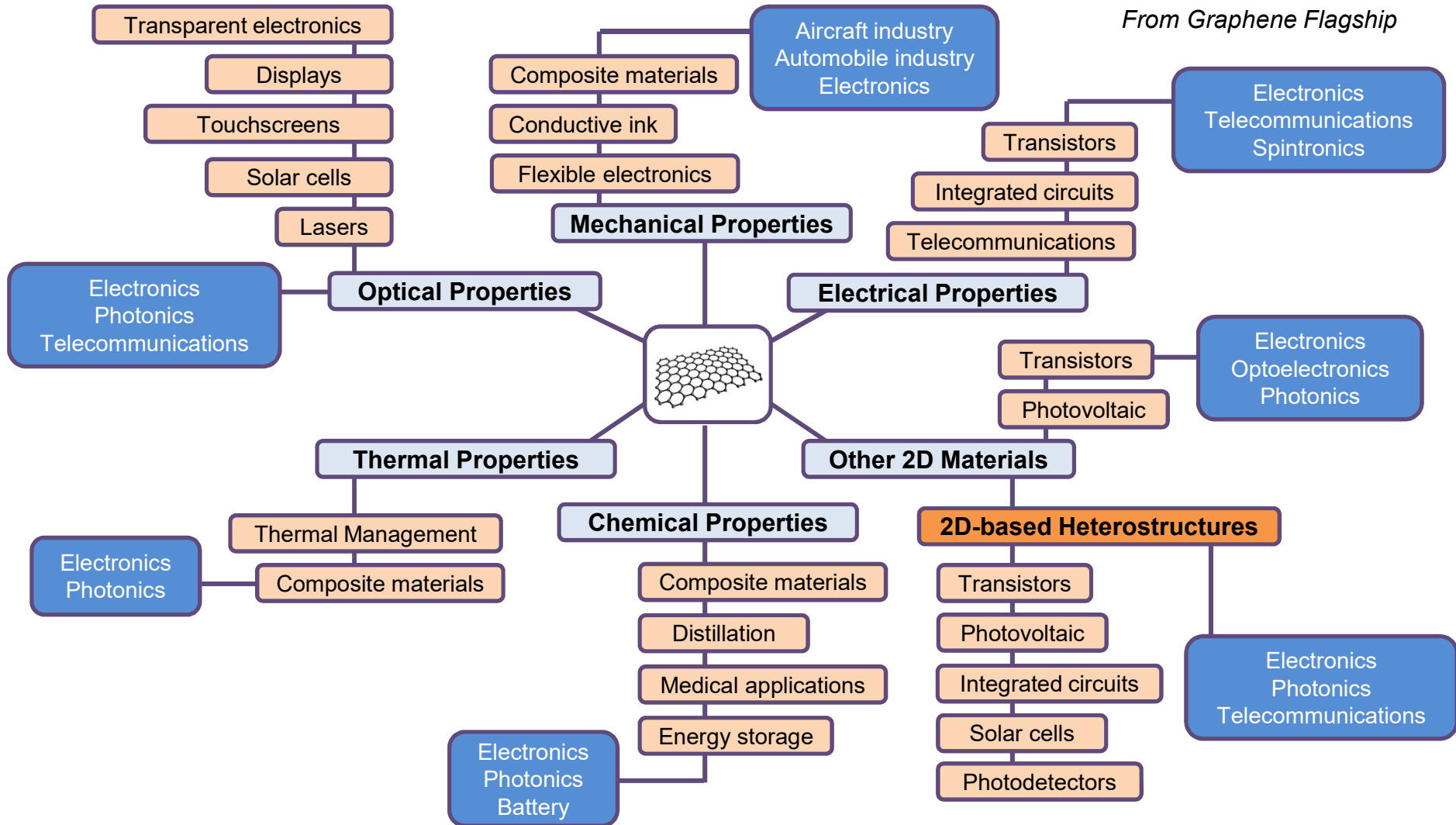


Two-dimensional materials and applications

9. Applications of 2D Materials

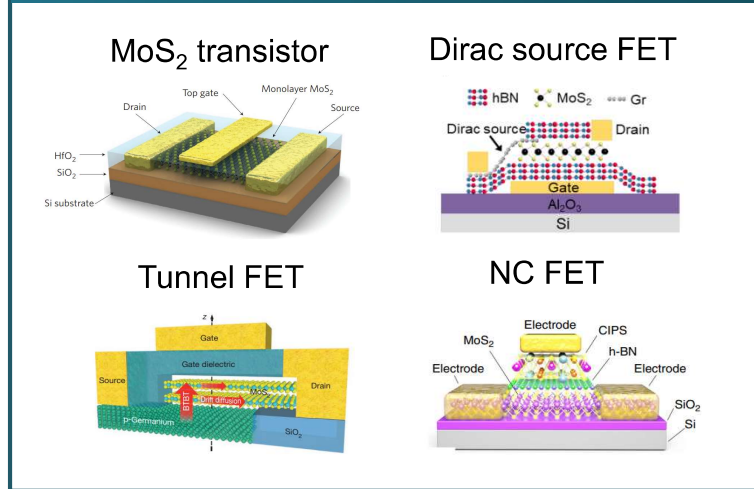


Various Applications of 2D Materials



Electronic Applications: Single Devices

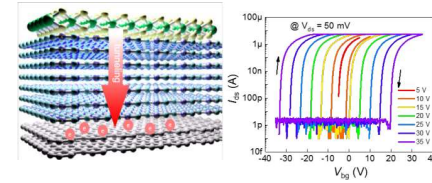
Transistor



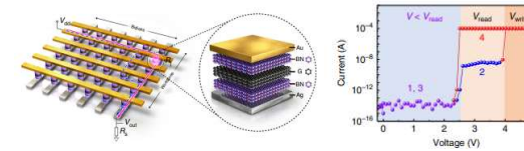
Nature(2011) Nano Lett. (2021) Nature (2015); Nat. Commun.(2019)

Memory

Ultrafast floating gate



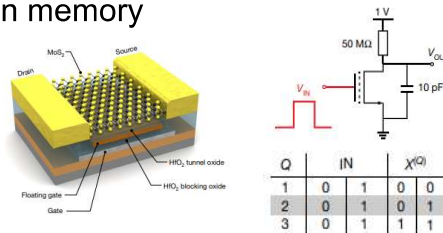
Resistive memory



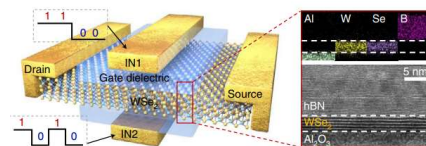
Nat. Nanotechnol. (2021); Nat. Commun. (2019)

Logic

Logic in memory



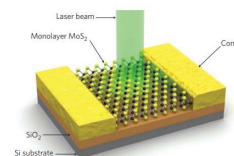
Reconfigurable logic



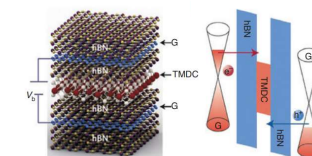
Nature (2021), Nat. Electron.(2021)

Optoelectronic device

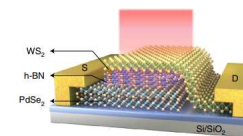
MoS₂ photodetector



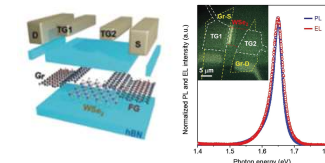
Light emitting diode



Unipolar barrier photodetector

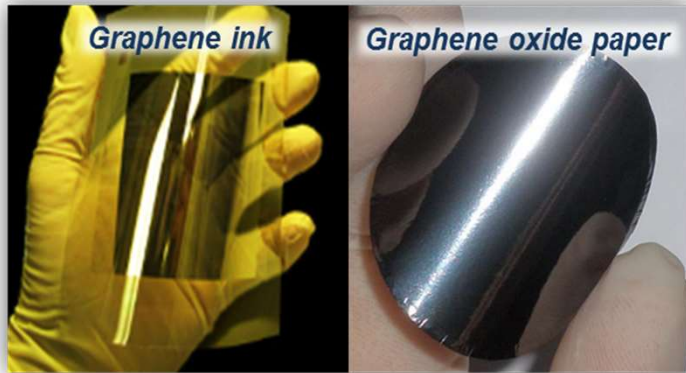


Light emitting transistor



Nat. Nanotech. (2013) Nat. Electron (2021) Nat. Mater. (2015), Adv. Mater. (2020)

Flexible Applications

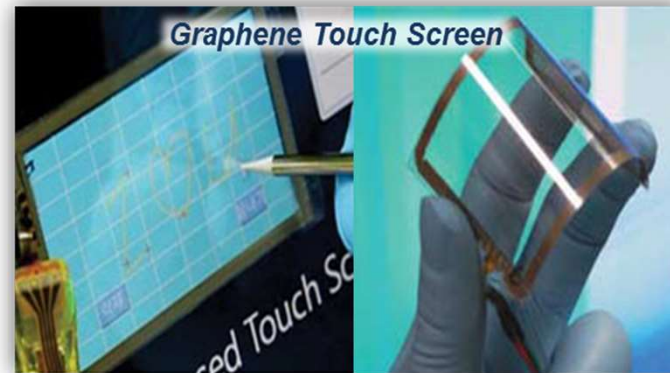


Graphene ink

Graphene oxide paper

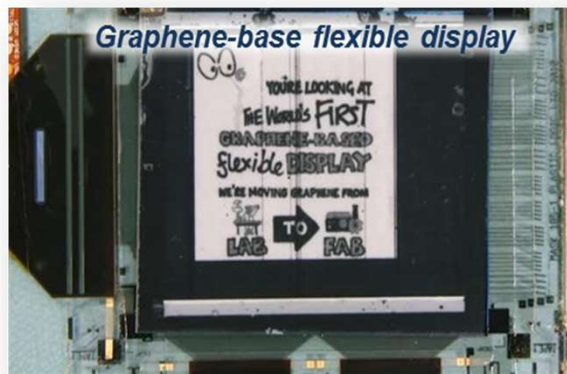
Haydale, UK

D. Li et al. Science (2008)



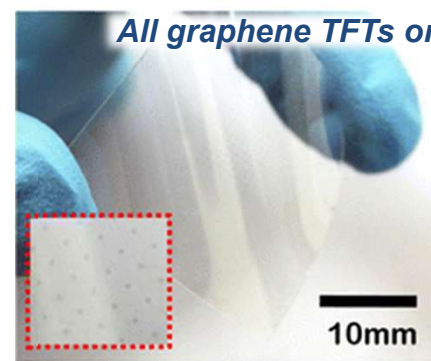
Graphene Touch Screen

S. Bae et al. Nature Nanotechnol. (2010)

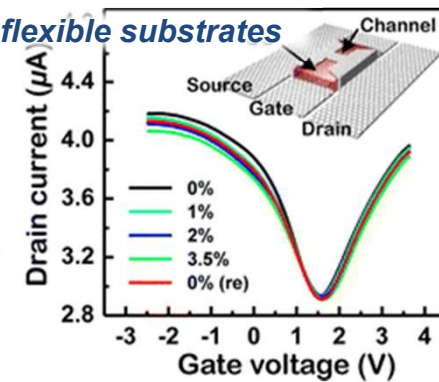


Graphene-base flexible display

Cambridge Graphene Centre and Plastic Logic



All graphene TFTs on flexible substrates



S. K. Lee et al. Nano Lett. (2012)

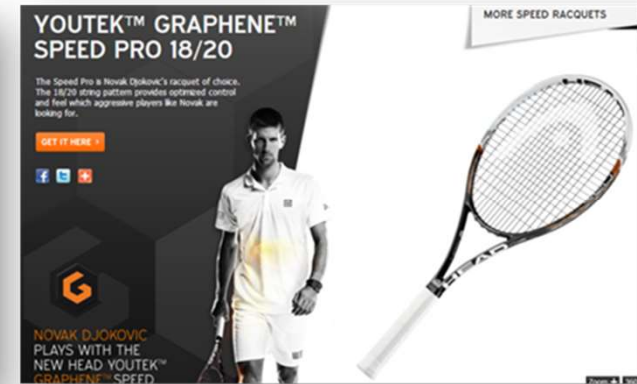
Graphene Composite



H. Hu et al. *Adv. Mater.* (2013)

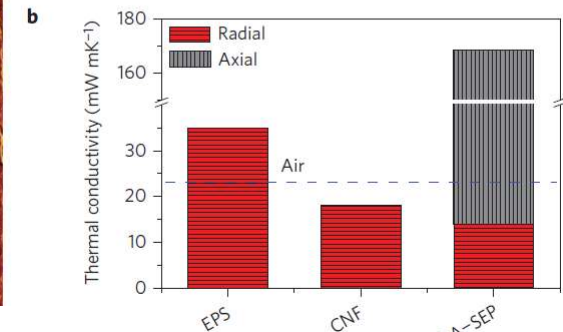
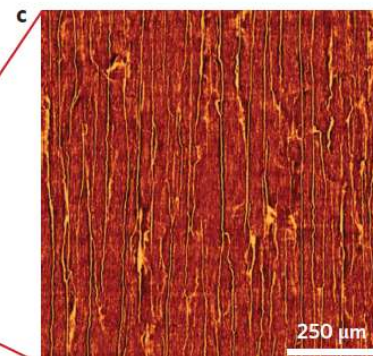
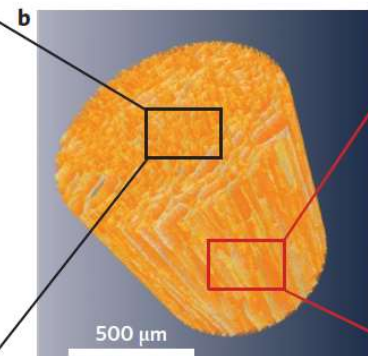
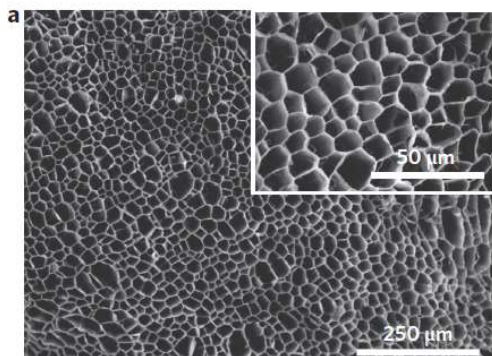
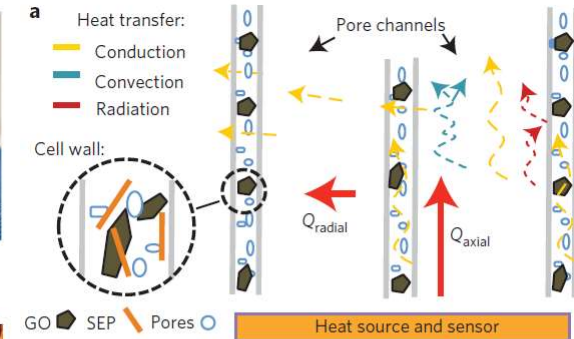
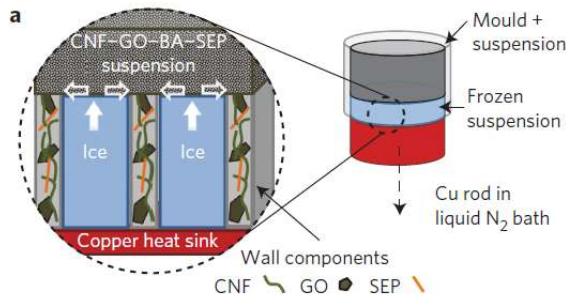


Y. Zhao et al. *Angew. Chem.* (2012)



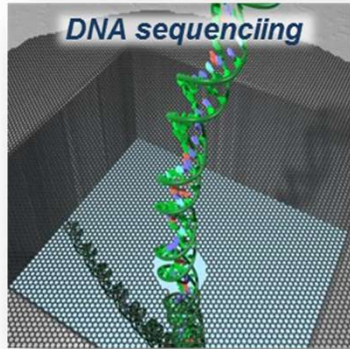
Graphene Racquet, HEAD

CNF-GO-BA-SEP Fabrication

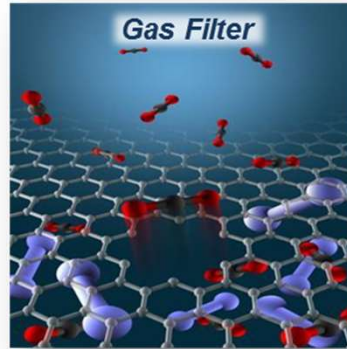


B. Wicklein et al. *Nature Nano.* (2014)

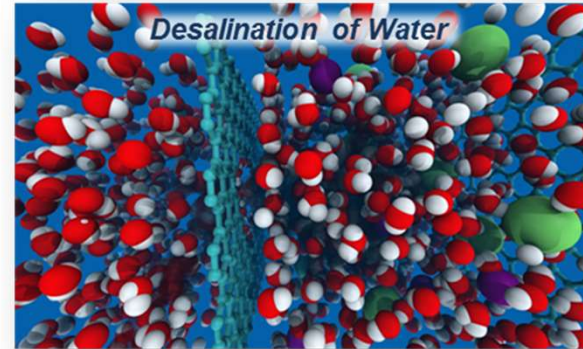
Bio Applications



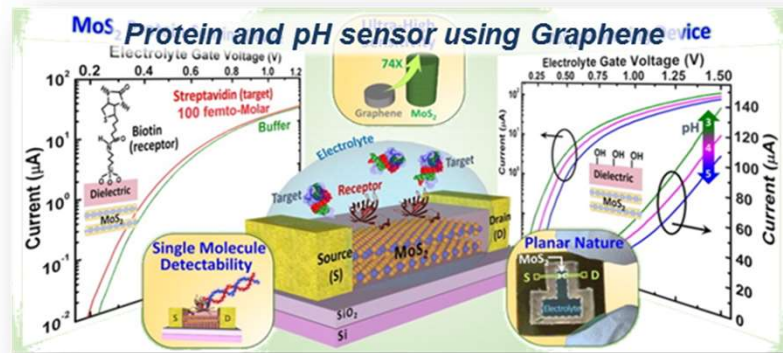
S. Garaj et al. Nature (2010)



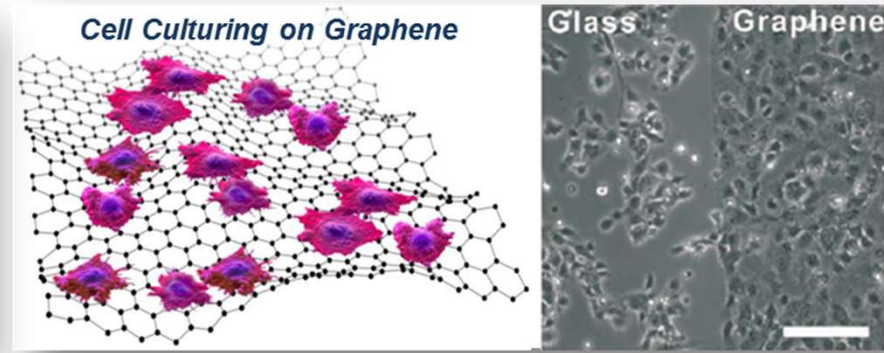
S. P. Koenig et al. Nat. Nanotech. (2012)



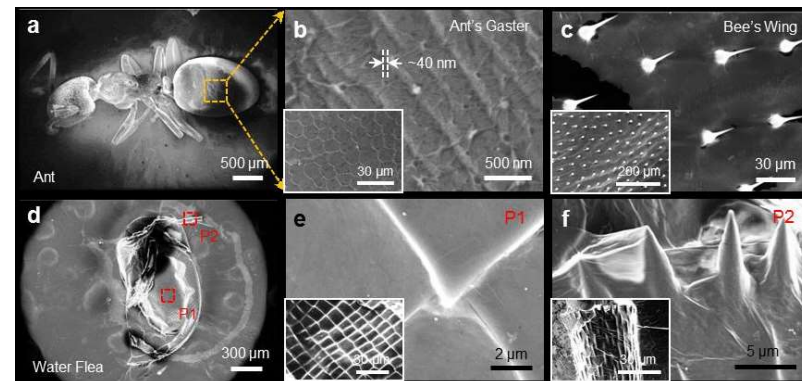
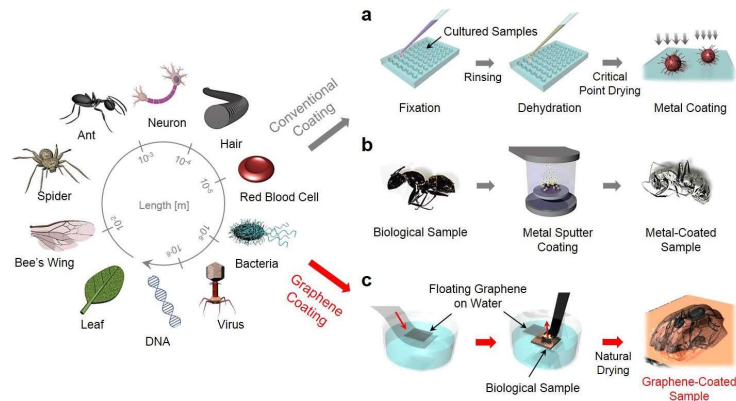
D. Cohen-Tanugi et al. Nano Lett. (2012)



D. Sarkar et al. ACS Nano (2014)

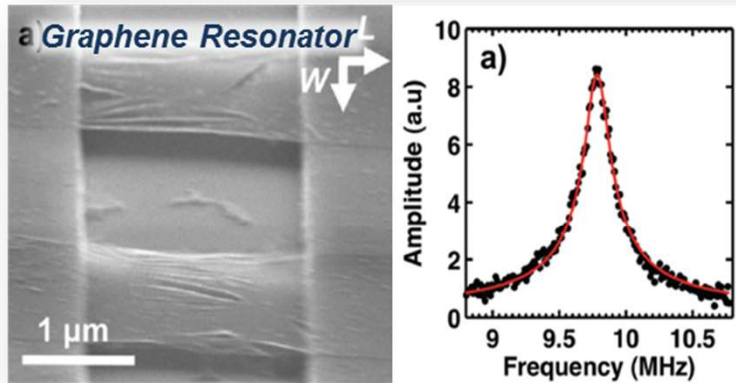


C. Chung et al. Acc. Chem. Res. (2013)

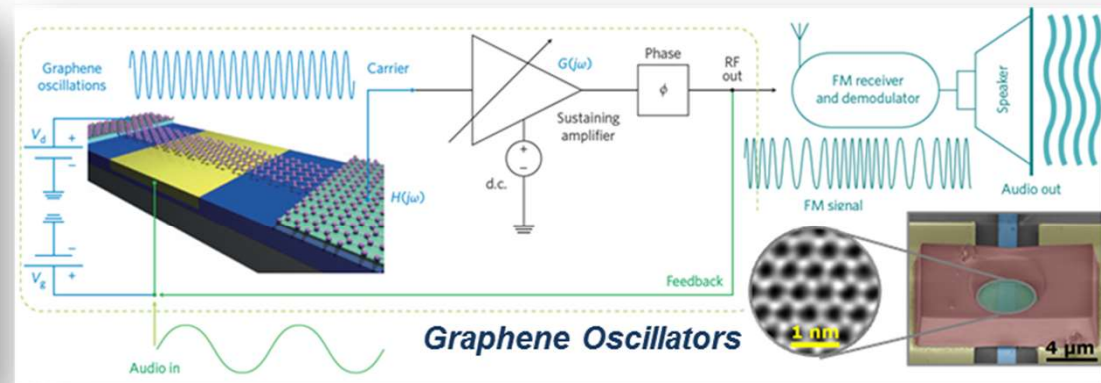


J. B. Park et al. arXiv (2014)

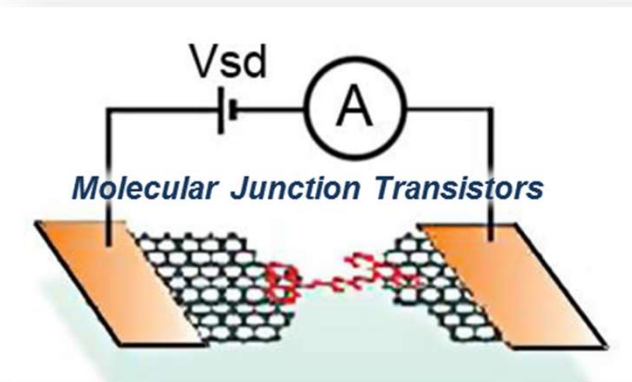
Other Applications



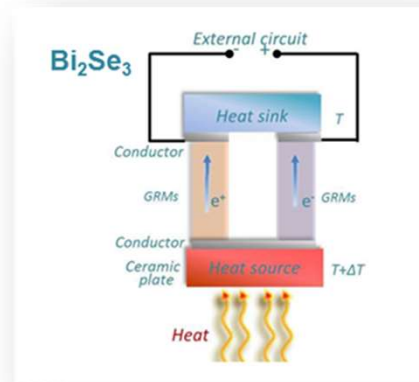
A.M. van der Zande et al. *Nano Lett.* (2010)



C. Chen et al. *Nature Nanotechnol.* (2013)

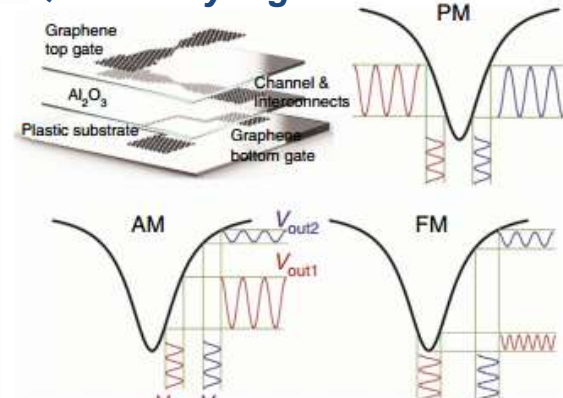


F. Prins et al. *Nano Lett.* (2011)



F. Bonaccorso et al. *Under review* (2014)

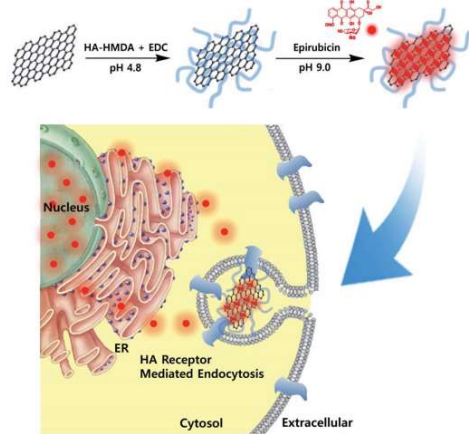
Quaternary digital modulations



S. H. Lee et al. *Nature Commun.* (2012)

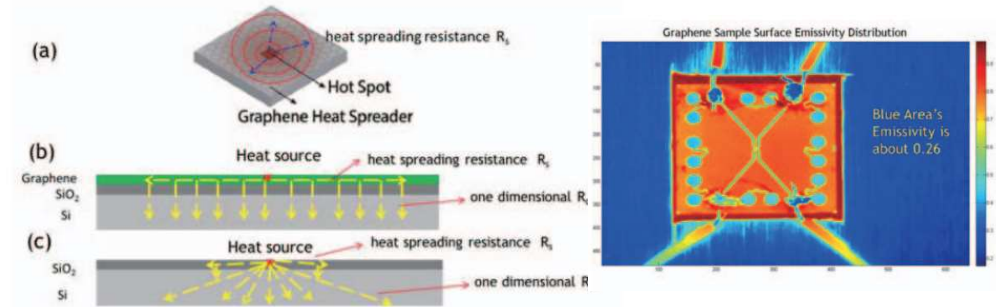
Other Applications

Graphene oxide drug delivery



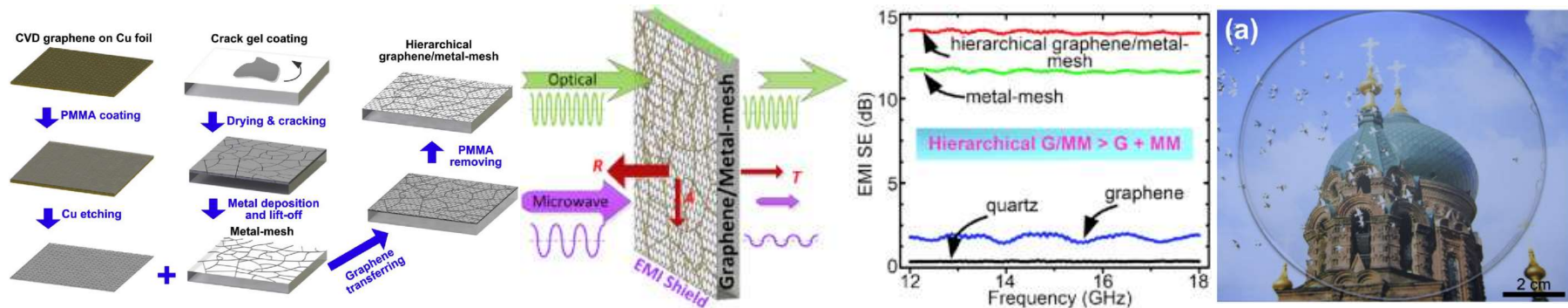
H. S. Jung et al. RSC Advances (2014)

Graphene heat spreader



S. Huang et al. IEEE (2013)

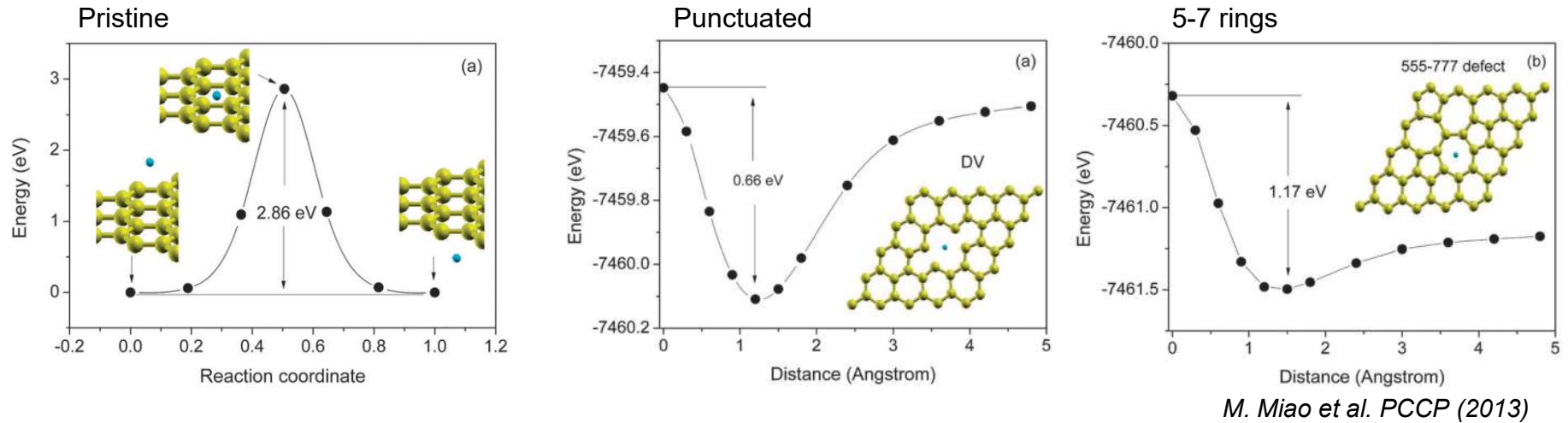
Transparent graphene/metal mesh EM wave shielding



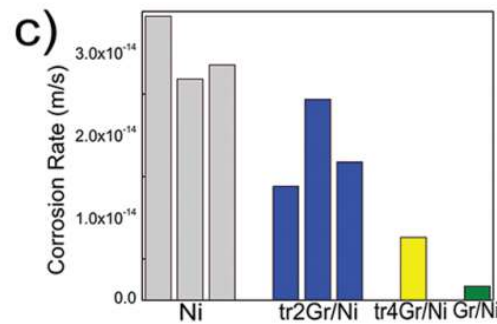
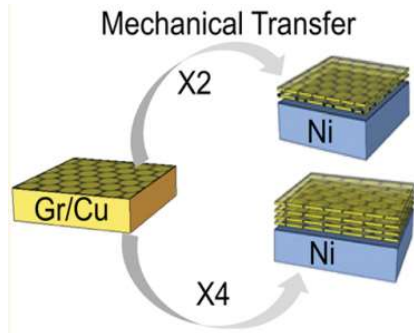
Y. Han et al. Carbon (2017)

Impermeable Graphene Barrier

Direct penetration of H atom through graphene

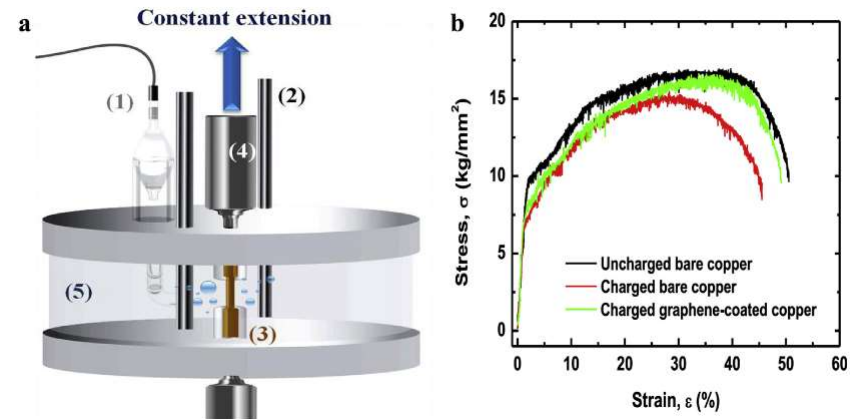


Graphene corrosion barrier



D. Prasai et al. ACS Nano (2012)

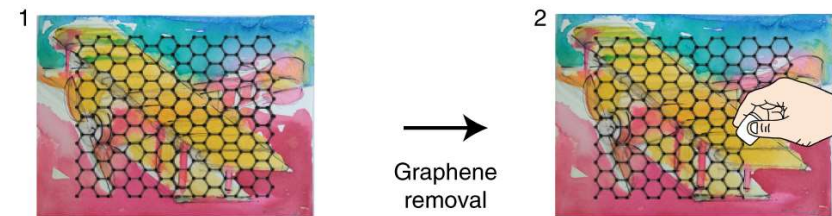
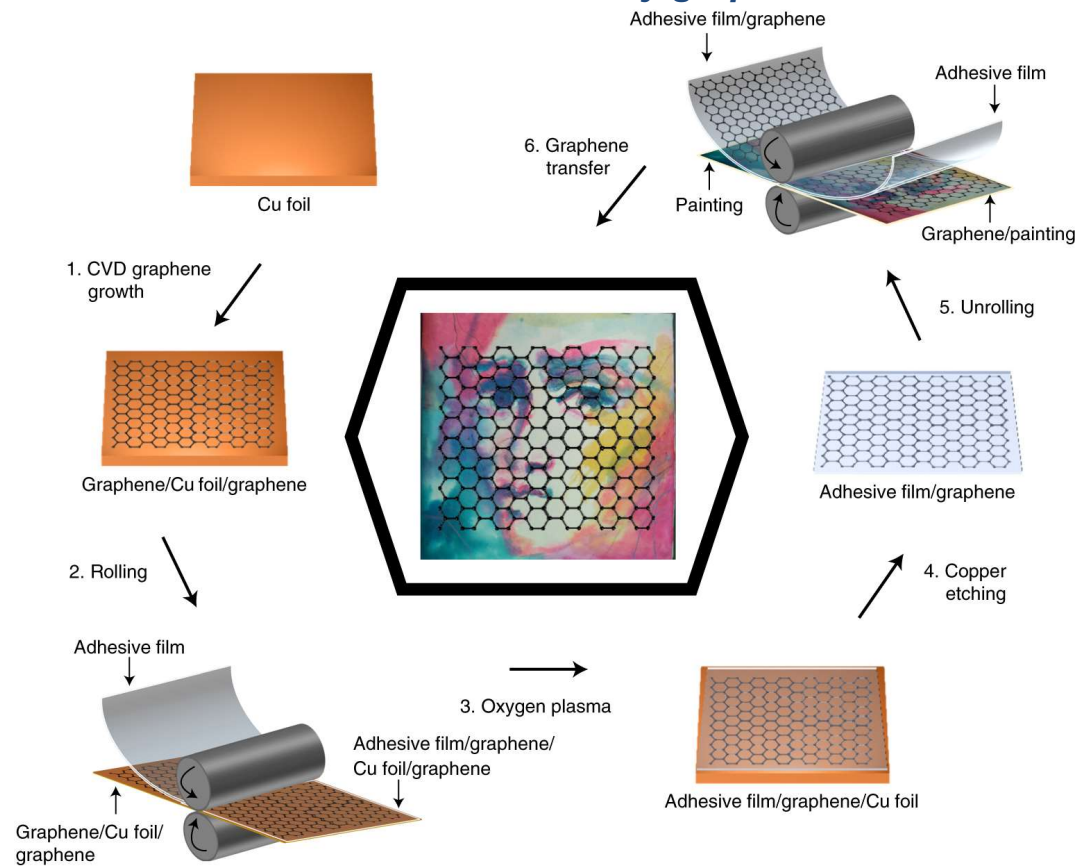
Graphene H₂ barrier



T-H. Nam et al. Int. J. Hydrog. Energy (2014)

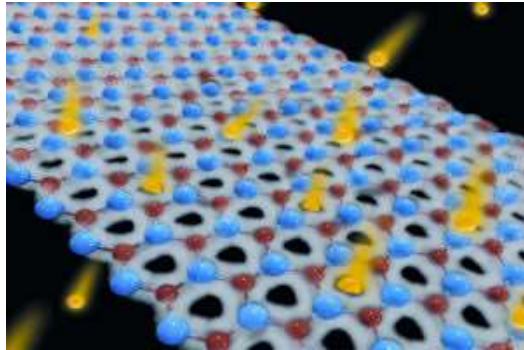
Impermeable Graphene Barrier

Protection of artwork by graphene

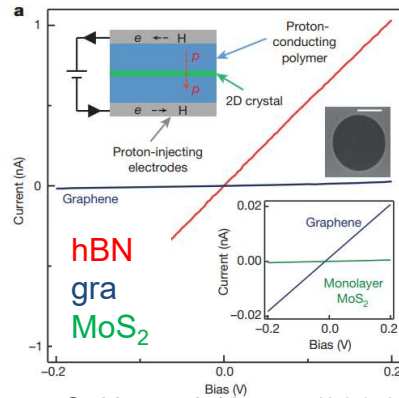


Graphene Filters

1L graphene & hBN as proton filter

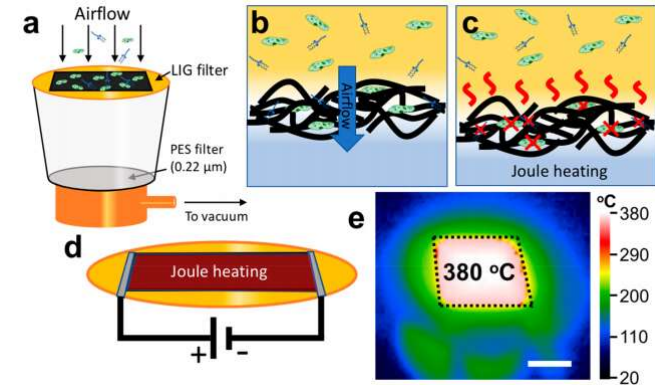


manchester.ac.uk



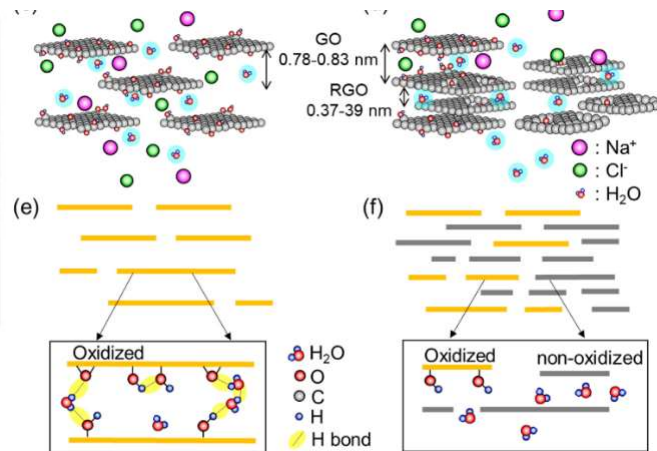
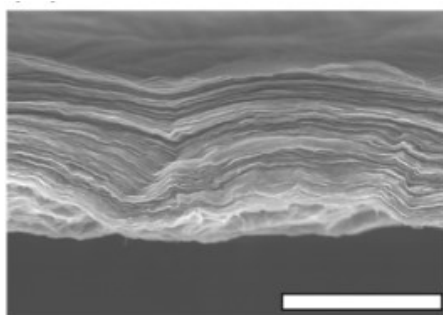
S. Hu et al. Nature (2014)

Reusable graphene biofilter (destroying bacteria by heating)



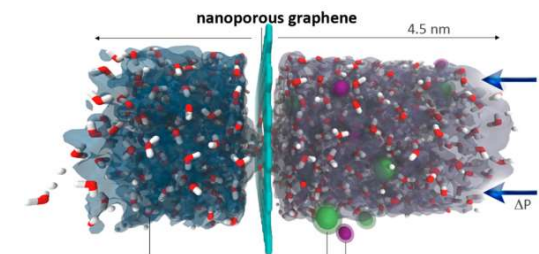
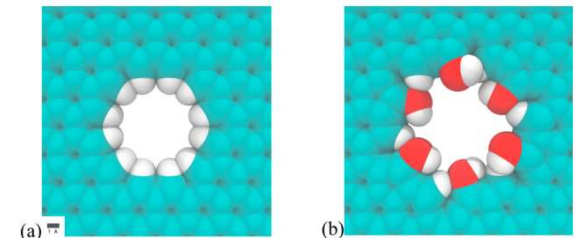
M.G. Stanford et al. ACS Nano (2019)

Desalination by interlayer gap between rGO



H-H Huang et al. J Membrane Sci (2019)

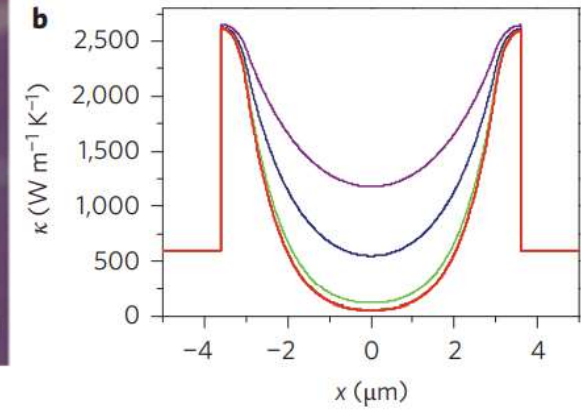
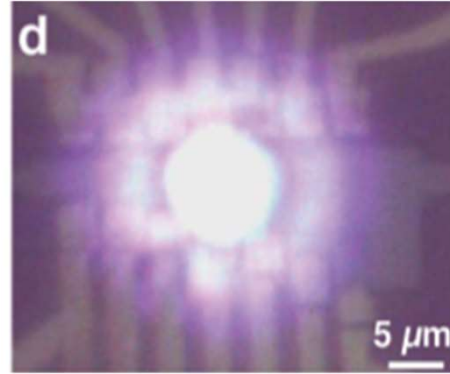
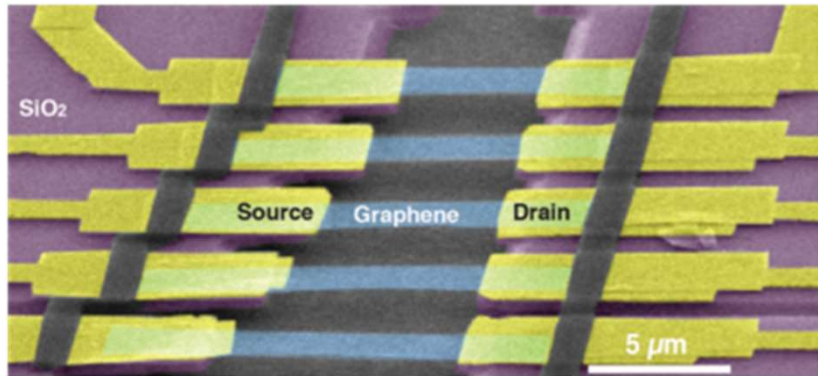
Porous graphene as desalination



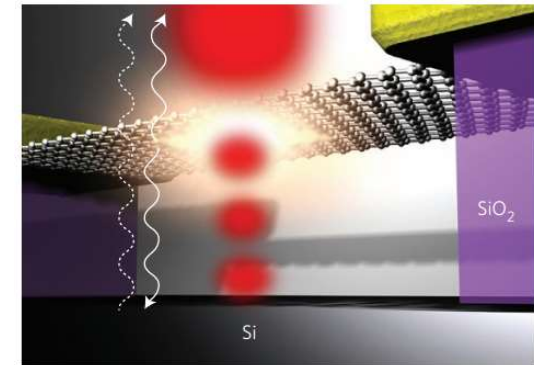
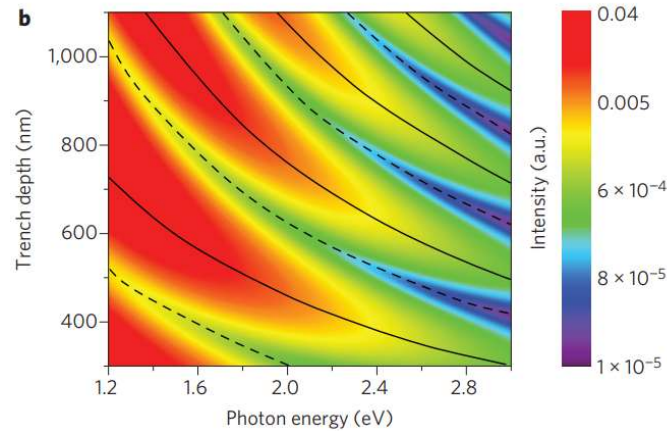
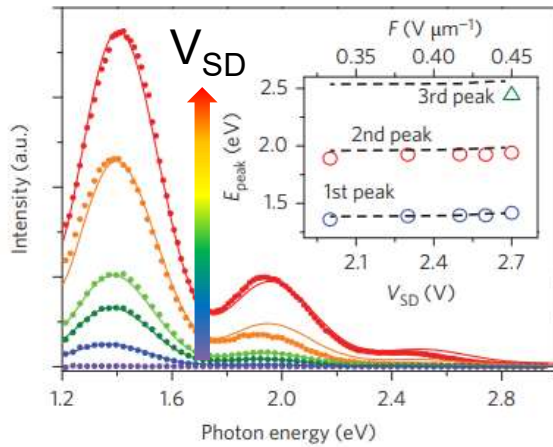
D. Cohen-Tanugi et al. Nano Lett. (2012)

Graphene Light Emitter

Visible light emission from suspended graphene

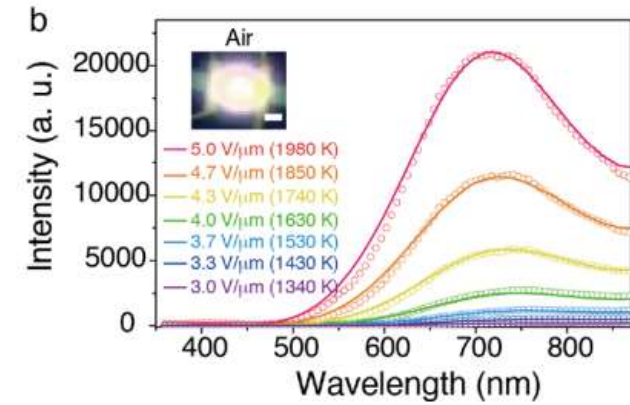
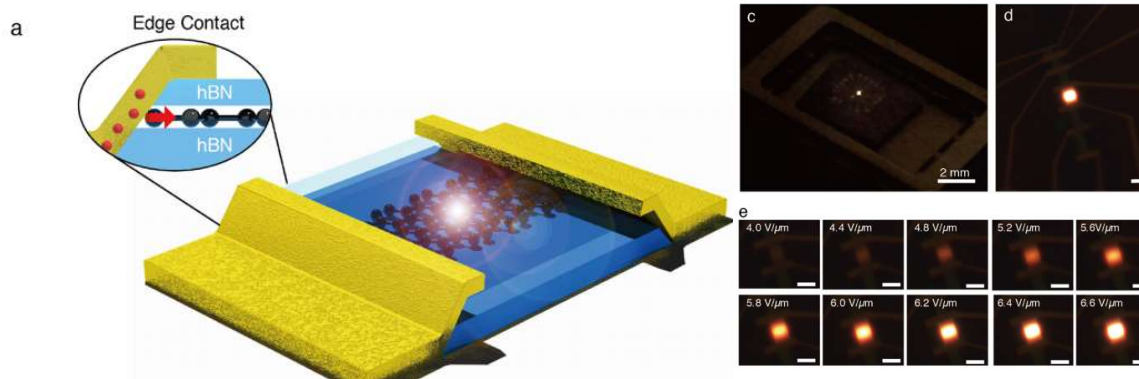


a Peak position modulation by trench depth

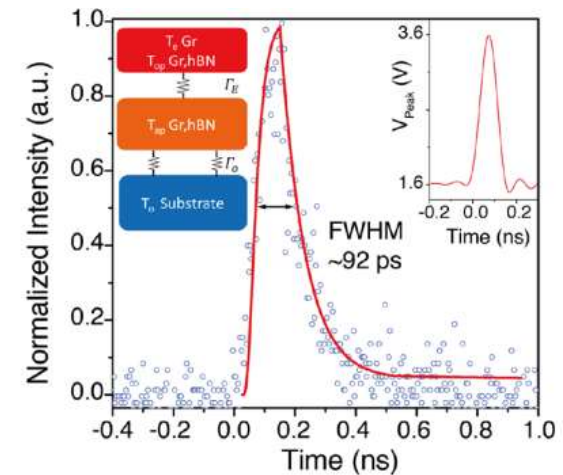
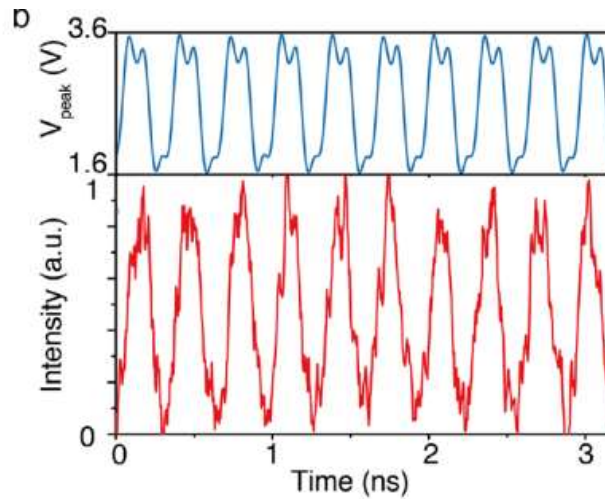
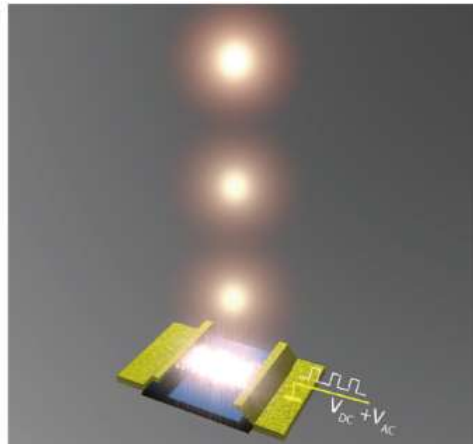


Graphene Light Emitter

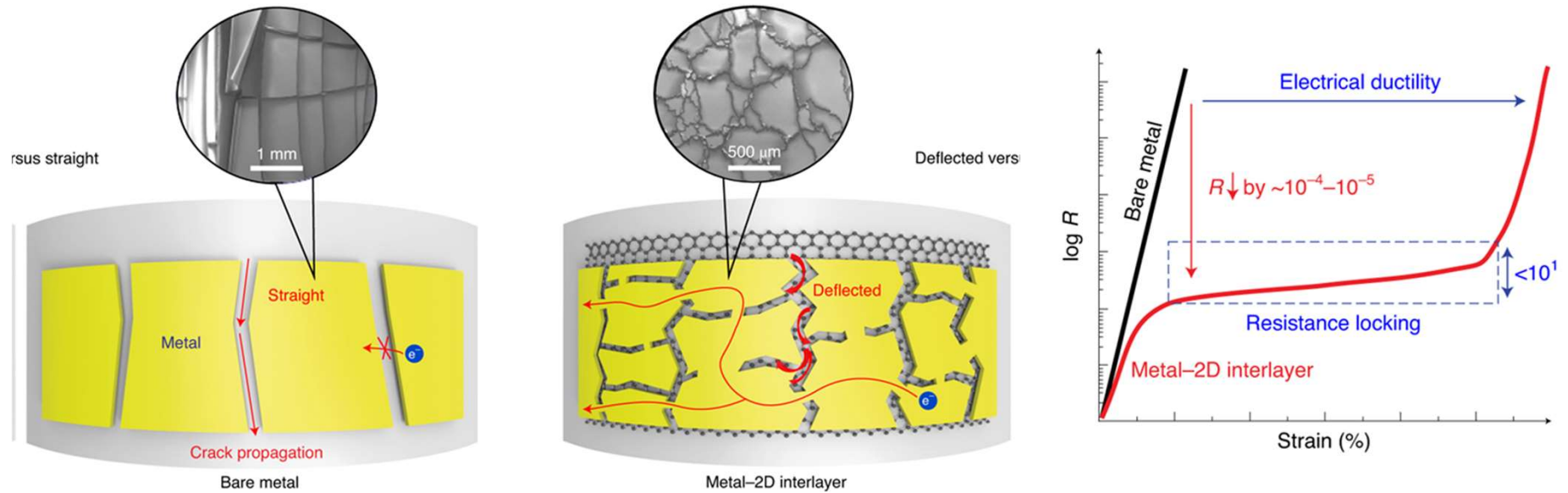
Encapsulation by hBN: Passivation & Cooling



Generation of ultrafast light pulses



Flexible 2D-metal Interlayer Electrode



Crack development in a bare Au electrode under bending deformation

Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

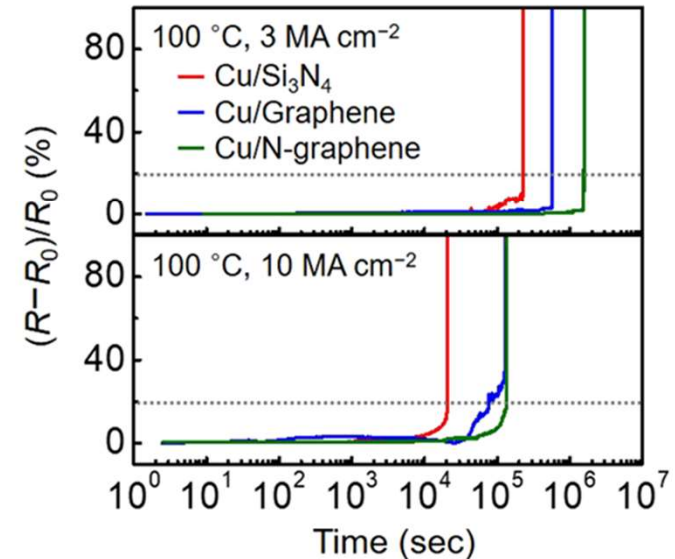
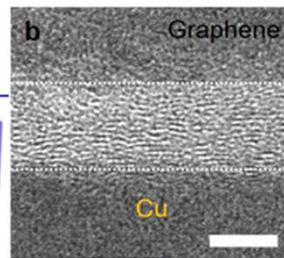
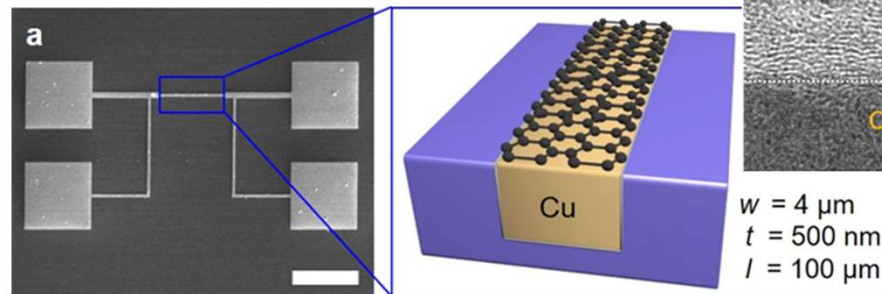
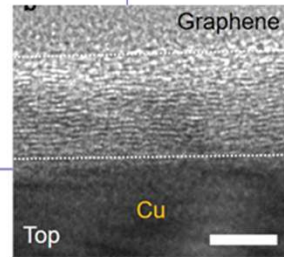
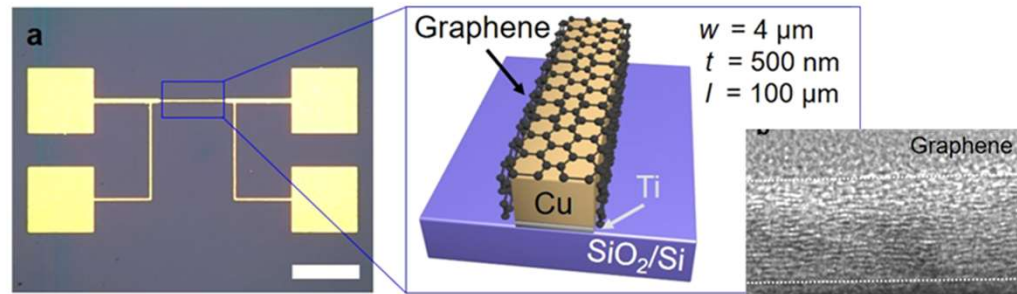
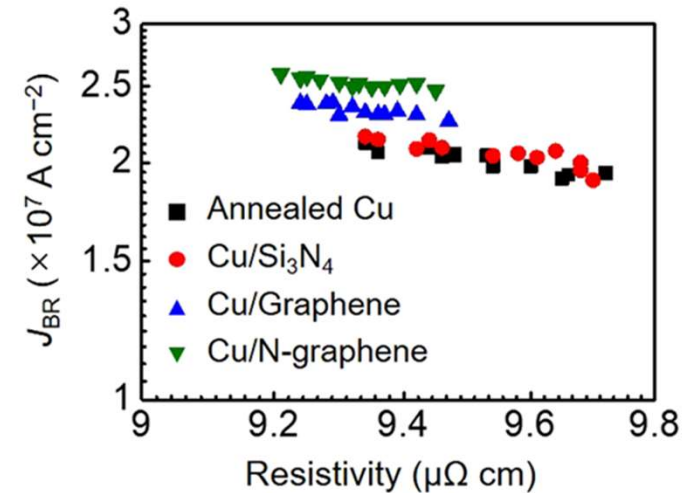
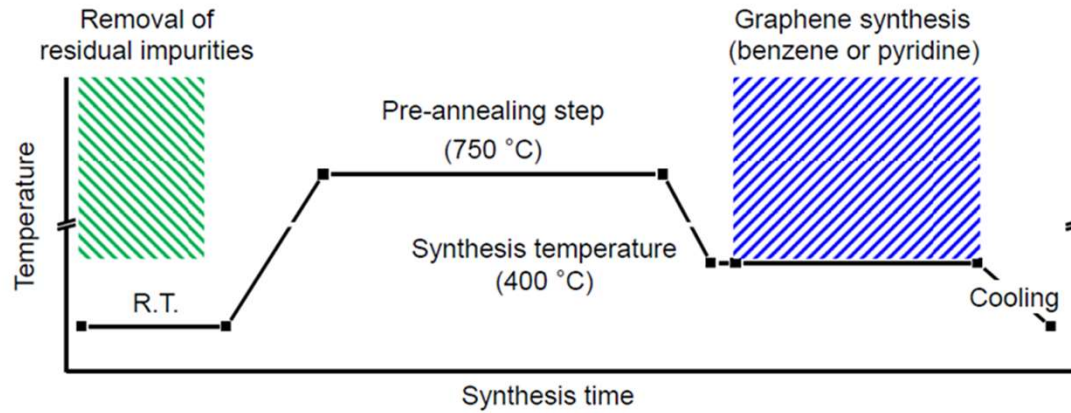
Crack development in an Au/1LG electrode under bending deformation

Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

Practical functionality demonstration of flexible light emitting devices with a metal-2D interlayer interconnector

Department of Mechanical Science and Engineering
University of Illinois at Urbana-Champaign

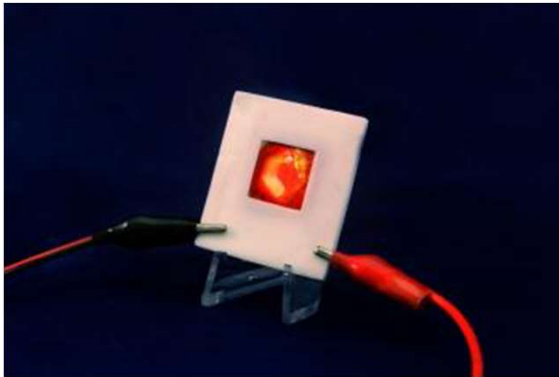
Graphene-capped Cu Interconnects



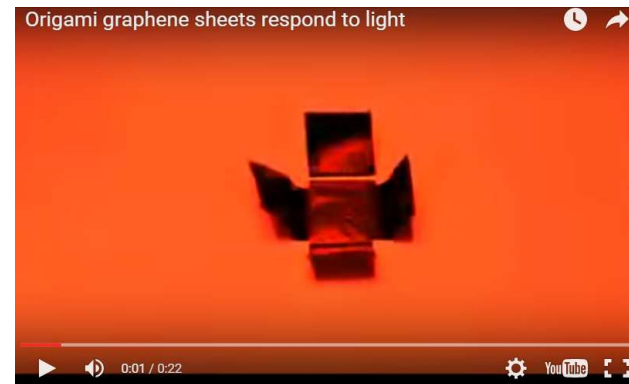
Graphene Products



Graphene Products

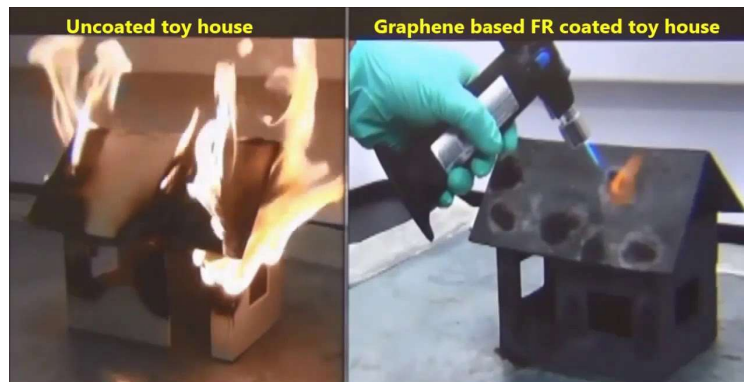


3D printed graphene-based OLED (Graphene 3D lab)
<https://www.youtube.com/watch?v=zvMqLayQXv4>



Origami-inspired GO sheets
(stimulated by light and heat)

<https://youtu.be/zlbnU0kpXEc>
<https://youtu.be/c05wfOjDwik>



Graphene based fire resistant

firstgraphene.net



Graphene coating for watch

arcadiawatches.com

Graphene Products

Origami graphene sheets respond to light

FINANCIAL TIMES

March 27, 2015 3:26 pm

Lightbulb moment as first mass-market graphene product goes live

Andrew Bounds, Enterprise Editor

3D print

[e/zlbnU0kpXEc](#)
[e/c05wfOjDwik](#)



The first mass market product made with the “miracle material” **graphene** is about to go on sale: a lightbulb.

The invention is a dimmable LED lightbulb that can cut energy costs by at least 10 per cent and last for several years. Its developers at Manchester University say it is within

months of going on sale.

Graphene-Cu foil for SSD cooling

firstgraphene.net

Graphene coating for watch

arcadiawatches.com

Graphene in Transport



First flight of graphene-skinned aircraft
newatlas.com (2018.08)



The world's first graphene car is unveiled in Manchester
bbc.com (2016.07)



대형 트럭 및 버스용 그래핀(Graphene) 엔진오일 첨가제 출시
hellaasiaagent.co.kr



Talga launches commercial-scale trial of graphene coating on ocean-going cargo vessel
graphene-info.com (2019.11)

Graphene Products in Electronics

Graphene-Cu foil for SSD cooling



www.teamgroupinc.com

Graphene film for smartphone cooling



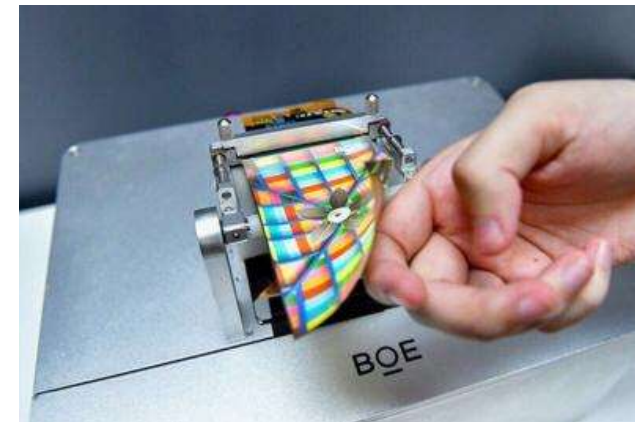
www.teamgroupinc.com

Graphene-augmented wireless earphone



zoloaudio.com

Graphene-based flexible touch panel



boe.com

Graphene Products in Korea

[UNISEX] 헤비아우터 그래핀 발열 솃패딩
HEAVY OUTER GRAHENE EXOTHERMIC PADDING

Musinsa store
store.musinsa.com (searched in 2020. 03)



KEEP WARM
다이아몬드보다 2배 높은 graphene의 열전도성이
체온을 빠르게 전도하고 온기를 유지합니다.
ANTIBIOSIS
공기순환이 원활하여 항균성을 가진 그래핀 섬유는
외부오염에 강합니다.



“미세한 전류가 모공을 열어
에센스의 유효성분을 피부 깊숙이”

국내 최초 첨단 신소재
그래핀 공법 시트

그래핀 공법으로 만들어
스마트 에너지 시트가
전도제 역할을 하여
에센스의 유효성분이
효과적으로 피부에
흡수되도록 도움을 줍니다

그래핀은 2010년 노벨상을
받은 첨단 신소재로
구리보다 약 100배 이상
높은 전도율과
다이아몬드보다 2배 높은
열 전달율을 가지고 있습니다

phany.kr (searched in 2020.03)

Supplier



BihurCrystal



Gr-related companies

SAMSUNG



POSCO



NOKIA

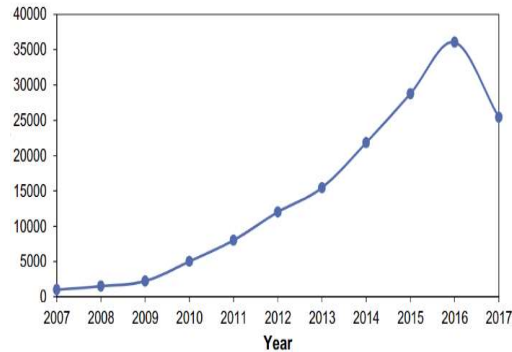


TATA STEEL

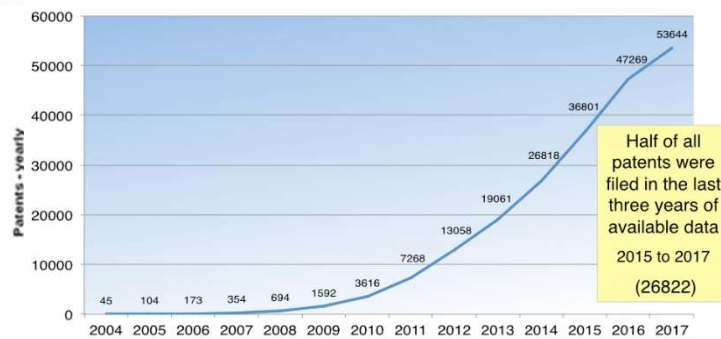


Future of 2D Materials

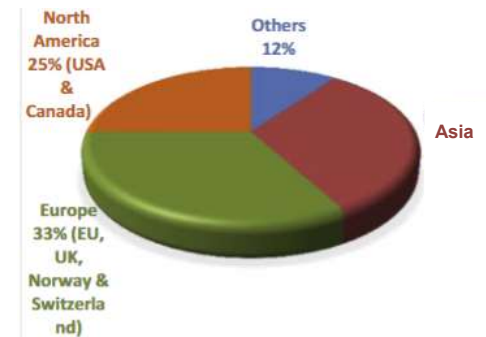
Number of publications



Number of patents



Distribution of scientific papers



Composites Part B 142 (2018) 200–220



USA National Science Foundation: \$10,000,000 (103 억원) for 2D heterostructure



EU: graphene flagship €1,000,000,000 (1 조3 천억원) for graphene and other 2D materials



China: 80% of graphene patent in 2012-2013



*“It’s a bit silly for society to throw a little bit of money at something and expect it to change the world. **Everything takes time.**”*

Andre Geim, August, 2013