CHALLENGES AND PERSPECTIVES OF GRAPHENE-GEOPOLYMER COMPOSITES

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https://graphene.nus.edu.sg/

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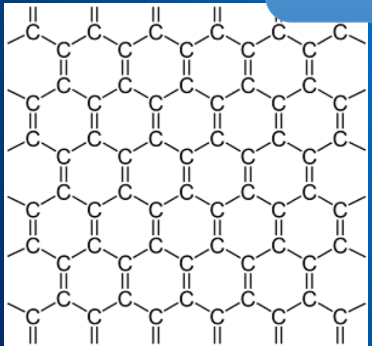
Graphene

Isolated in 2007, is an allotrope form of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice

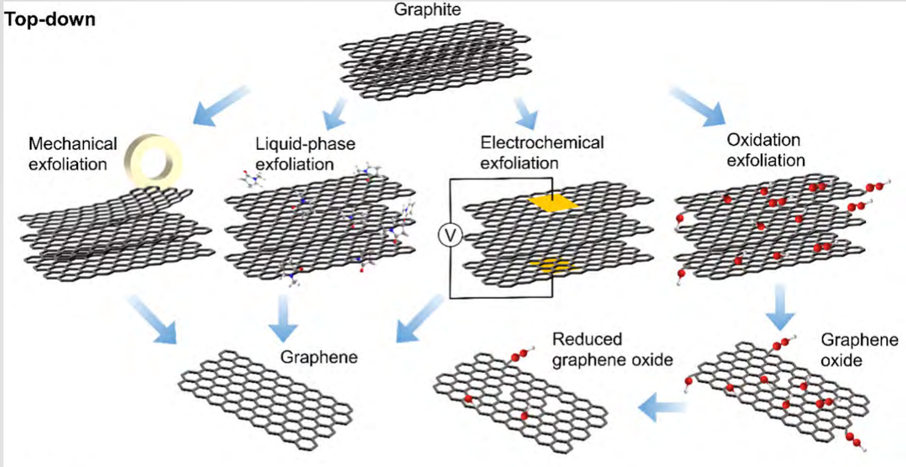
- Thin and lightweight
- High electrical conductivity
- High thermal conductivity
- 200x stronger than steel
- Easy to Functionalize



Applications in Optical, Biological, Electronical, Thermal and Structural devices:

Selective membranes, Thermal management, Solar cells, Inks, Batteries, Flexible screens, Filler for composites, Supercapacitors, Semiconductors, sensors, and many others

Graphene-family materials



Graphene Material	Water Solubility	Electrical Resistance (films)
Graphene Nanoplatelets (GNP)	Low	10 to 900 Ω/sq
Graphene Oxide (GO)	High	10^6 Ω/sq
Reduced Graphene Oxide (rGO)	Medium	100 to 10^4 Ω/sq

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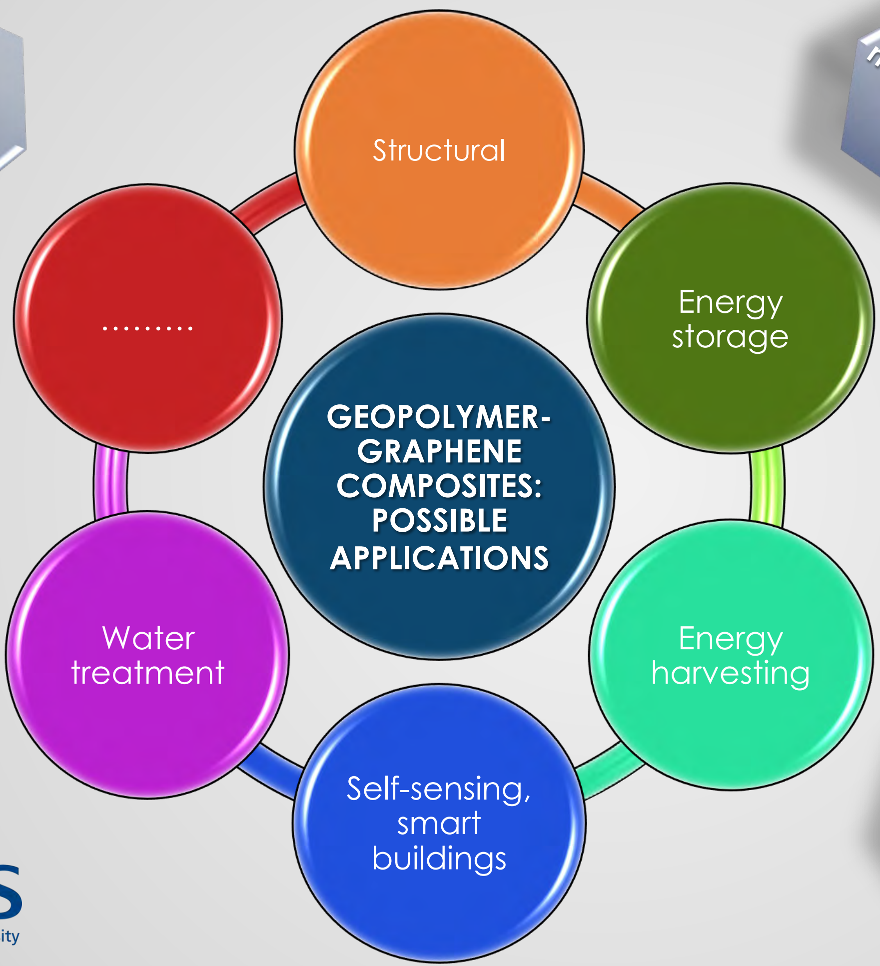
Graphene

Graphene nanoplatelets (GNP)



There is no universal solution/recipe! For each application, the class, amount and functionalization of carbon nanofiller changes in order to achieve the desired performance/properties, which requires proper product/process designs

Reduced Graphene Oxide (rGO)

Graphene Oxide (GO)

Graphene: Some Basic

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✓Graphene is an hydrophobic material - water suspensions are not stable. Graphene easily agglomerates and poorly interacts with geopolymer binders.

✓Commercially, is not possible to procure graphene as a pristine material for bulk applications. By definition, graphene nanoplatelet (GNP) can have up to 10 layers of stacked graphenes.

✓Graphene oxide (GO) is hydrophilic, disperses easily and well in water but differ in properties compared to GNP (i.e., presents lower thermal and electronical conductivities).

GO and its intermediary forms (reduced-graphene oxide, rGO) are gradually reduced when exposed to highly alkaline environment, resembling graphene properties

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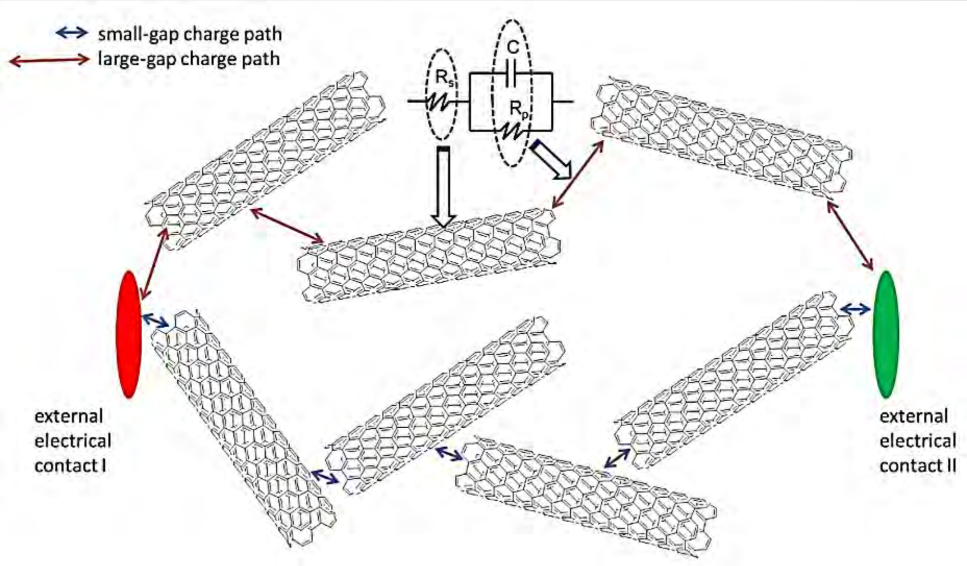
Thermal/Electrical conductivities

Goal - Achieve Percolation

- Filler
  - Nature
  - Size
  - Shape
  - Level of interaction with the geopolymers matrix
    - Interphase
    - Degradation/transformation



- Volumetric quantity required can be quite high (depend on the particle shape and size)
  - Pros: extend the application range of geopolymers-based materials
  - Cons: decrement of other properties usually come along

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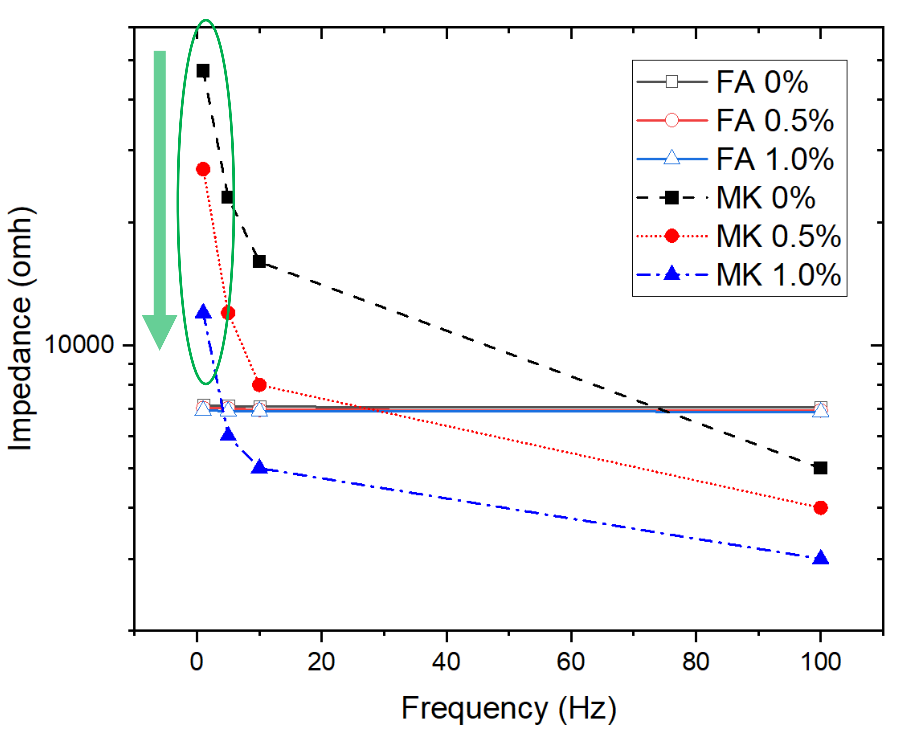
State-of-the-art

Electrical properties

- Carbon nanotube
- Carbon Black
- Graphene Nanoplatelets
- Carbon Nanofiber

Percolation effect not detected for up to 1 wt% concentrations of carbon nanofiller using fly-ash-based geopolymer

Very long CNT (tens of µm)



	no CNT	0.5% CNT	1.0% CNT
Flexural strength (MPa)	6.2	5.3	5.8
Compressive strength (MPa)	66.6	60.7	59.0

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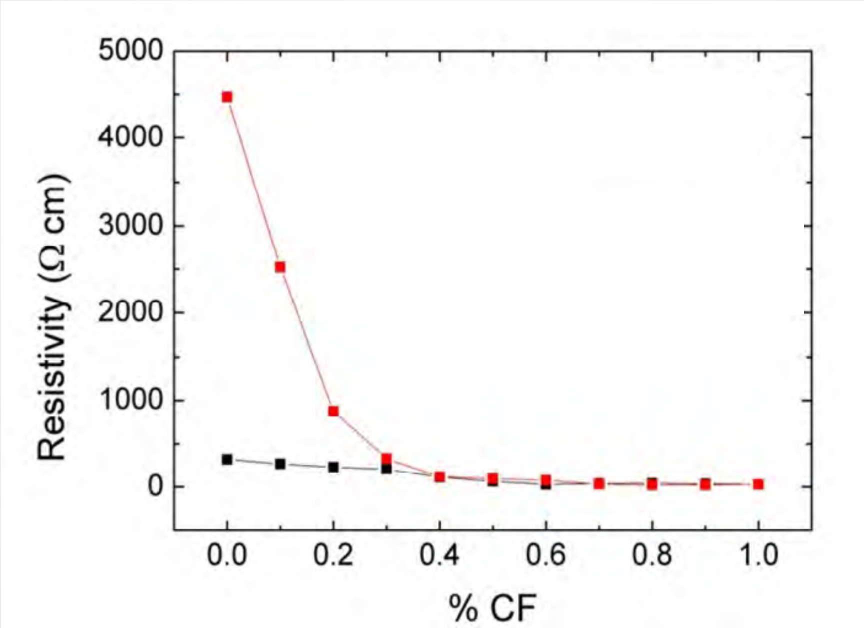
Electrical properties

Micro vs. nano conductive additives

- Carbon fibres - percolation achieved adding 0.3-0.4 wt.% carbon fibre in FA-based geopolymers
- Secondary effects should be considered (e.g., mechanical properties)



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Energy Storage Capability

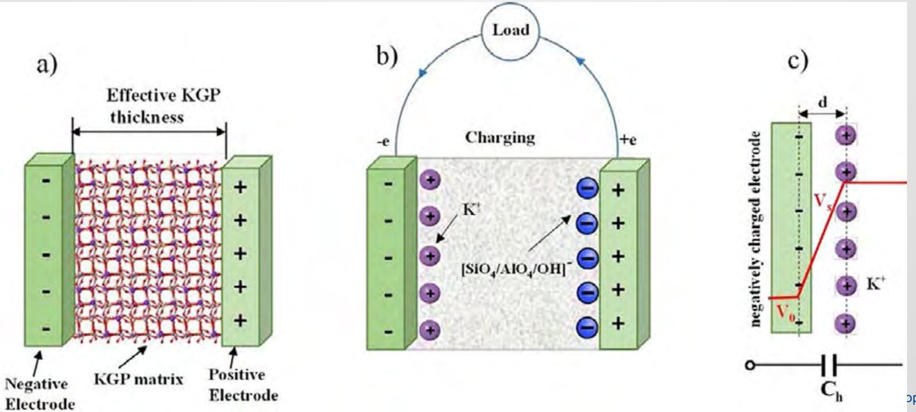
Present electrolyte/separator properties:

- Allows ionic transport and is electronical insulatior

There is potential to be applied in capacitors

- Authors demonstrated a power density of 0.27 kW/m^2 with a discharge life 1.5 to 2.2 h

↑ rate = ↓ capacitance (insufficient time for ions to diffuse within geopolymer matrix)
↑ rate = ↓ adsorption and desorption
↑ rate = ↓ life and power capacity



Challenges and perspectives

There is hope! However, there are also challenges to be faced.

- *Develop stable dispersion of hydrophobic & conductive carbon nanomaterials in highly alkaline water-based media*
- *Design of engineered compositions for achieving required percolation levels with multi-size/multi-shape conductive additives without compromising (severely) the structural properties and workability*
- *Improve physical-chemical interaction between binder and carbon filler*
- *Secondary effects should be considered (e.g., mechanical properties decrement)*

Filler <u>costs</u> X <u>quantities</u> required
Desirable X achievable properties (<u>balance</u>)

Composition and Product Engineering are required

THANK YOU

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