Emerging Technologies and Advanced Materials: Industry Perspectives on Exposure, Hazard and Risk Assessment

Graphene/Graphene Oxide

Quantum Materials

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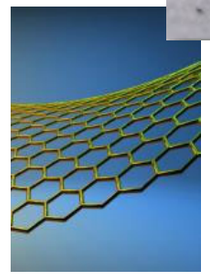
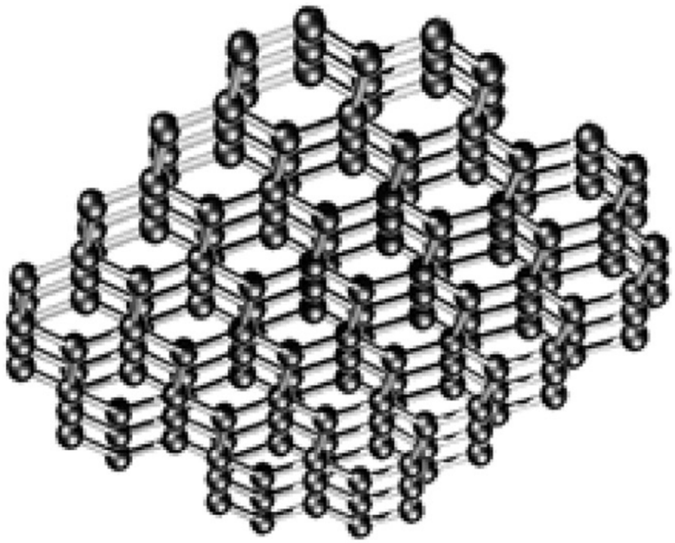
Graphene

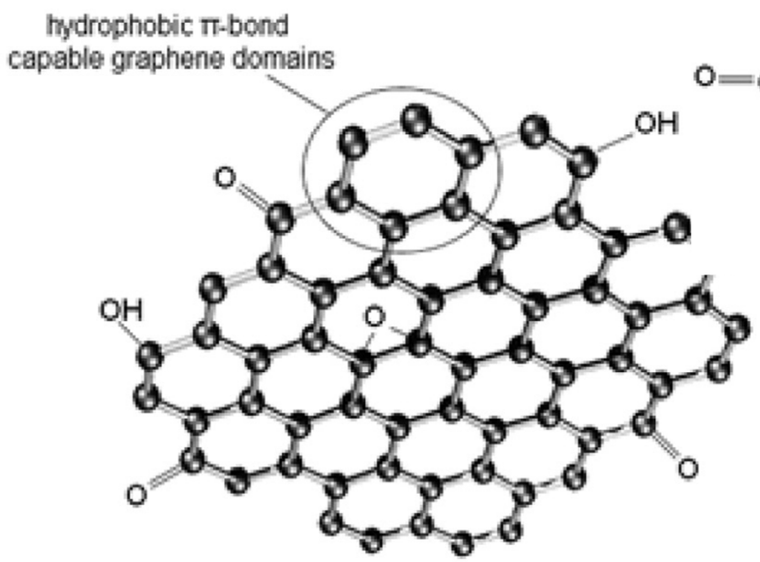
- **Superior Electrical Properties**
  - highest intrinsic mobility *(100 times more than in Si)*
  - highest current density at room T *(100 times of copper)*
  - longest mean free path at room T *(micron range)*
  - lightest charge carriers *(zero rest mass)*
  - record thermal conductivity *(outperforming diamond)*
- **Geometrical Properties**
  - thinnest imaginable material
  - largest surface area *(~2,700 m^2 per gram)*
- **Mechanical Properties**
  - strongest material 'ever measured' *(theoretical limit)*
  - most stretchable crystal *(up to 20% elastically)*
  - completely impermeable *(even He atoms cannot squeeze through)*

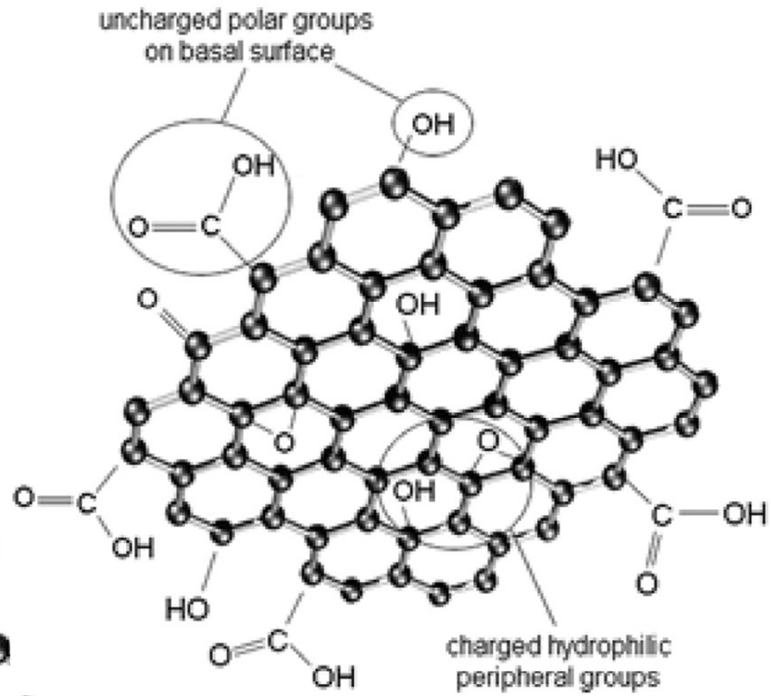


Geim and Novoselov, 2010 Nobel Prize

“Graphene+” Materials





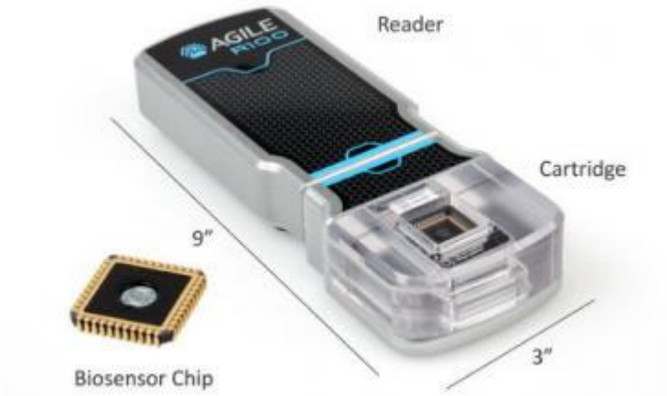


"Graphene+" Industry

- touchscreens (for LCD or OLED displays)
- transistors
- computer chips
- batteries
- energy generation
- supercapacitors
- DNA sequencing
- water filters
- antennas
- solar cells
- spintronics-related products

GRAPHENE SUPERMARKET

Vorbeck



Nanomedical DIAGNOSTICS

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Review

An overview of graphene materials: Properties, applications and toxicity on aquatic environments

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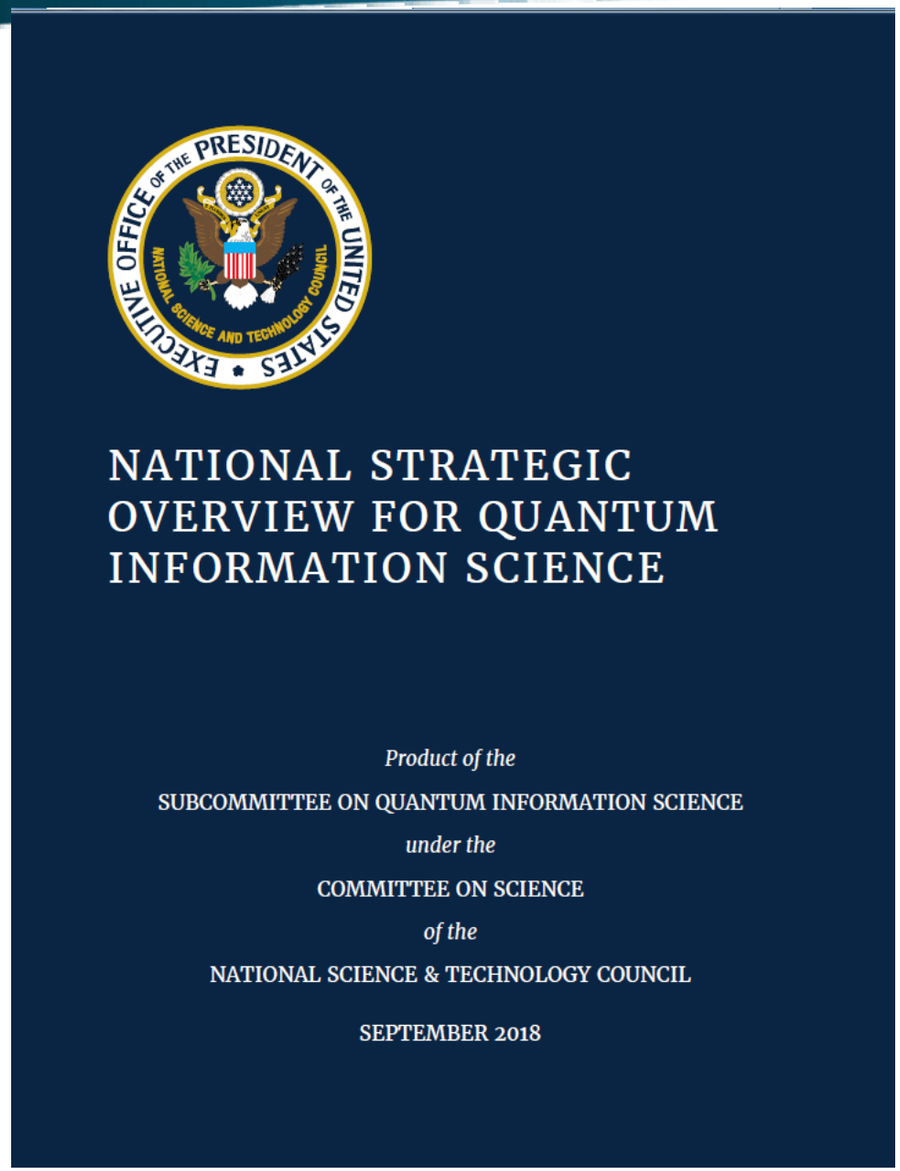
"So far, ecotoxicity of GFMs has been tested on various model and non-model organisms among which bacteria, algae, invertebrates and fish. There are however many questions that still need to be addressed. In fact, many challenges are faced in GFMs studies due to their diversity making difficult to compare the results."


NATIONAL STRATEGIC OVERVIEW FOR QUANTUM INFORMATION SCIENCE
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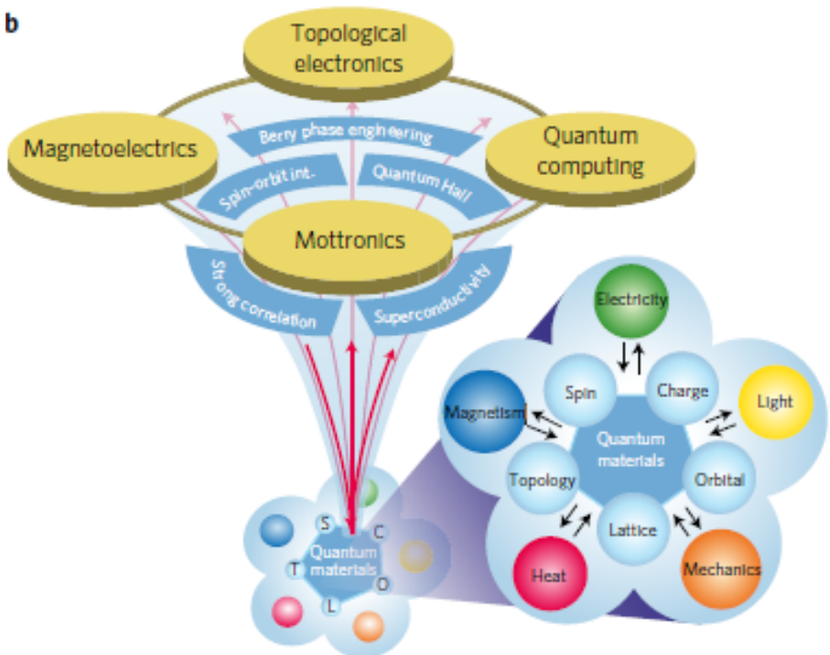
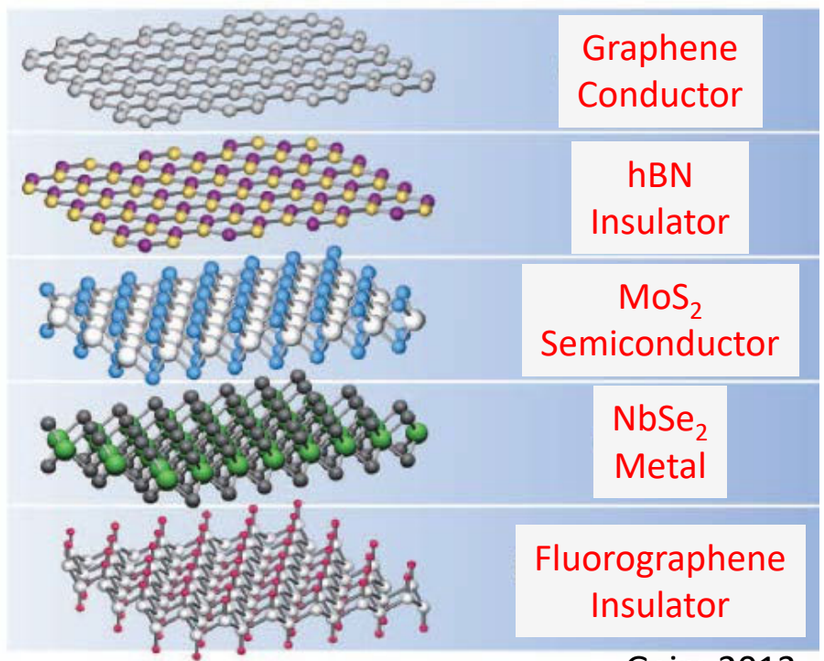
The US Department of Energy (DOE) describes quantum materials as "solids with exotic physical properties, arising from the quantum mechanical properties of their constituent electrons, that have great scientific and/or technological potential."

TABLE 1. Two-dimensional Heterojunctions Produced by van der Waals Epitaxy

layer	substrate	ref
graphene	sapphire	322
C_{60}	MoS_2	323
MoS_2	graphene	75
GaS	GaSe, Si(111)	324
GeS	SiO_2/Si	74
TaS_2	mica	325
WS_2	graphite	326,327
HfS_2	WSe_2	328
CdS	InSe/H-S(111)	329
SnS_2	WSe_2, MoS_2, $MoTe_2$, GaSe, WSe_2	330,331
$SnSe_2$	SnS_2,WSe_2, MoS_2, $MoTe_2$, GaSe	330,331
Bi_2Se_3	graphene/SiC, Si(111)	238,332
$BiTe_2Se$	h-BN	333
ZnSe	InSe, GaSe	334
$MoSe_2$	SnS_2, MoS_2, GaAs(111)	335
GaSe	GaAs(111), Si(111)	336,337
$NbSe_2$	mica, GaAs(111)	338
CdTe	$MoSe_2$, WSe_2	339
PbTe	Si(111)	340





Geim 2013