

# GRAPHENE AND CORONAVIRUS

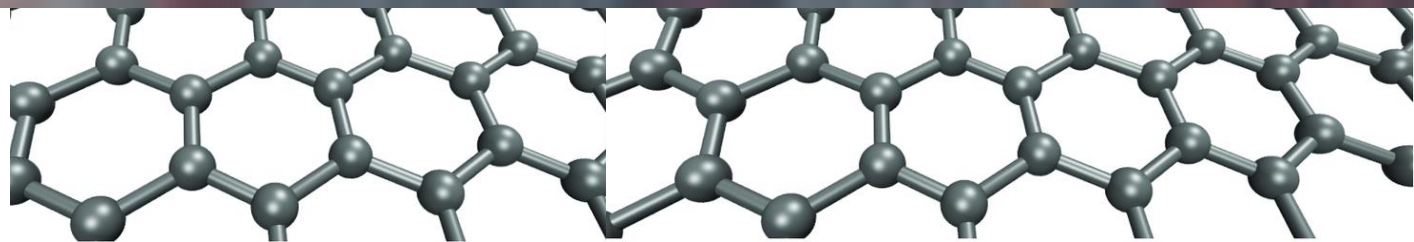
**Faisal Amri Tanjung, PhD**

*Dean, Faculty of Science and Technology*

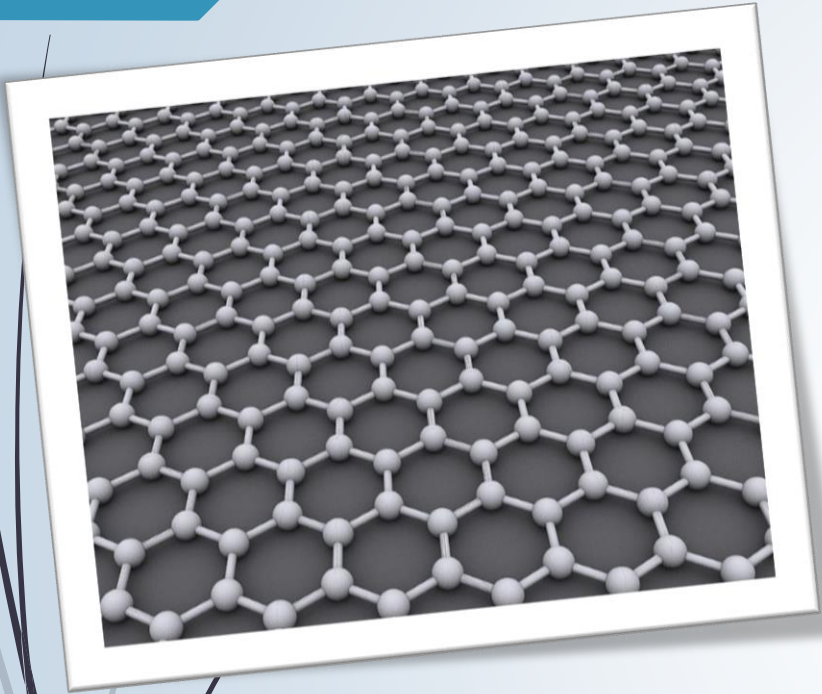
*University Associate, Curtin University*



**FACULTY OF SCIENCE AND TECHNOLOGY**  
**UNIVERSITAS MEDAN AREA**

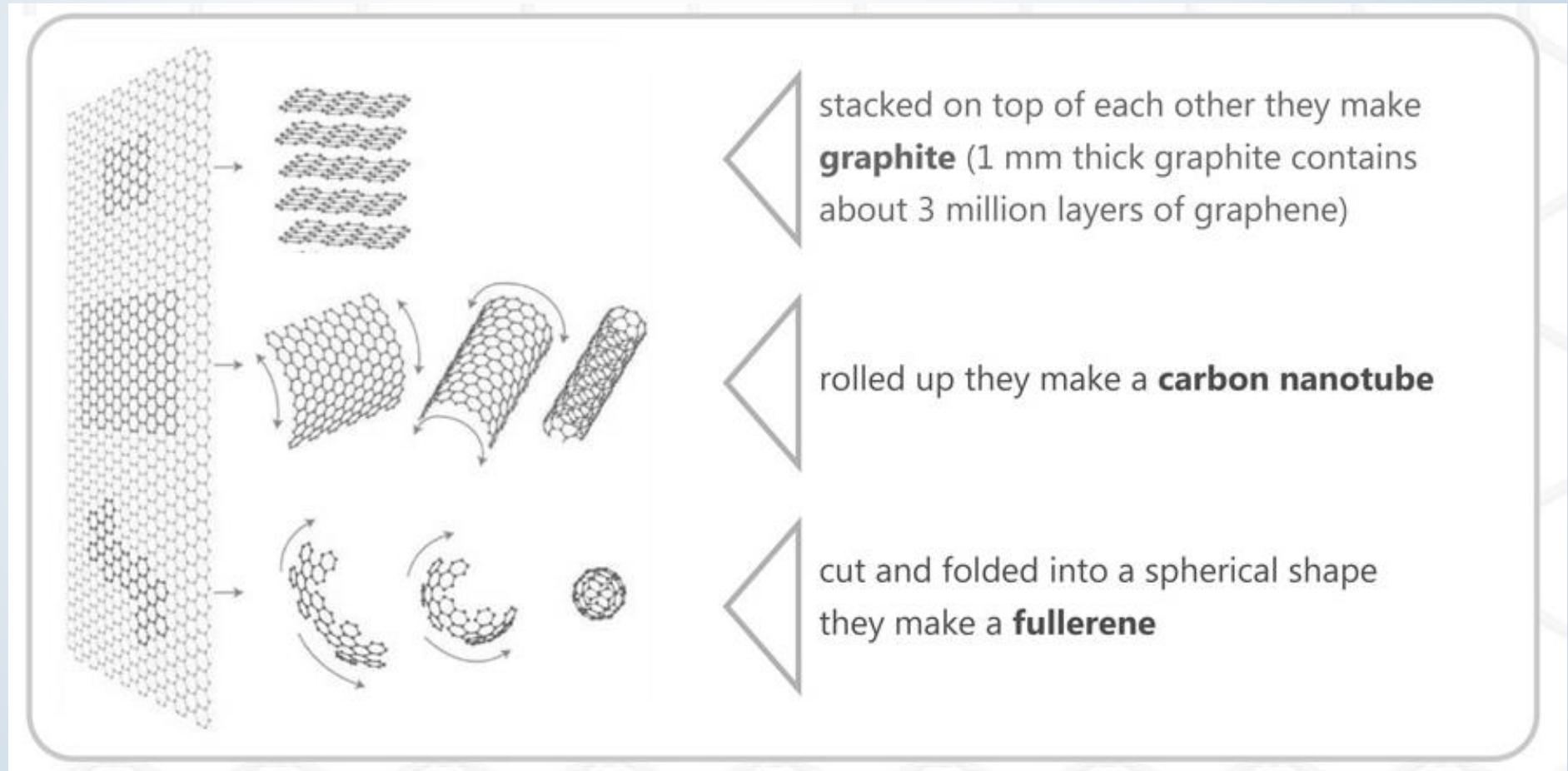


# What is graphene?



- Graphene is a material made from carbon
- It represents a conceptually new class of materials that are only one atom thick, so-called two-dimensional (2D) materials (they are called 2D because they extend in only two dimensions: length and width)
- It has many different properties which make it potentially useful
- It is expected to replace common materials (i.e. plastic, silicon) on certain products as early as the next decade

# Graphene sheets are building blocks for other graphitic materials





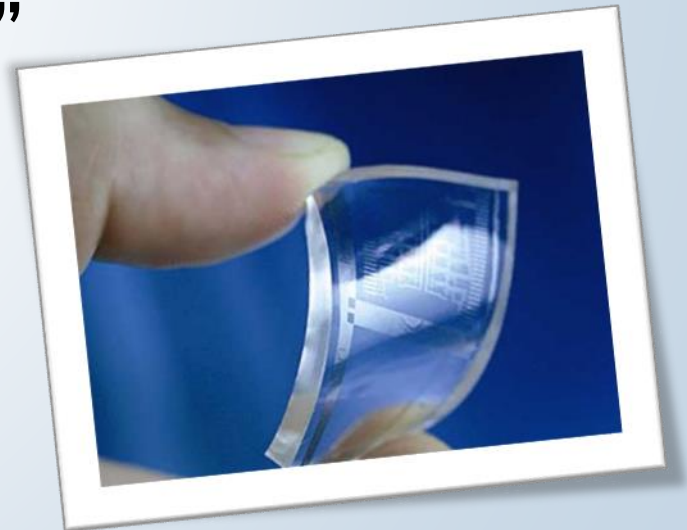


# Properties of graphene

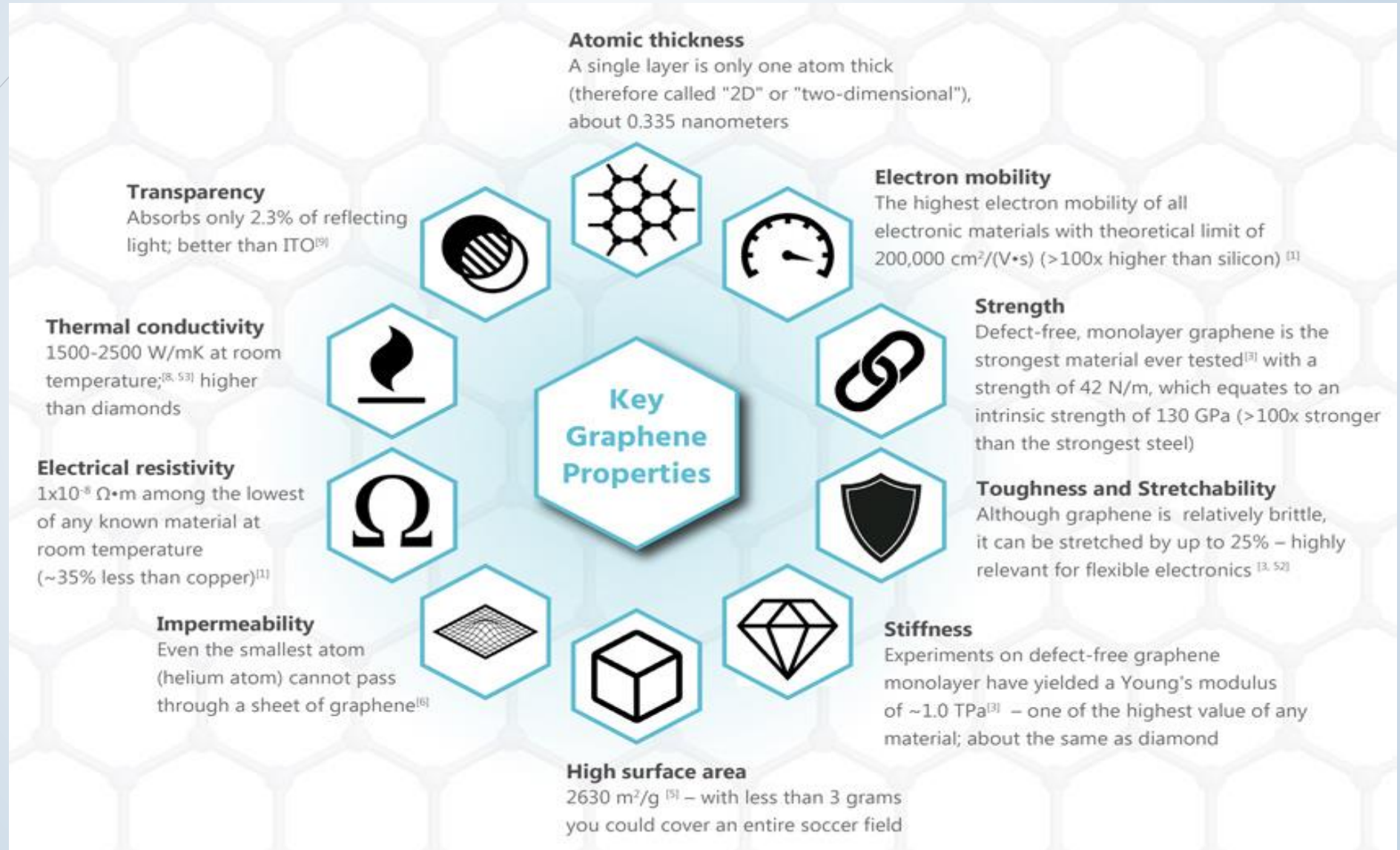
- **Great semiconductor – electrons can move with minimal resistance**
- **Extraordinarily strong – 100x stronger than steel**
- **Thermal conductor - heat can move 10x faster in graphene than in copper**
- **Nearly transparent – 97.3% transparent due to it only being one atom thick**

# Properties of graphene

- Flexible and malleable – attributed to its light weight and thinness, can flex 20% without damage
- Potential to be cheap/affordable – carbon is incredibly abundant on Earth
- Incredibly thin – one atom “thick”



# The graphene's extraordinary properties





# Application of graphene

## Membranes

Due to graphene's impermeability, a single layer of atoms can act as a perfect barrier when dealing with liquids and gasses. However, pores in graphene (defects) can selectively allow the transport of gas and water molecules, which allows graphene to be tuned to enable selective permeability of gases.

### Applications

- Electrical control of water flow through graphene membranes<sup>[40]</sup>
- Gas barriers, for instance in food packaging
- Water purification and desalination<sup>[41, 42]</sup>
- Separation of organic solvent from water<sup>[43]</sup>

## Biomedical Technologies

Graphene is paving the way for novel biomedical technologies, thanks to high surface area, electron mobility, and functionalization potential. Graphene bioelectronics (transistors and electrode arrays) has become a ground-breaking field that offers exciting opportunities for developing new kinds of biosensors capable of establishing outstanding interfaces with soft tissue.

### Applications

- Thermal ablation of highly resistant cancer cells<sup>[44]</sup>
- Targeting and neutralizing cancer stem cells<sup>[45]</sup>
- Bioelectronics (bionics)<sup>[46]</sup>
- Electronic interface to living cells and nerve tissue<sup>[47]</sup>
- Luminescent graphene tags for bioimaging<sup>[48]</sup>

## Energy Harvesting & Storage

There are four major energy-related areas where graphene and graphene-based nanomaterials have an impact: **solar cells, supercapacitors, graphene batteries, and catalysis for fuel cells.**

### Applications

- Graphene improves both energy capacity and charge rate in rechargeable batteries<sup>[49]</sup>
- Activated graphene makes superior supercapacitors for energy storage<sup>[50]</sup>
- Graphene electrodes may lead to a promising approach for making solar cells that are inexpensive, lightweight and flexible<sup>[51]</sup>
- Experimental designs for several graphene-based solar cells have been reported so far, with graphene serving as different parts of the cell<sup>[52]</sup>
- Multifunctional graphene mats are promising substrates for catalytic systems<sup>[53]</sup>

## Electronics

The unique atomic arrangement of the carbon atoms in graphene allows its electrons to easily travel at extremely high velocity without the significant chance of scattering, saving precious energy typically lost in other conductors. The electronic properties of the graphene system rely heavily on the number of graphene layers and the coupling effects from the underlying substrate.

### Applications

- Flexible, stretchable and foldable devices<sup>[54]</sup>
- Low-cost printable electronics<sup>[55]</sup>
- High-frequency electronics<sup>[56]</sup>
- High-performance transistors<sup>[57]</sup>
- Thermal management and heat dissipation in nanoelectronic devices<sup>[58]</sup>
- The optical properties of graphene can be controlled by doping and make it well-suited for optoelectronic devices (electronic devices that source, detect and control light)<sup>[59]</sup>

## Sensors

Because every atom in graphene is exposed to its environment it is an ideal material for biological, gas, and chemical sensors.

### Applications

- Explosives detection<sup>[60]</sup>
- Biosensor to detect biomarkers for Parkinson's disease<sup>[61]</sup> and bacteria<sup>[62]</sup>
- Selective gas sensing<sup>[63]</sup>
- Self-healable, multifunctional electronic sensor tattoos<sup>[64]</sup>
- Environmental monitoring<sup>[65]</sup>

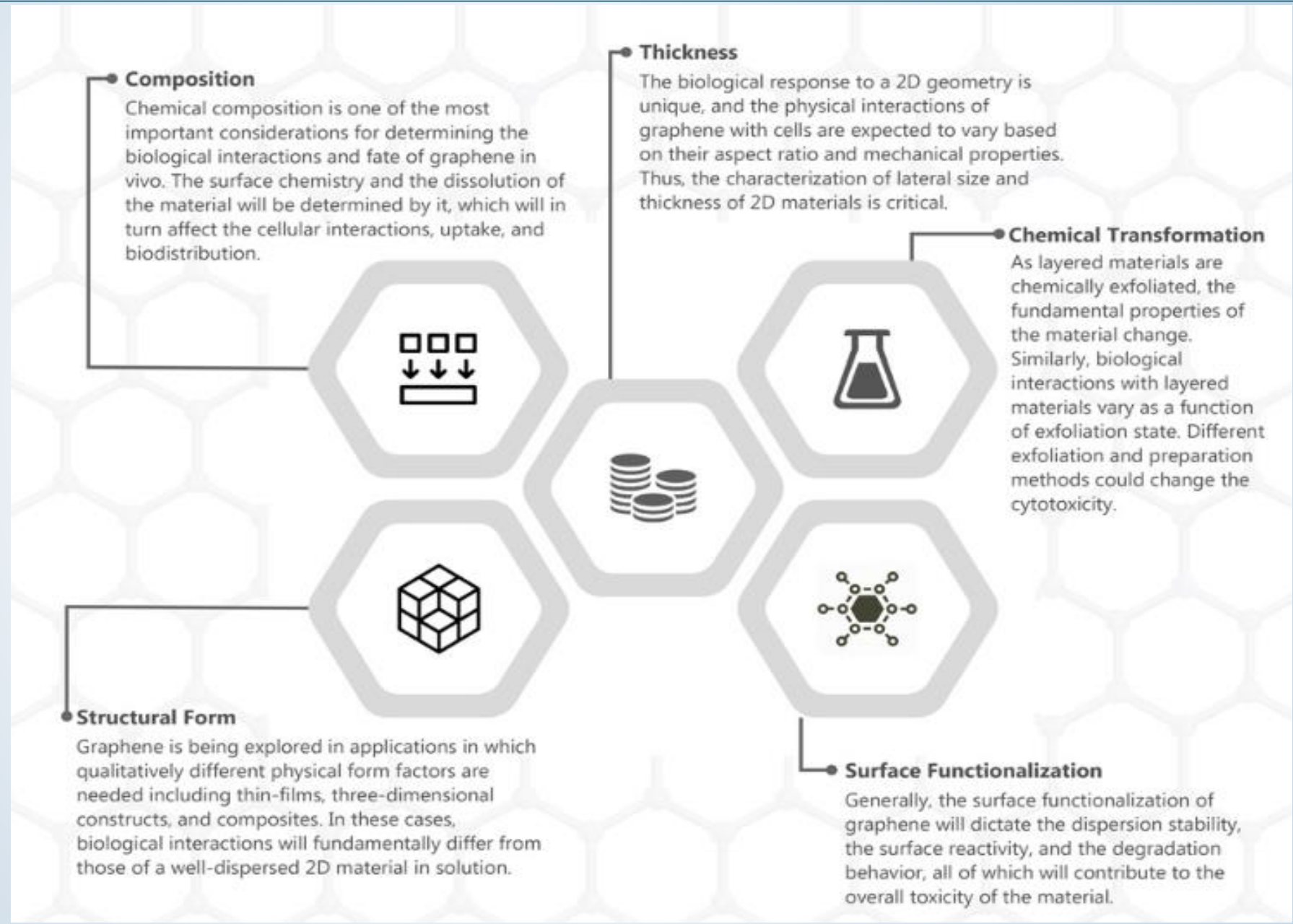
## Composites and Coatings

In addition to the impressive intrinsic mechanical properties of graphene, its low mass and low loading requirements (that you can get a big change with relatively little material) make graphene stand out as a reinforcing agent in composites. Coating objects and reinforcing composites with graphene can serve different purposes:

### Applications

- Lightweight composites for body structures
- Lubricants with enhanced anti-wear properties<sup>[66]</sup>
- Nanolaminates as ultra-high permeation barrier films<sup>[67]</sup>
- Corrosion protection<sup>[68]</sup>
- Transparent conductive coating for photonic devices<sup>[69]</sup>
- Radiation shielding and lightning strike protections<sup>[70]</sup>
- Superhydrophobic coatings<sup>[71]</sup>
- Transparent, flexible and conductive thin films<sup>[72]</sup>

Based on the current knowledge on hazard of nanomaterials, a number of characteristics can be identified that may be relevant for hazard assessment of graphene





# Graphene against Coronavirus

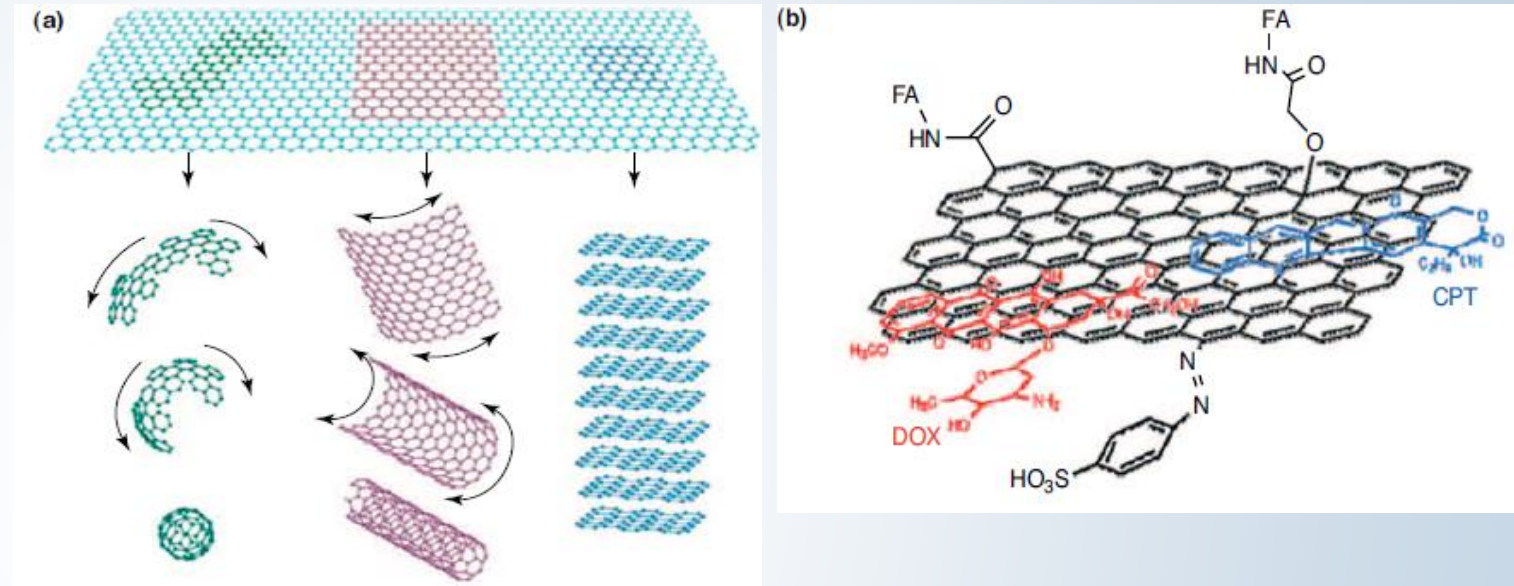
- The unprecedented pneumonia outbreak of coronavirus disease 2019 (COVID-19) is tearing global health systems apart
- The coronavirus is formed by surface proteic projections on the viral lipid envelope enclosing single-stranded positive-sense RNA.
- Graphene has captured much attention due to its superb electronic properties, including approaches to fight or detect drug-resistant bacterial infections.



# Graphene and Graphene Oxide: Biofunctionalization

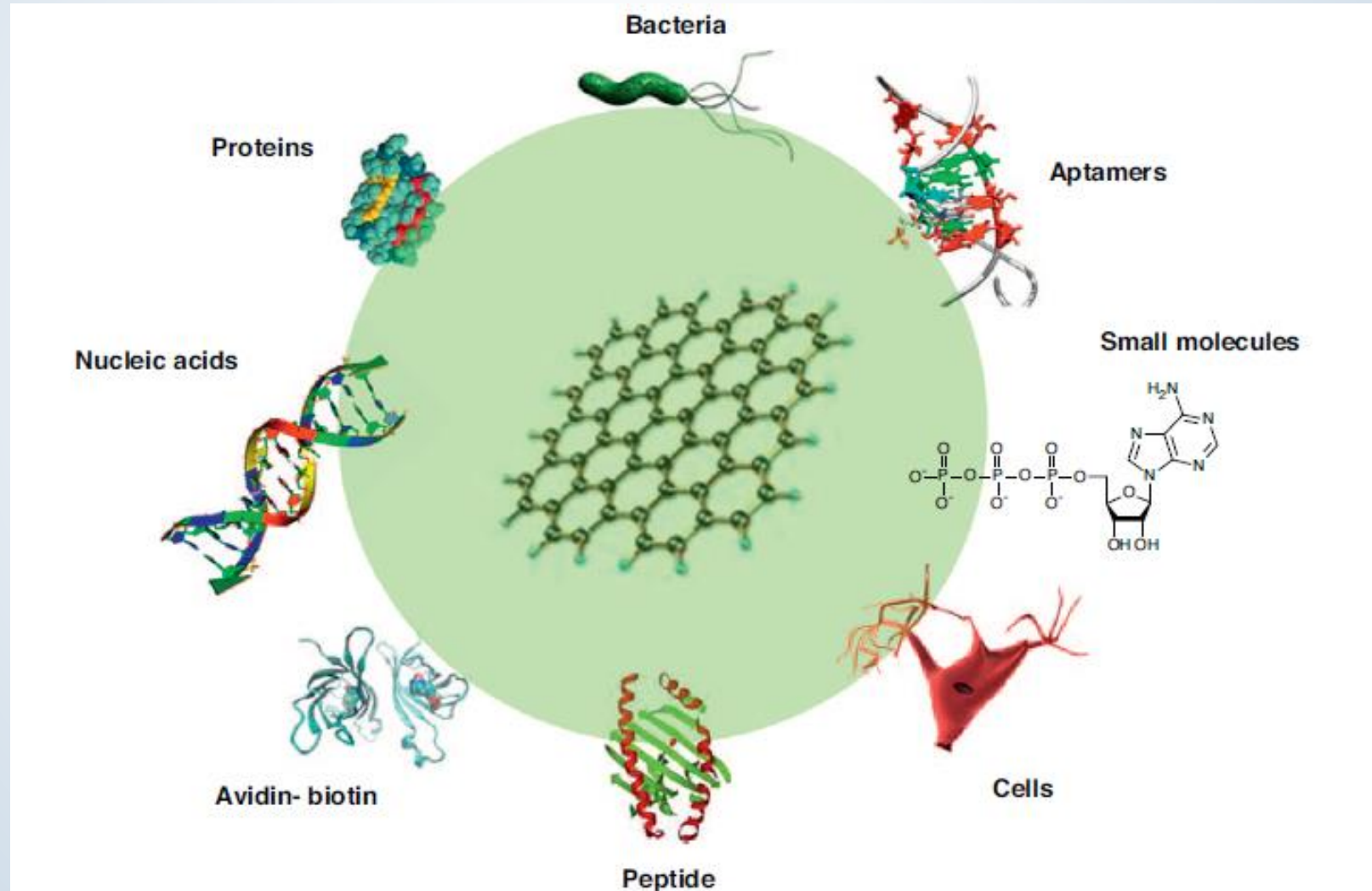
- Graphene, graphene oxide (GO), and graphene derivatives are promising candidates in biotechnology development

Biological modification in turn benefits graphene and GO by improving their biocompatibility, solubility and selectivity.



**(a)** Epitome of graphite forms, **(b)** Schematic image representing the loading of doxorubicin (DOX) and camptothecin (CPT) onto FA-modified GO.

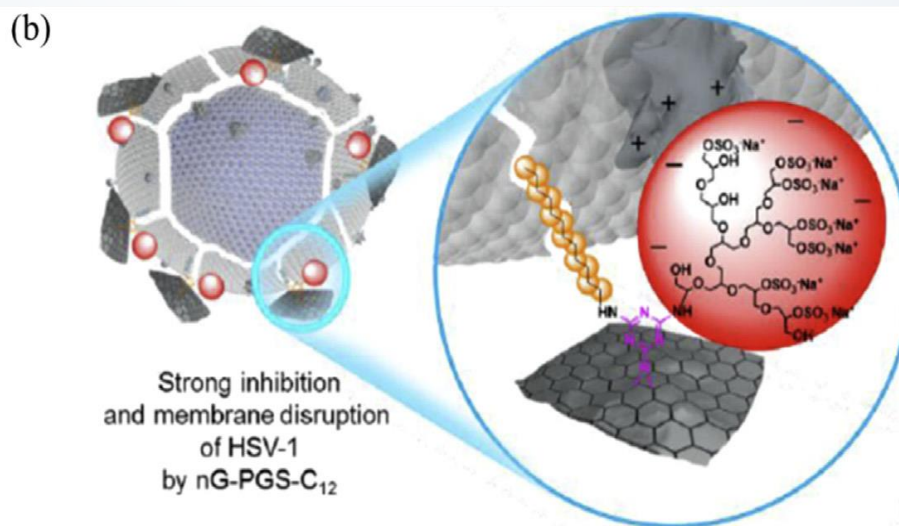
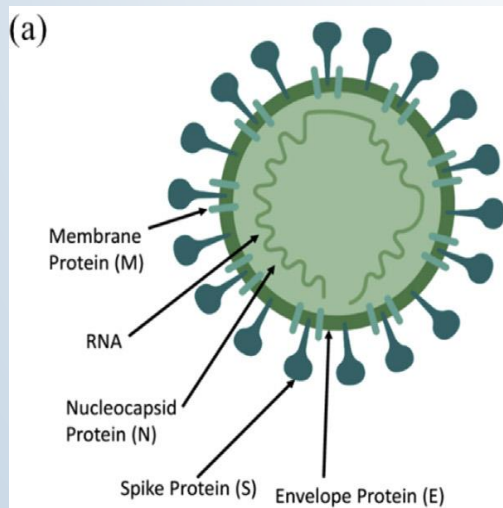
Graphene and its derivatives have been reported to be functionalized with avidin–biotin, peptides, NAs, proteins, aptamers, small molecules, bacteria, and cells through physical adsorption or chemical conjugation. The functionalized graphene biosystems with the unique properties have been used to build up biological platforms, biosensors, and biodevices





# Graphene materials interact with viruses

- In 2012, thin films of rGO–tungsten oxide were exploited for photo-inactivation of bacteriophages under visible light irradiation.
- The large surface of graphene provides the highest ligand contact area for the adsorption of negatively charged which can interact with virions' positively charged residues and block microorganisms.
- rGO sulfate derivatives demonstrated their antiviral activity against African swine fever virus, orthopox virus and herpes virus strains.
- $\beta$ -cyclodextrins-functionalized sulfonated graphene to treat the respiratory syncytial virus (RSV).
- Polyglycerol sulfated graphene functionalized with fatty amine chains wrap and inactivate HSV-1.



- a. Main structure of coronavirus
- b. Representation of HSV wrapping by sulfated graphene derivatives and illustration of long alkyl chain disrupting virus envelop

# Graphene textile for pandemic spread control

- Graphene filters have been produced for capturing particulates and bacteria to decrease the transmission of nosocomial infections.
- The bacteria blocked on the filter are not able to proliferate and by increasing filter temperature over 300 °C microorganisms along with molecules that can cause diseases are destroyed.
- Filters can be used also for sampling bioaerosols for characterization of transmission in hospital settings and exposure risk of workers in general.
- A textile screen-printed biosensor based on a GO transduction film for the detection of environmental exposure to viruses.
- GO films are also useful for creating breathable barrier layers in fabrics.
- Protective graphene facemasks could be recycled by photocatalysis or heat.



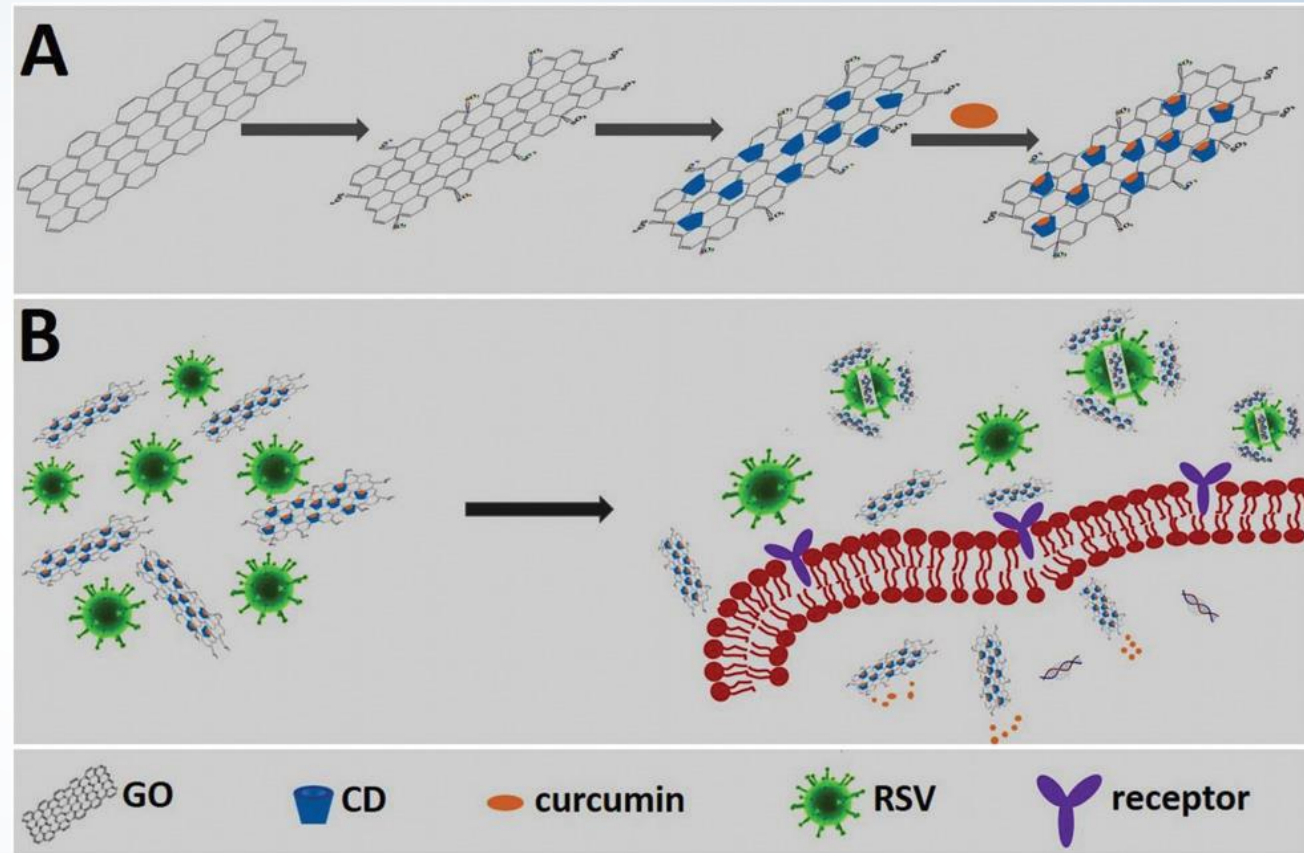
Sensors arrays implemented on textiles and interfaced with flexible electronics can report the location of positives and identify sources of the outbreak.





# Curcumin Functionalized Graphene Oxide against the viruses

- Curcumin, as a natural polyphenol, is isolated from the rhizomes of the perennial herb *Curcuma longa* and holds various functions including antioxidant, antifungal, antibacterial, anti-inflammatory, and anti viral.
- This polyphenolic compound has gained significant attention due to a variety of biological activities and low toxicity
- The introduction of sulfonate groups to the functionalized GO surface can mimic the cell's surface and inhibit RSV infection through a competitive inhibition mechanism.
- The synergistic antiviral activity is due to the nanomaterials themselves and the drug curcumin



**Schematic representation of work principle. (A) The synthesis of functional nanomaterial composite; (B) the proposed inhibition mode of functional nanomaterial composite against RSV infection**

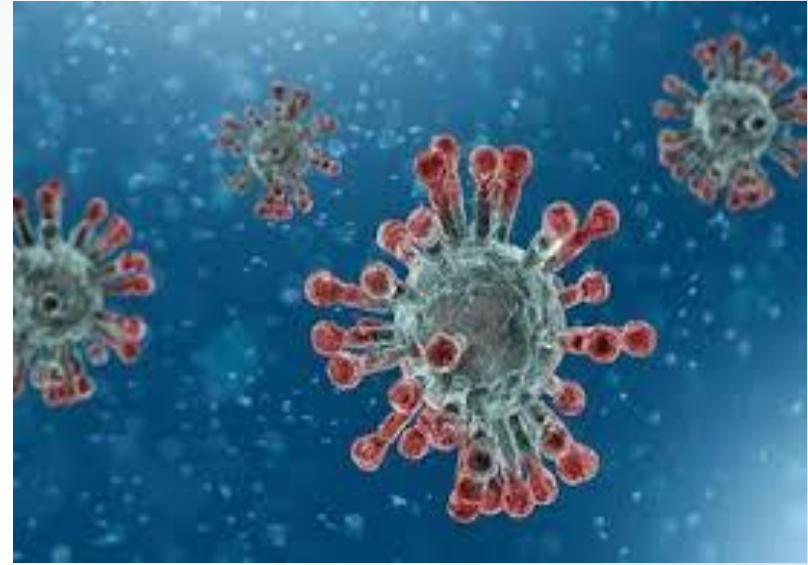
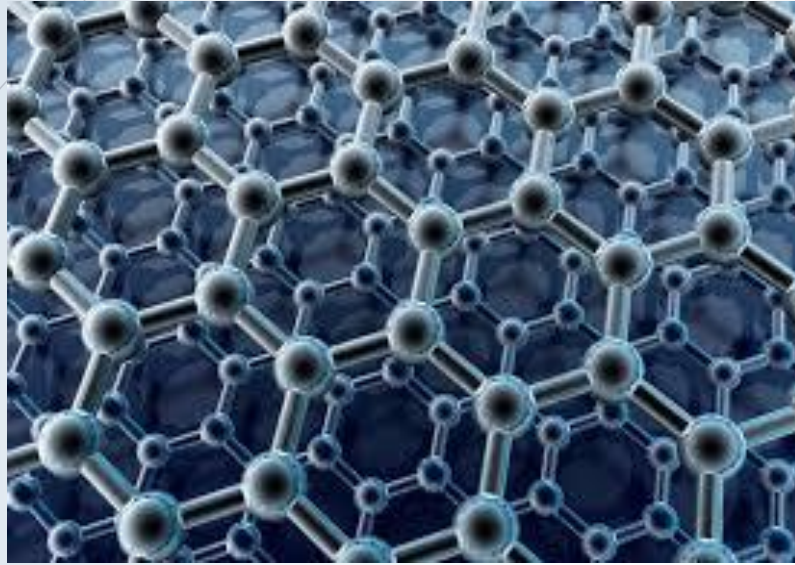


# Limitation and Challenges

- The immediate use of graphene for treatment of COVID-19 is unrealistic. The only available *in vivo* test for virus treatment demonstrated the efficacy of GO-hypericin in ducklings infected with the Novel duck reovirus.
- *in vivo* toxicity of graphene is still a matter of debate.
- Graphene toxicity are made difficult due to the infinite combinations of dose, surface chemistry, exposure route used for the evaluation.
- Its instability and aggregation in solution are further problems, given the mandatory stability required for drugs and vaccine storage prior use

# References

1. V. Palmieri, M. Papi. Can graphene take part in the fight against COVID-19?. Nano Today 33 (2020) 100883.
2. Ying Wang, Zhaohui Li, Jun Wang, Jinghong Li, Yuehe Lin. Graphene and graphene oxide: biofunctionalization and applications in biotechnology. Trends in Biotechnology 29 (2011) 205-212.
3. Shiyi Ye, Kang Shao, Zhonghua Li, Nan Guo, Yunpeng Zuo, Qin Li, Zhicheng Lu, Lu Chen, Qigai He, Heyou Han. Antiviral activity of graphene oxide: how sharp edged structure and charge matter. ACS Appl. Mater. Interfaces 7 (2015) 21571–21579.
4. Xiao Xi Yang, Chun Mei Li, Yuan Fang Li, Jian Wang, Cheng Zhi Huang. Synergistic antiviral effect of curcumin functionalized graphene oxide against respiratory syncytial virus infection. Nanoscale 9 (2017) 16086.



**THANK YOU**