

Integration of graphene oxide in mixed-matrix membranes: balancing membrane performance with fouling resistance

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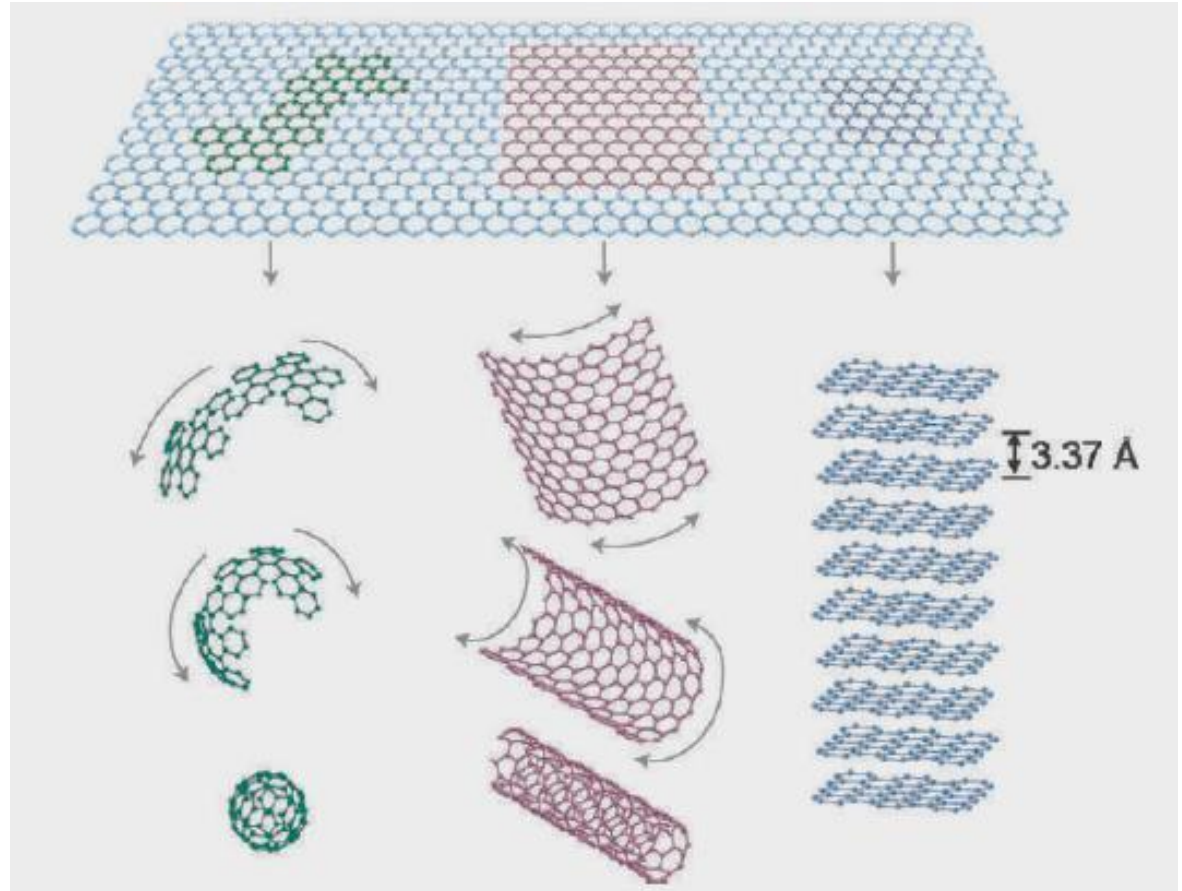
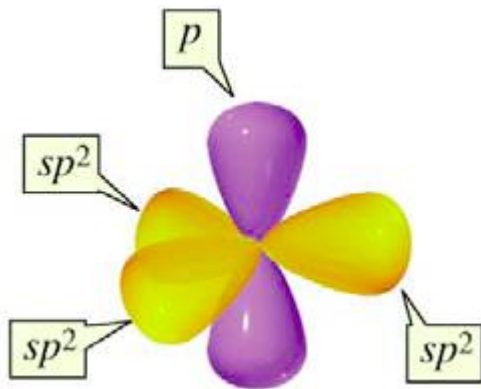
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Ira A. Fulton Schools of Engineering

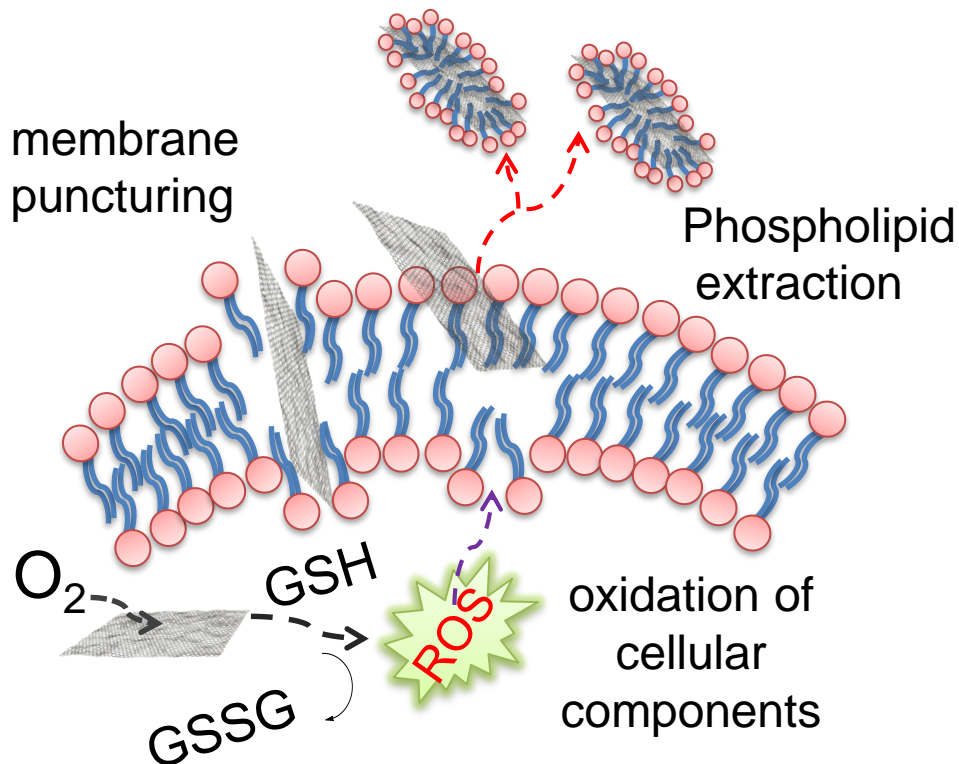
Arizona State University



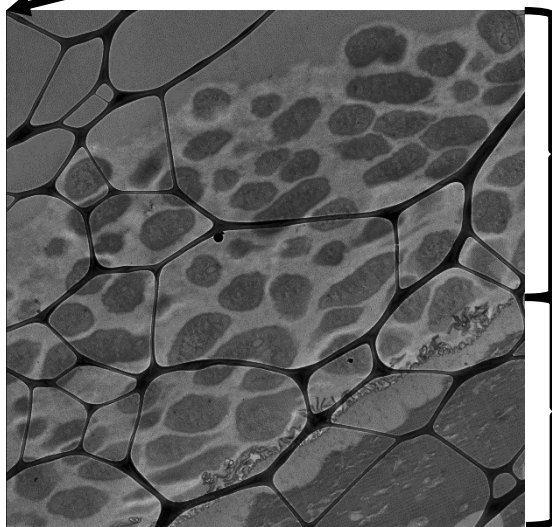
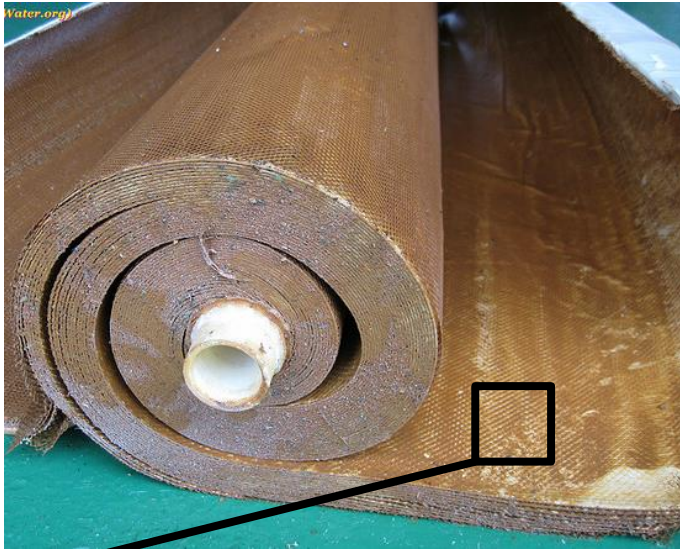
*Andre Geim and
Konstantin Novoselov
2010 Nobel price in physics*



- Highest electron mobility
- Highest thermal conductivity
- High breaking strength
- High optical transparency
- Highest aspect ratio ($2630 \text{ m}^2 \text{ g}^{-1}$)

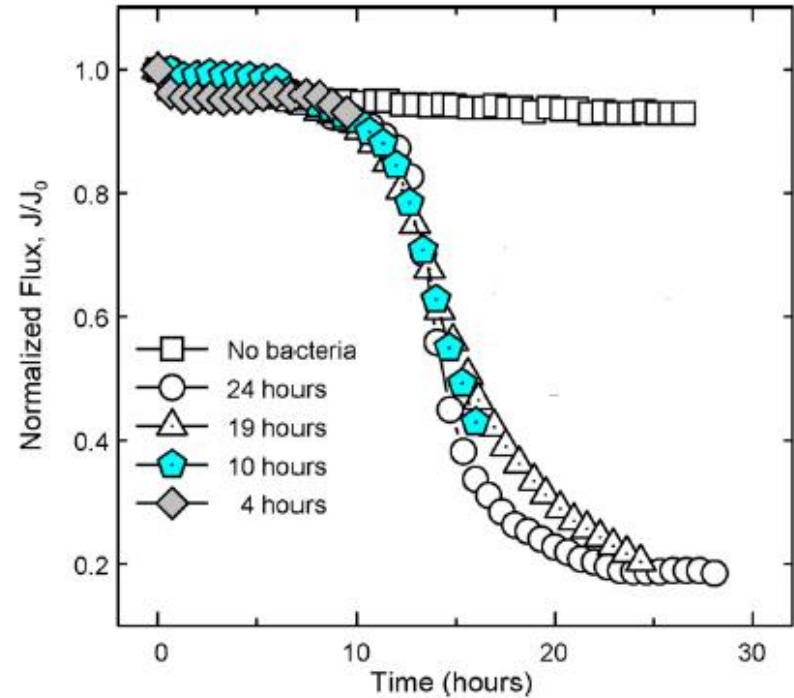


- Contact-mediated antimicrobial activity
- Does not deplete over time
- Does not release toxic compound

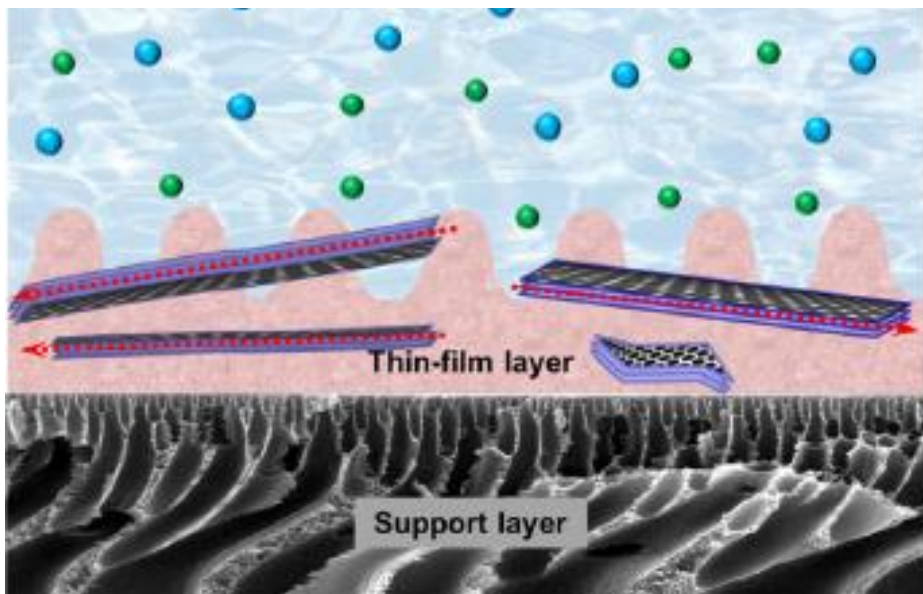


Biofilm

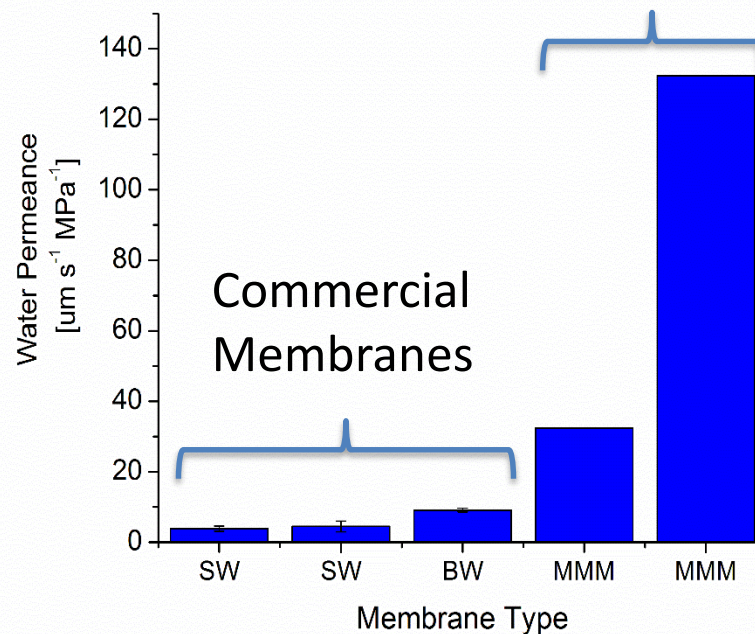
Membrane



- Reduces permeate flux
- Reduces membrane selectivity
- Reduces membrane lifetime
- Up to 30% increase in operation costs



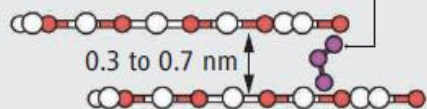
Estimate of new MMM



B

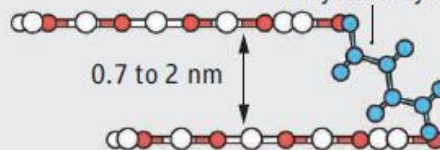
Desalination or hydrofracking

Covalent bonds or small functional groups

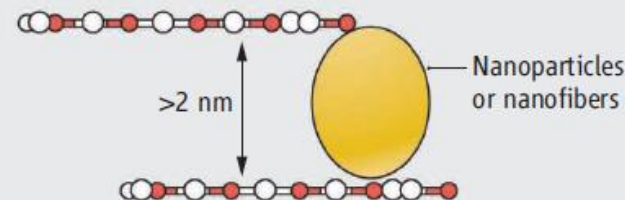


Water, fuel, or chemical purification

Polyelectlectrolytes



Biomedical filtration



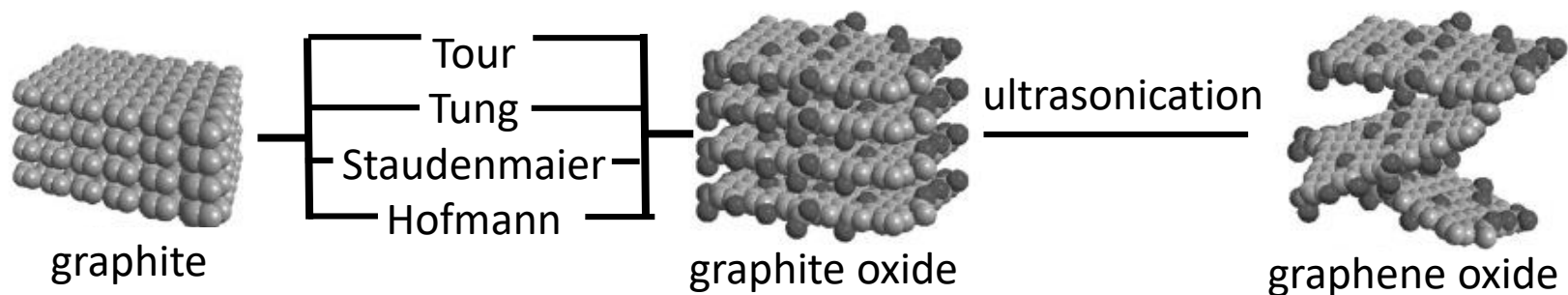
Embedding graphene oxide sheets into the active layer of RO membranes can form nanochannels to enhance membrane performances.

Hypothesis: GO is a multifunctional nanomaterial that can impart antifouling properties and improve the membrane permselectivity

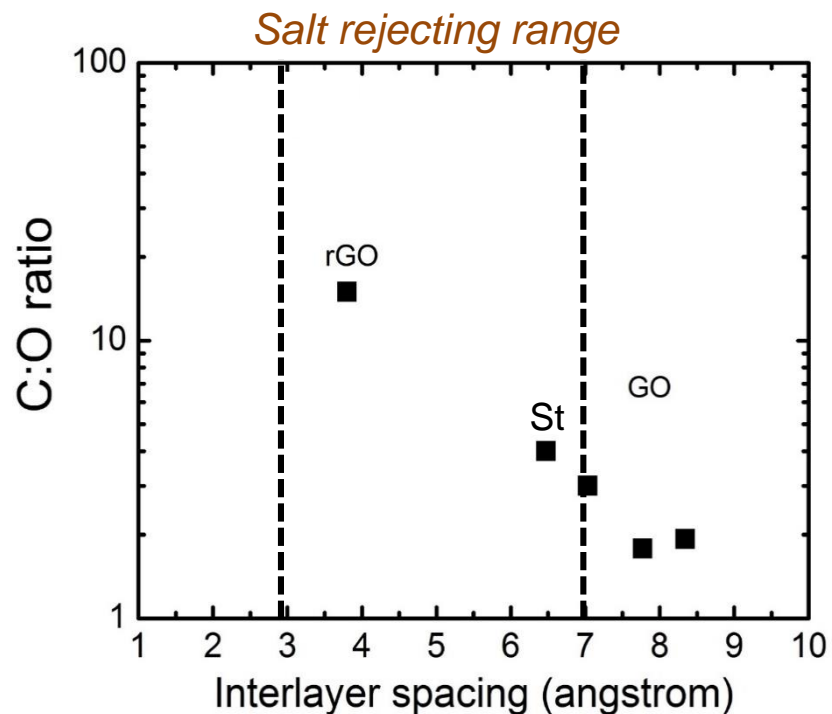
Objective 1: *Characterize the antimicrobial, anti-adhesive, and transport properties of GO mixed-matrix membranes of different GO loadings.*

Objective 2: *Compare MMM with surface-functionalized membranes.*

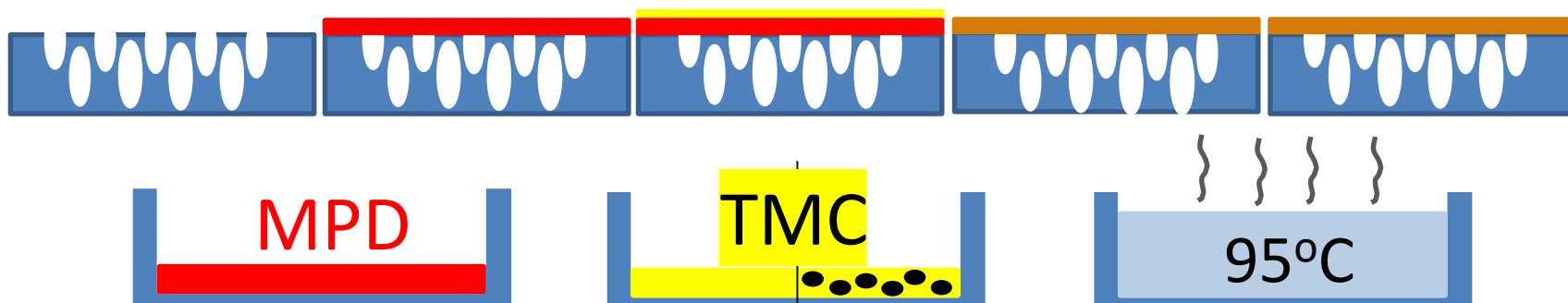
Graphene Oxide synthesis



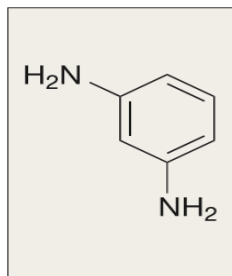
Graphene Oxide	Acid	Oxidizing Agent	Reducing Agent
Tung	H ₂ SO ₄	KMnO ₄	-
Tour	9:1 H ₂ SO ₄ : H ₃ PO ₄	KMnO ₄	-
Staudenmaier	9:1 H ₂ SO ₄ : 90% HNO ₃	KClO ₃	-
Hofmann	9:1 H ₂ SO ₄ : 63% HNO ₃	KClO ₃	-
rGO	H ₂ SO ₄	KMnO ₄	Hydrazine



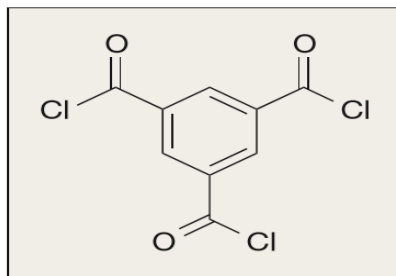
Polyamide



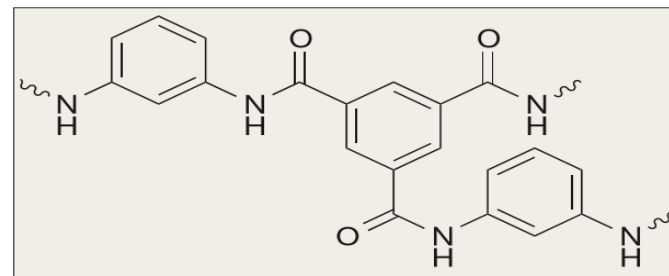
m-Phenylene diamine



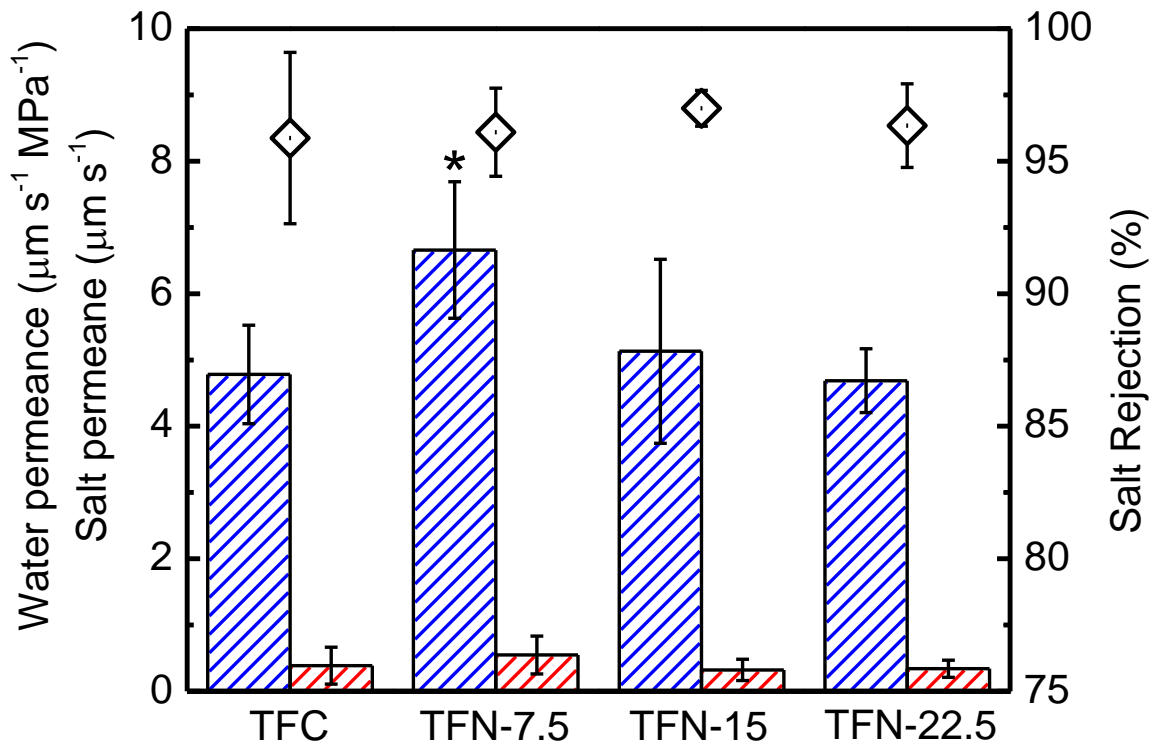
Trimesoyl chloride



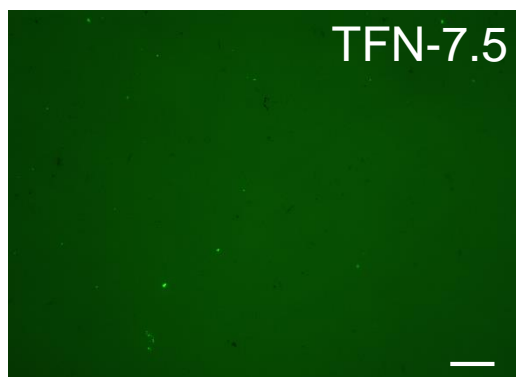
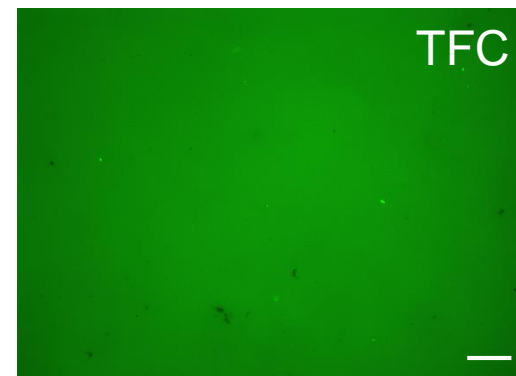
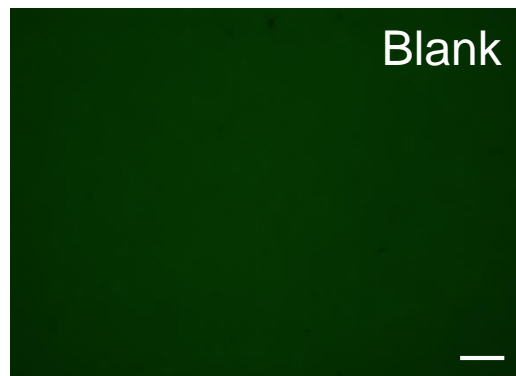
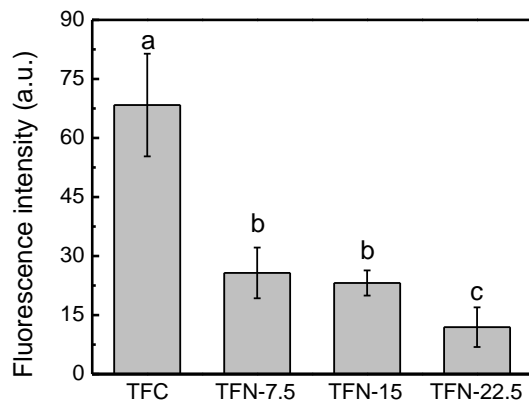
Crosslinked polyamide



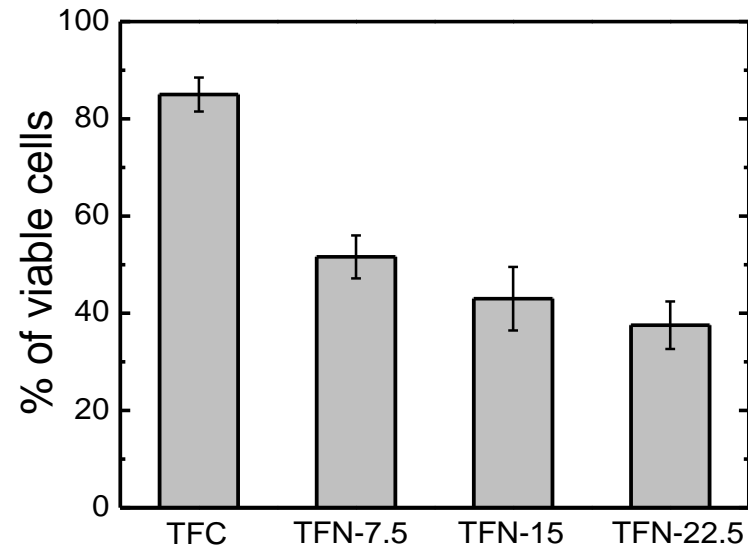
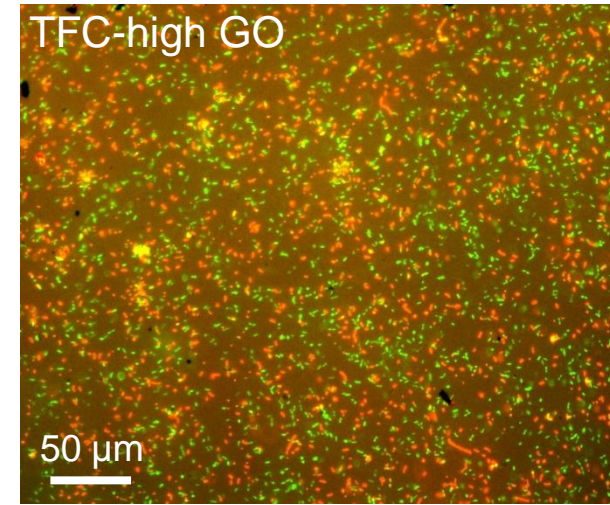
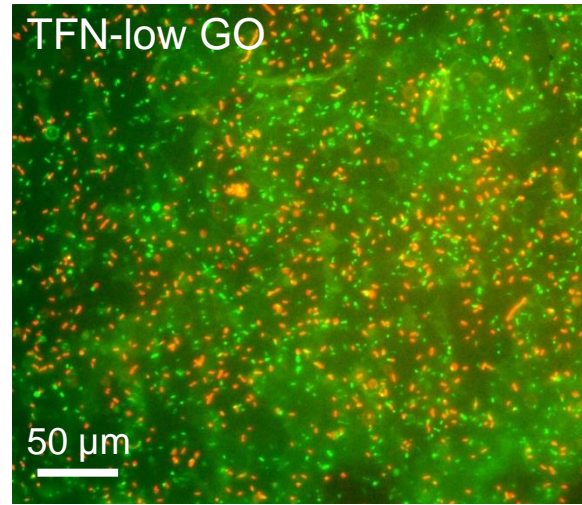
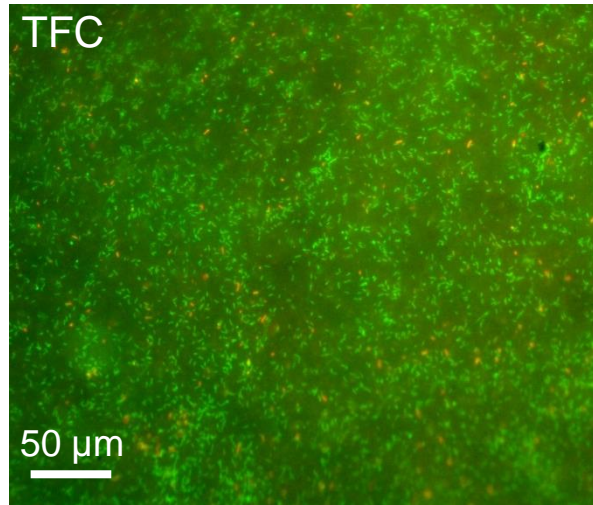
GO is added to the monomer solution before interfacial polymerization



Limited improvement in membrane performance, and decreasing benefit as GO concentration increases

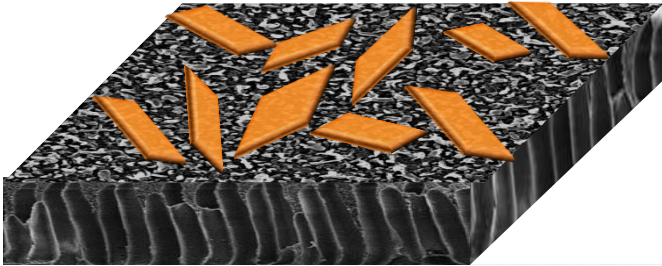


Membrane fouling by proteins is also reduced when more GO is integrated into the MMM



Increasing the concentration of GO in the MMM increases the antimicrobial properties of the membrane surface

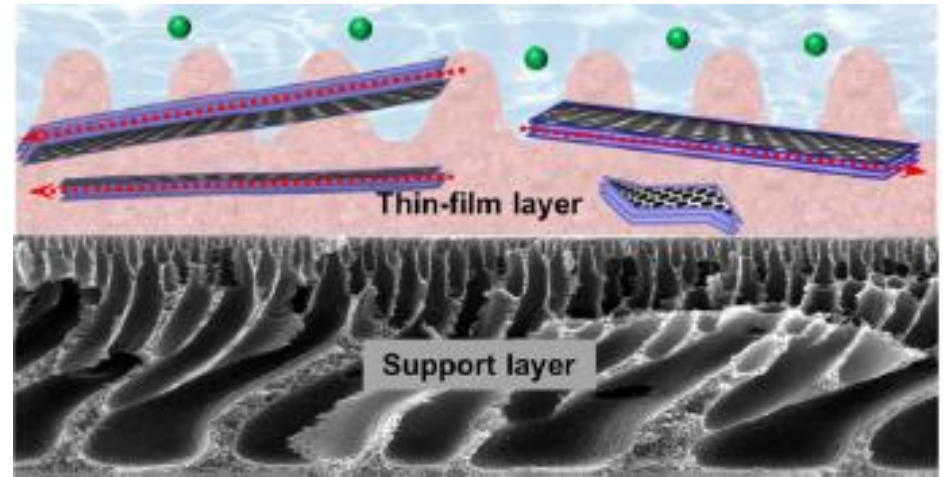
Surface functionalization



Nanomaterials is grafted on the surface

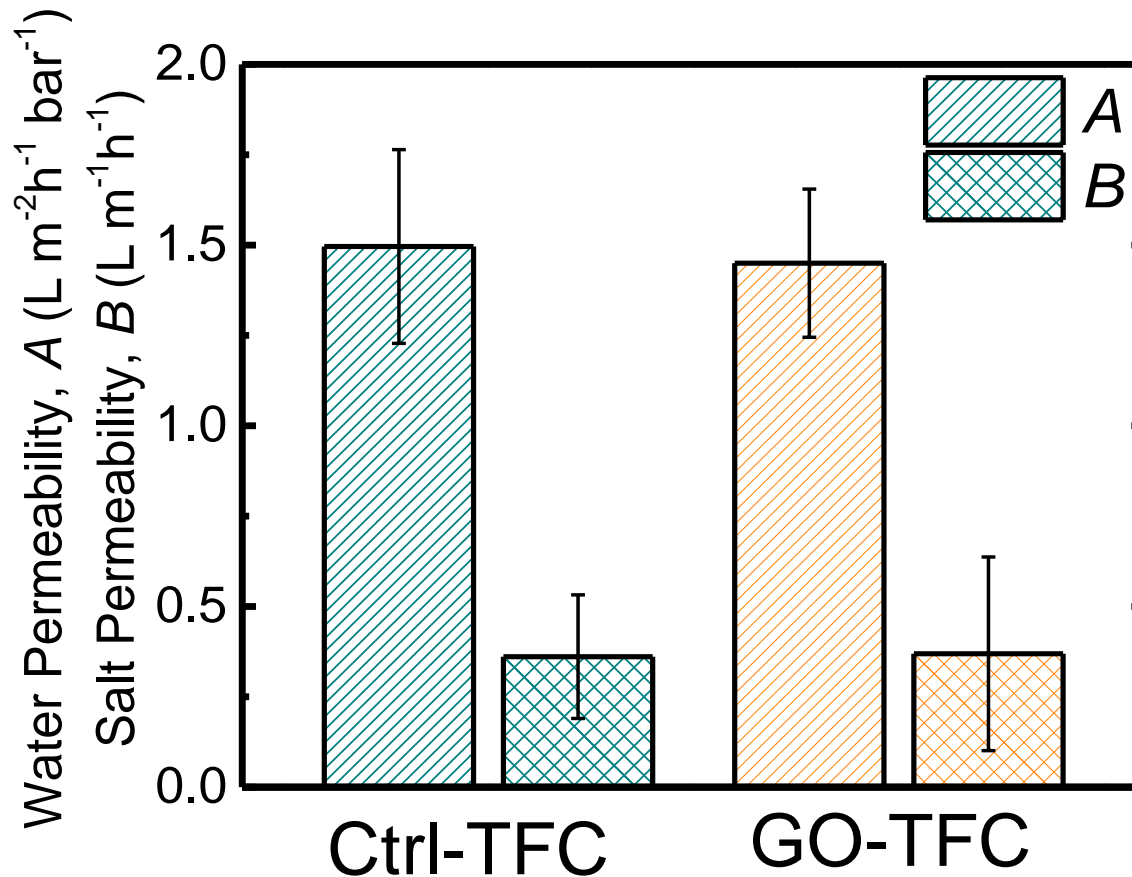
- *Use small amount of NMs*
- *Affect only surface properties*
- *Less stable*

Mixed-Matrix Membranes



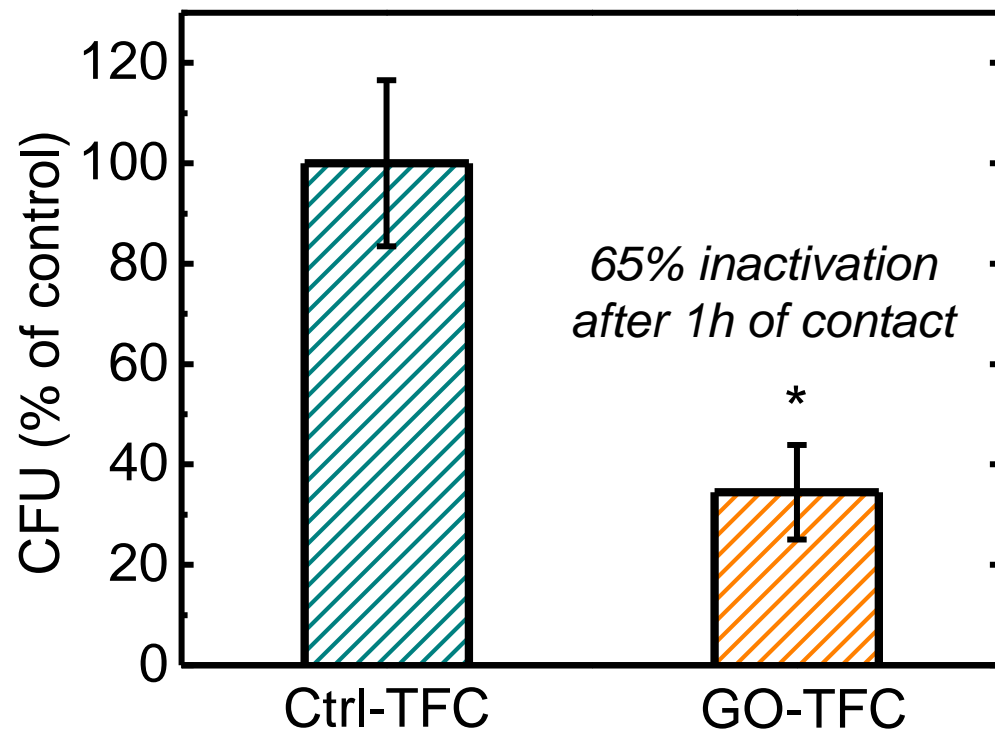
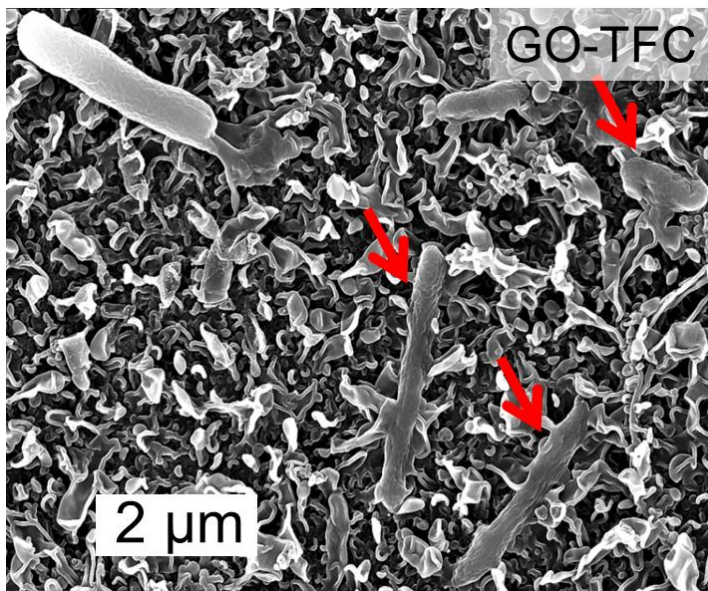
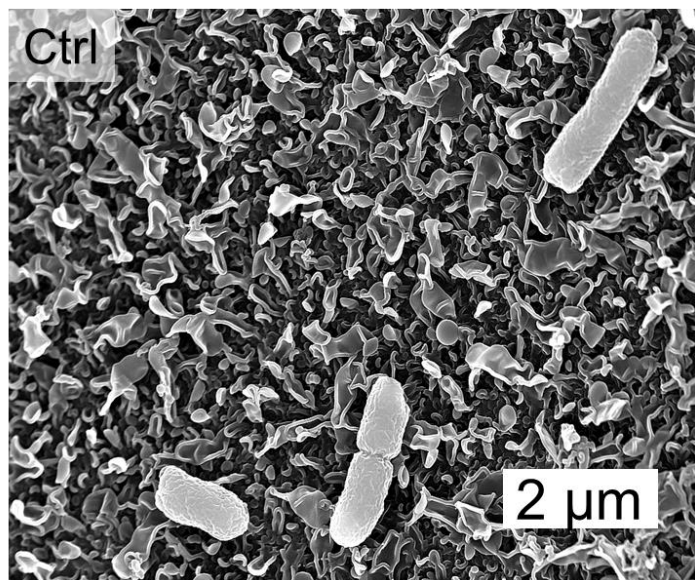
Nanomaterials is integrated into the polymer matrix

- *Provide stronger binding*
- *Can affect transport properties*
- *Use more NMs*

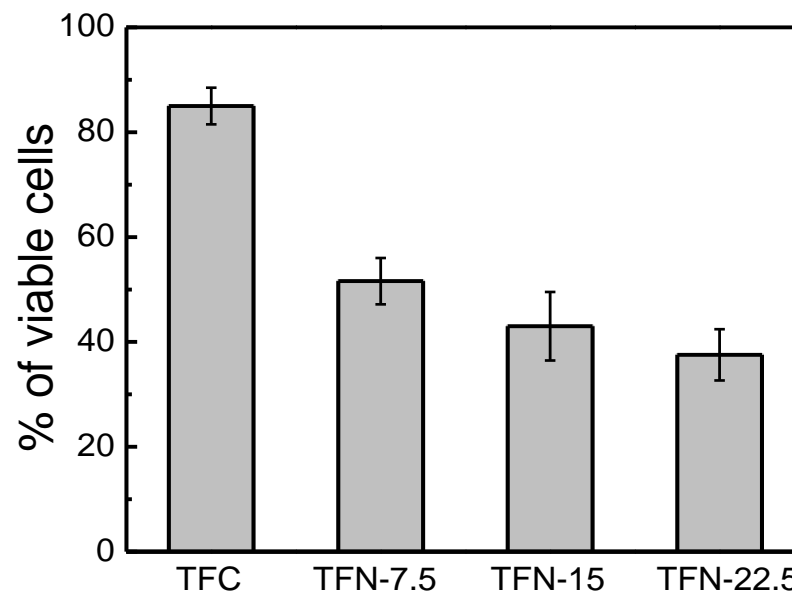
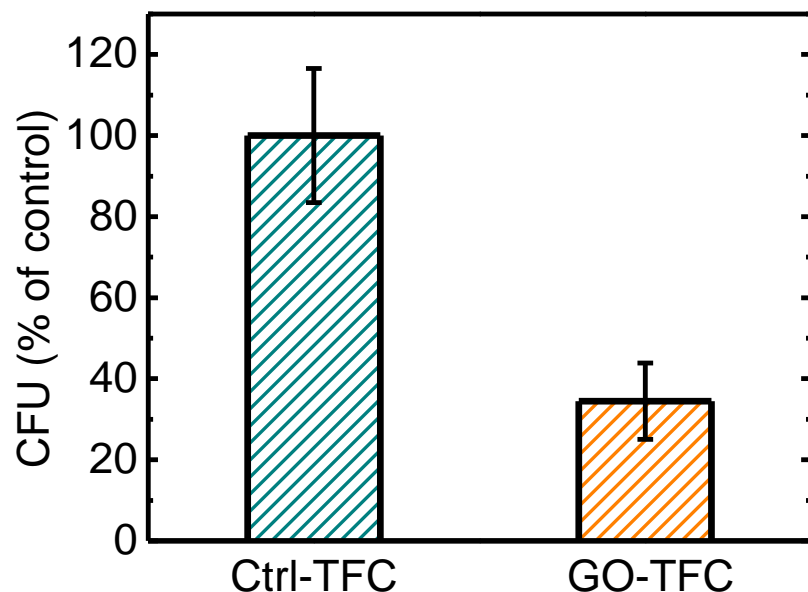


GO modification does not alter the membrane transport properties.

Antimicrobial Properties



Graphene oxide functionalized membranes inactivate E. coli cells attached to the membrane.



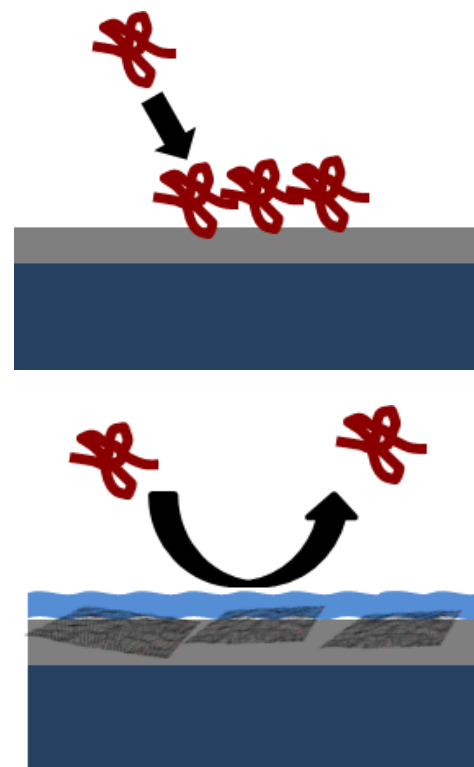
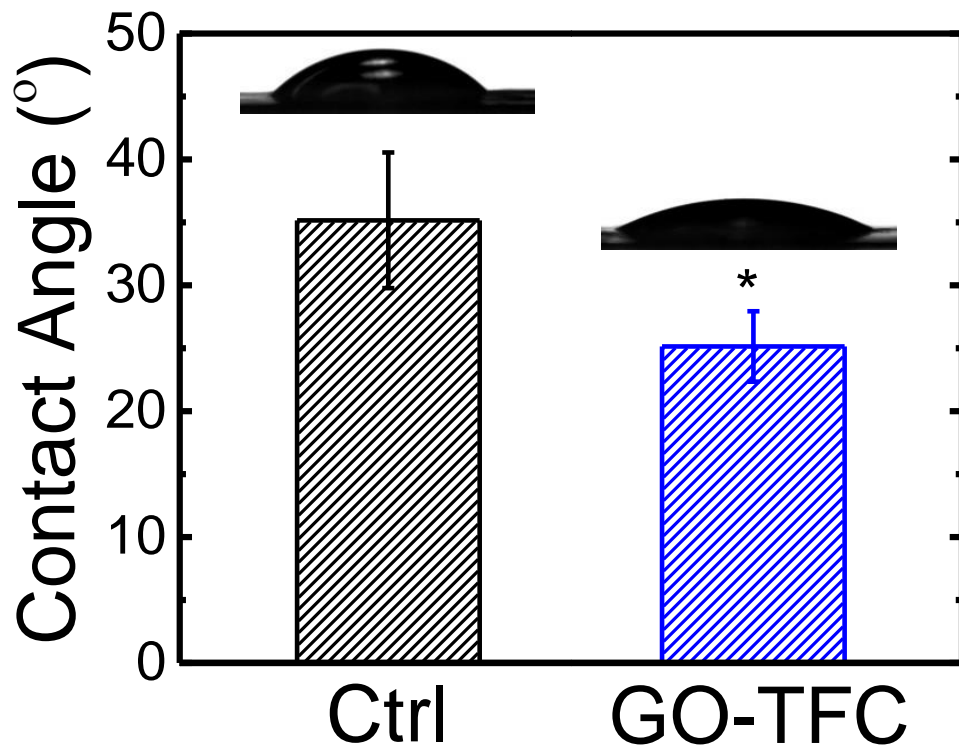
- *At similar antimicrobial effect, GO-MMM does not provide any improvement in membrane separation.*
- *GO-MMM uses more GO!*
- *GO-MMM cross-link the GO and reduce leaching.*

- Antifouling properties increase with GO loading
- GO improves the membrane permeability at low loadings
- GO may be more performant as an antifouling agent than a permselectivity enhancer
- MMM and surface functionalization offer similar nano-enabled performance
- Are they equal in sustainability?





Thank you!



The hydrated layer of more hydrophilic surfaces can reduce the adhesion of foulants