Investigating the effect of graphene oxide on scaling in thin-film composite polyamide reverse osmosis membranes

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Sixth Sustainable Nanotechnology Organization Conference
November 5-7, 2017

UNIVERSITY of HOUSTON

Water crisis

- Rapid population growth
- Water pollution from agricultural residues, sewage, and industrial waste
- Climate change
- Economy
- Water management

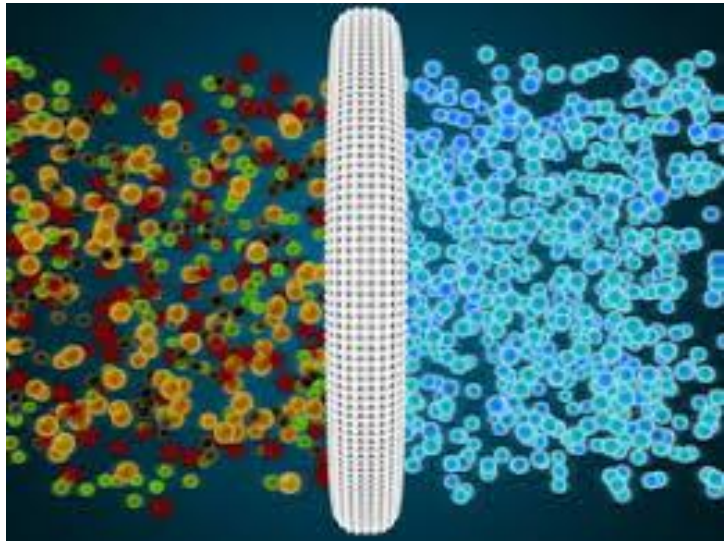
Solutions

- Water reuse

- Seawater desalination

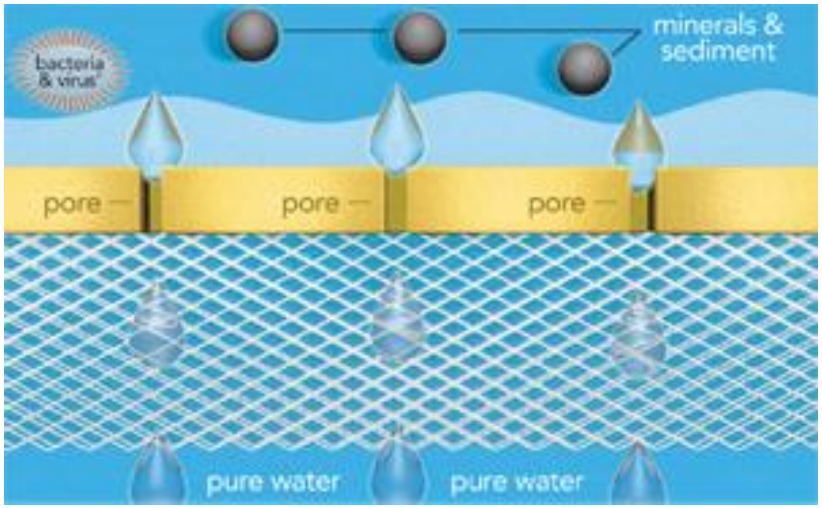
Membrane technologies

- Micro filtration (MF)
- Ultra filtration (UF)
- Nano filtration (NF)
- Reverse osmosis (RO)
- Forward osmosis (FO)
- Membrane distillation (MD)
- Electrodialysis (ED)



Reverse osmosis membrane

- Seawater desalination
- Drinking water production
- Brackish water treatment
- Wastewater treatment



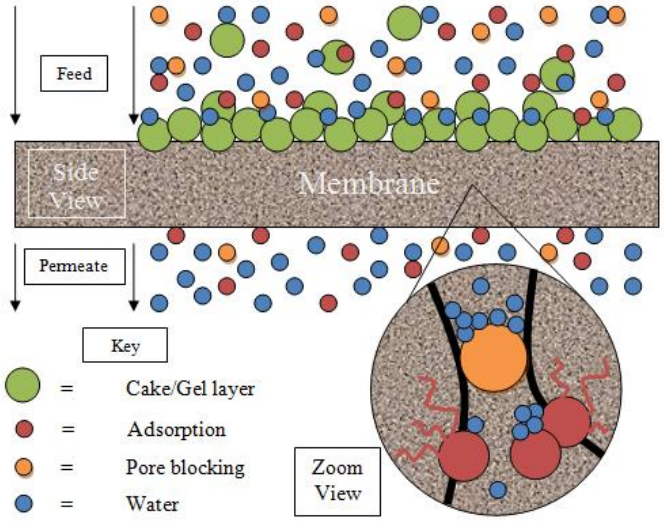
High water permeability

High salt rejection

Fouling in RO membrane

Accumulation of undesired deposits on the membrane surface or inside the membrane pores

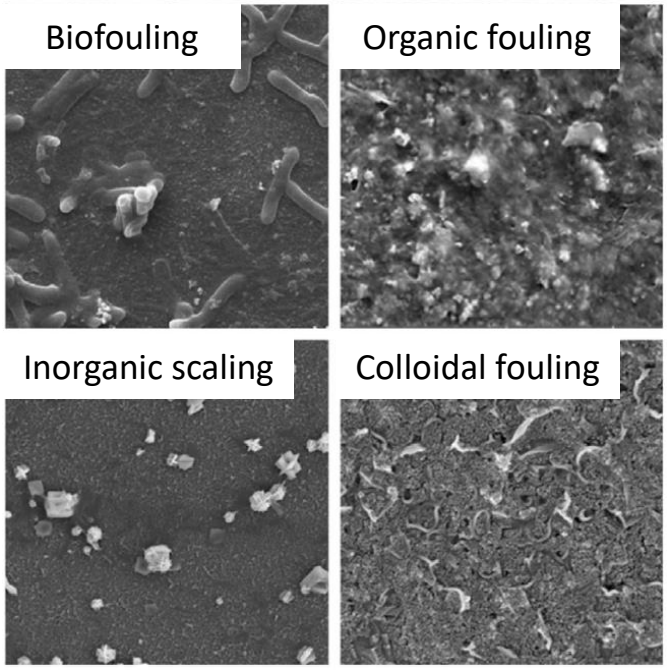
- Increase salt passage through the membrane
- Creates hydraulic resistance of water flow through the membrane
- Induce potential for accelerated scale formation



Fouling in RO membrane

In terms of place:

- Surface fouling
- Internal fouling



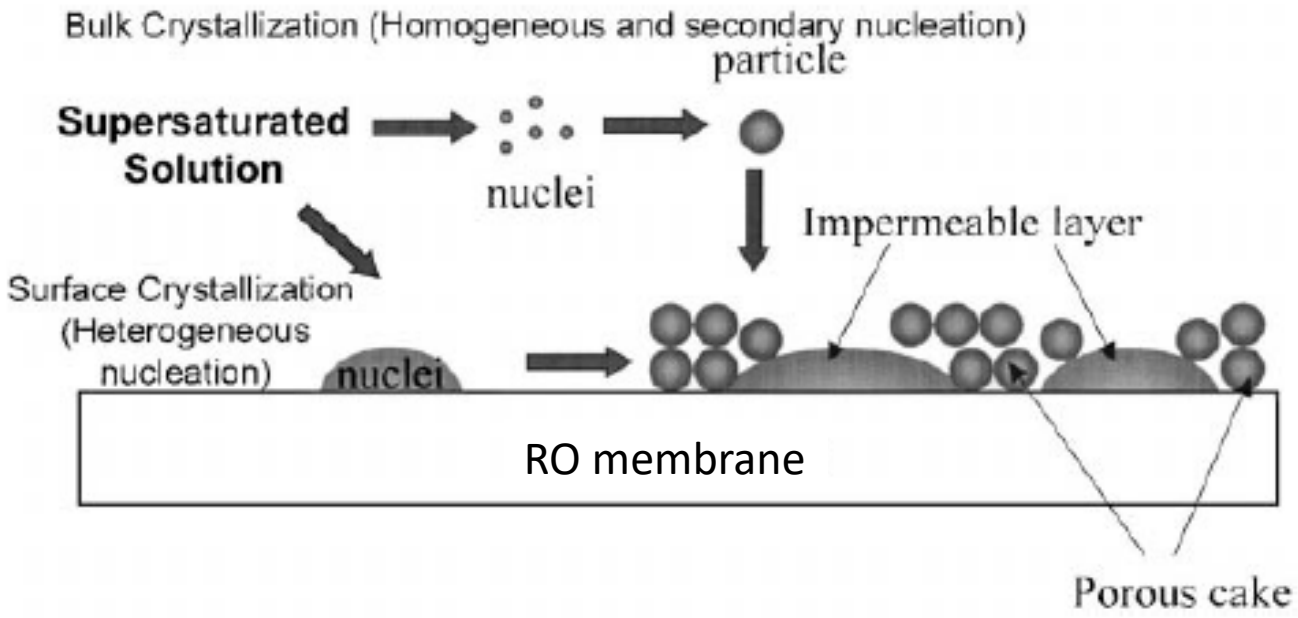
S. Jiang et al. / Science of the Total Environment 595 (2017) 567–583

In terms of type:

- Biofouling
  - Adhesion and proliferation of microorganisms
- Organic fouling
  - Deposition of organic matters
- Inorganic scaling
  - Crystal growth or deposition
- Colloidal fouling
  - Deposition of small particles

Scaling

Ions exceeding the solubility equilibrium will trigger crystal growth



S. Lee et al. / Journal of Membrane Science 163 (1999) 63–74

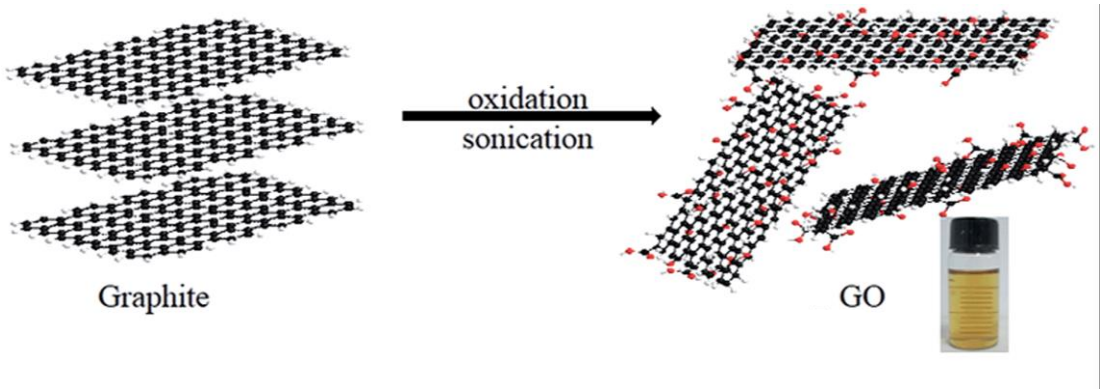
Factors affect scaling

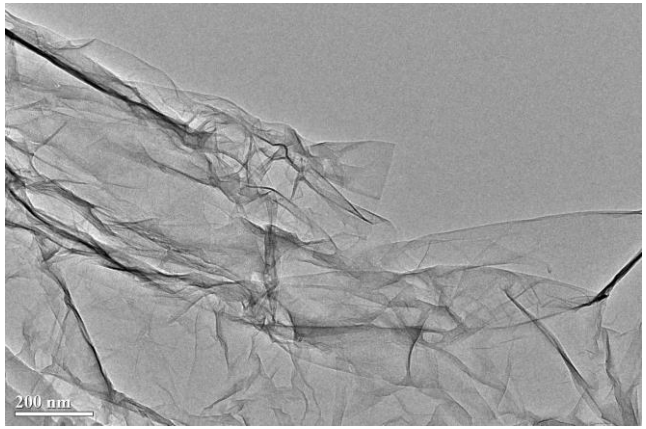
Concentration Polarization	Ionic Strength	Co-Precipitation
pH	Pressure	Velocity
Temperature	Surface Morphology	Surface Chemistry

Graphene Oxide (GO)

Well known antimicrobial property

Anti scaling property?



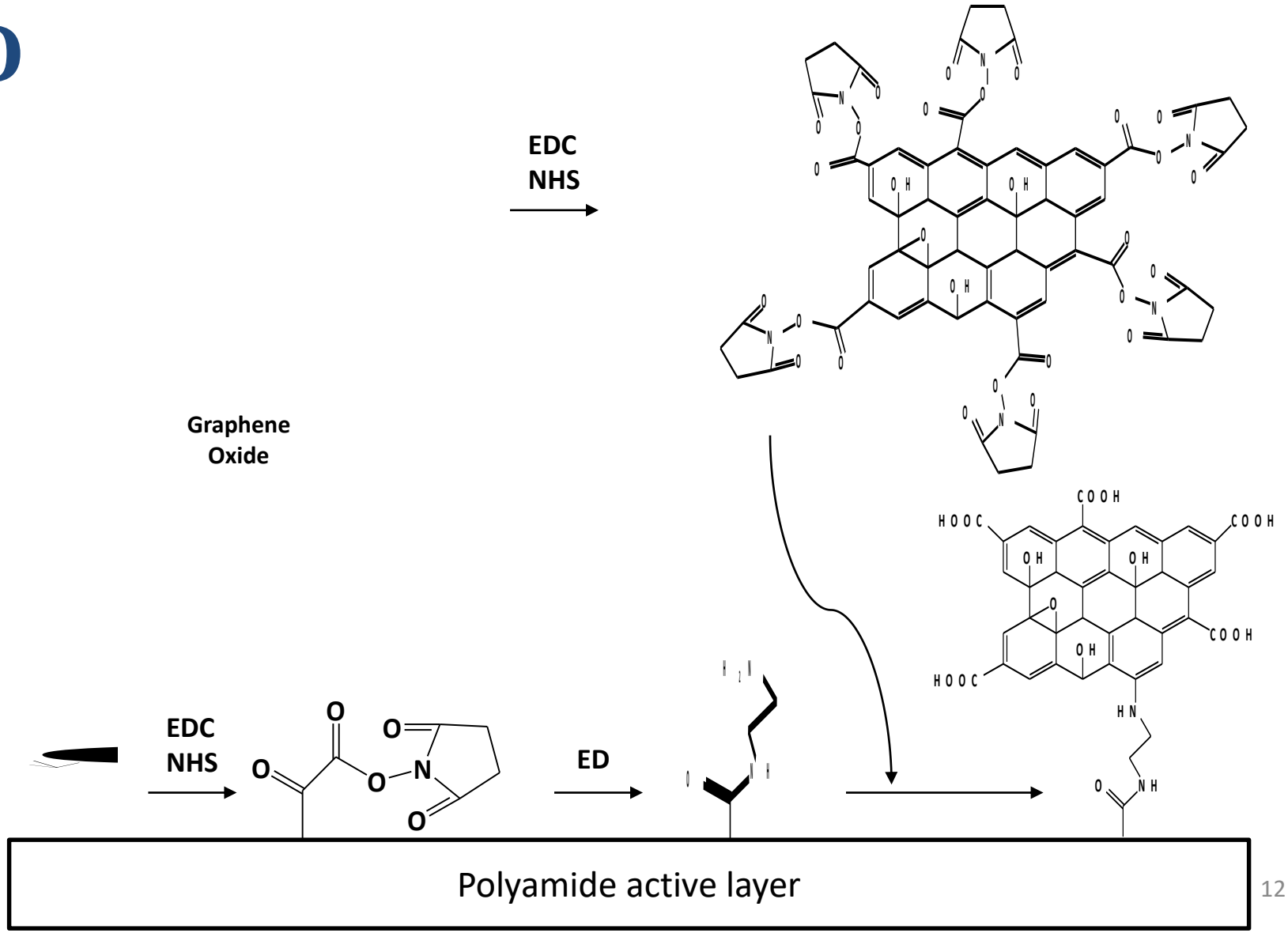


Graphene oxide effect on scaling

Research Questions:

- How GO affect the scaling and membrane recovery?
- What are the mechanism of the scaling?
- What type of scalant will form on the membrane coated with GO?

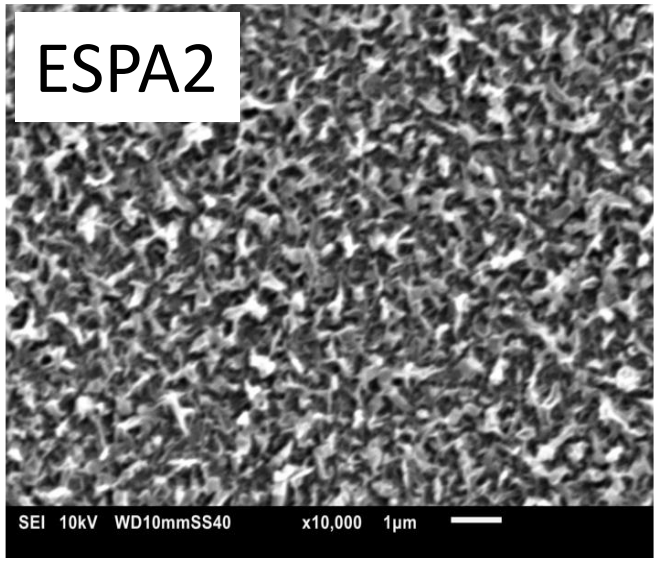
Coating RO membrane (ESPA2) with GO

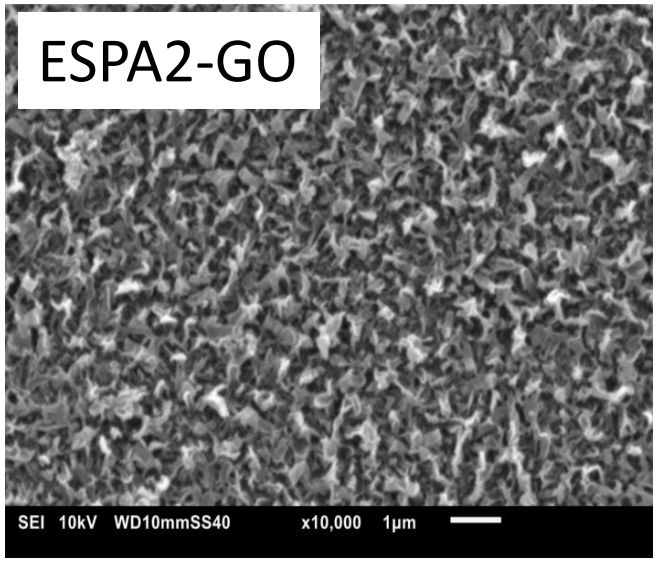


Coated membrane (ESPA2-GO) characterization

- Surface zeta potential
- Water contact angle
- SEM
- Salt rejection
- Permeability

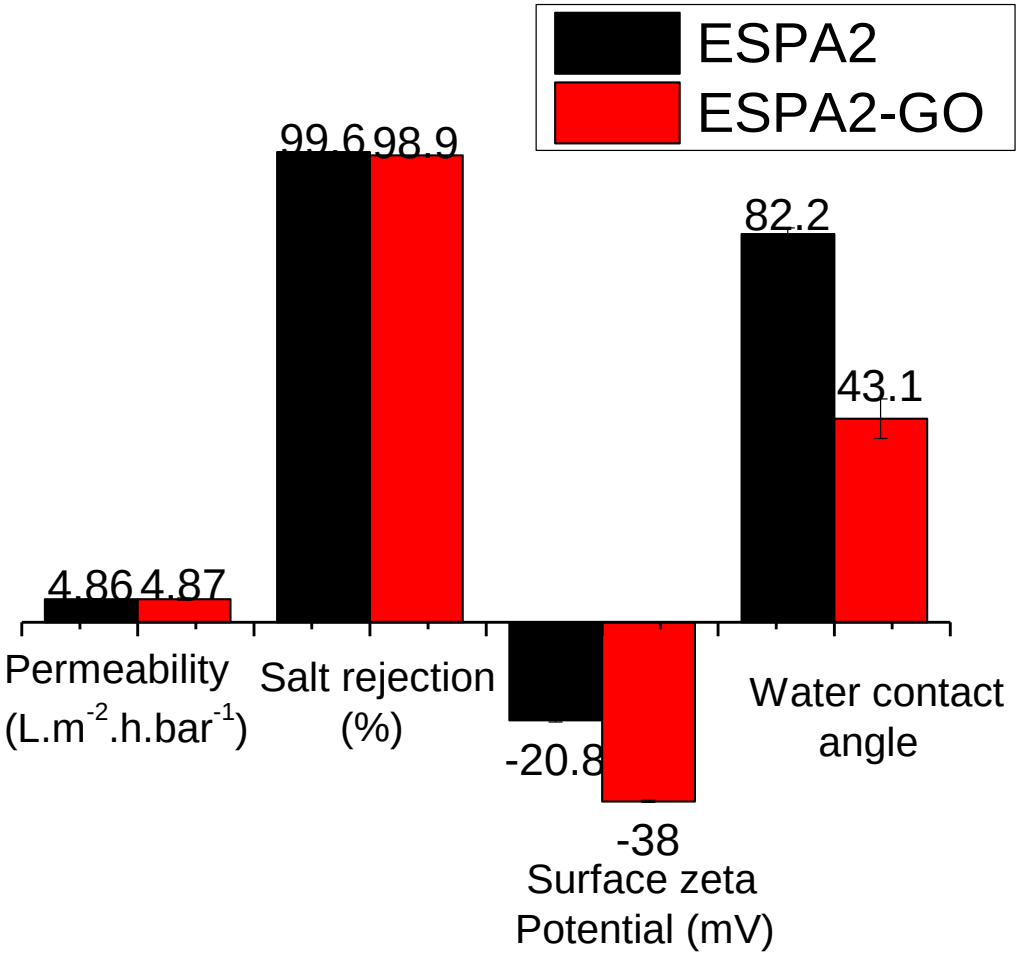
ESPA2-GO characterization: SEM





GO coating makes surface smoother

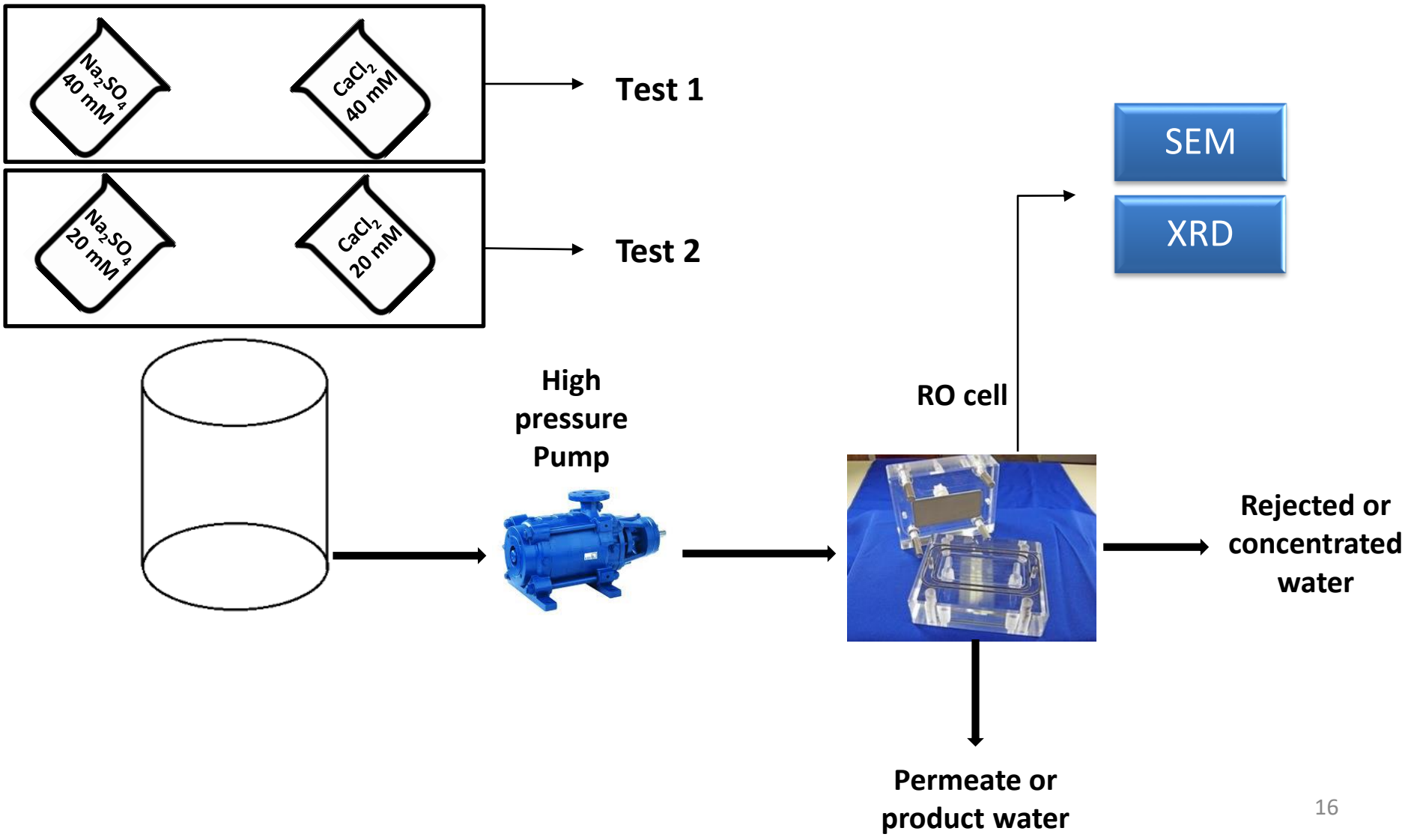
ESPA2-GO characterization



Coating effects:

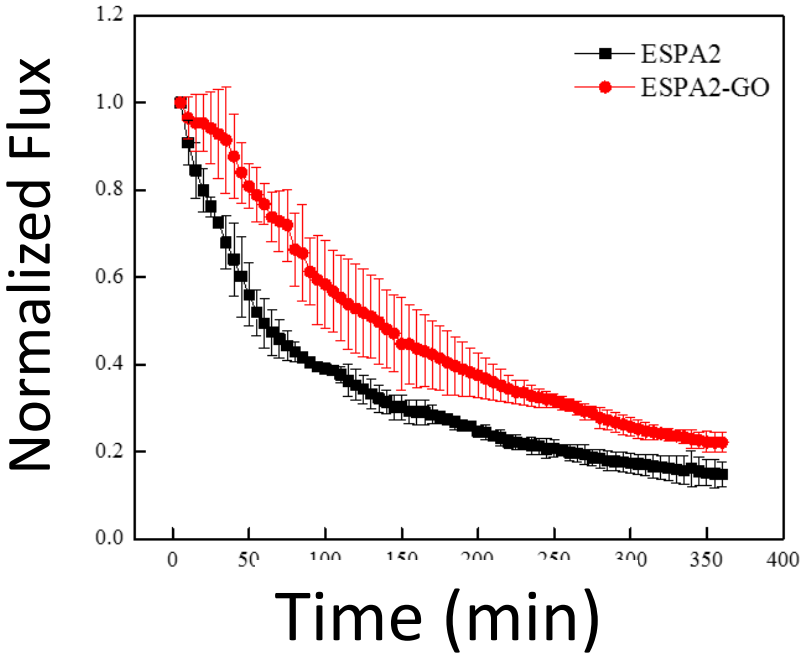
- ✓ **No changes in permeability and salt rejection**
- ✓ **Surface more negatively charged**
- ✓ **Surface more hydrophilic**

Scaling tests

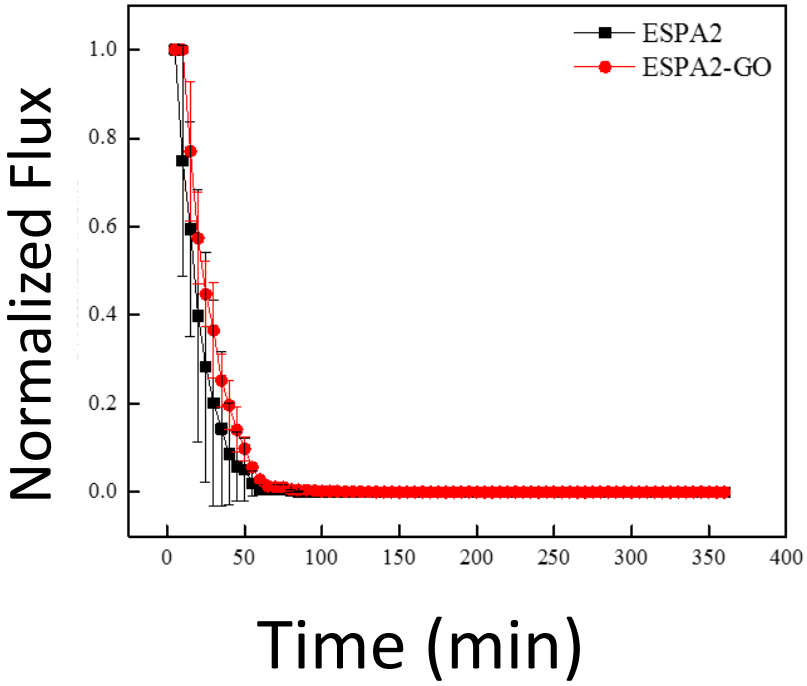


Scaling test: Flux decay

Test 1



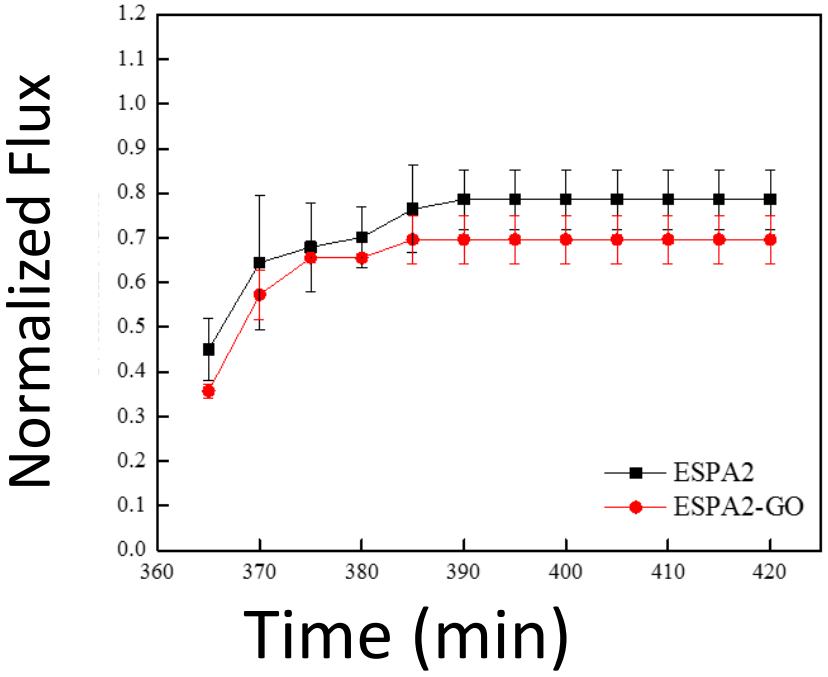
Test 2



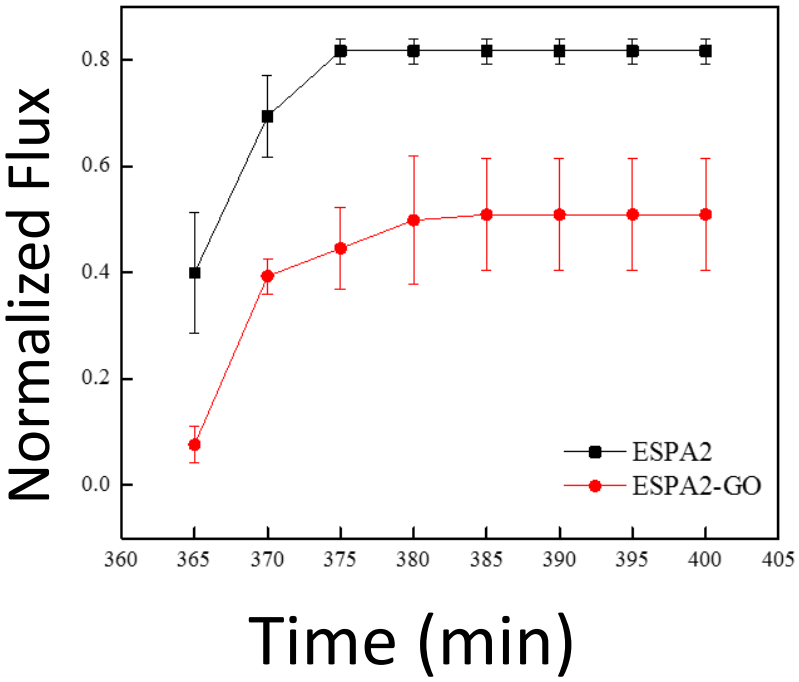
GO repels negatively charged gypsum crystals thus decreases formation of a cake on the membrane surface

Scaling test: Recovery

Test 1



Test 2

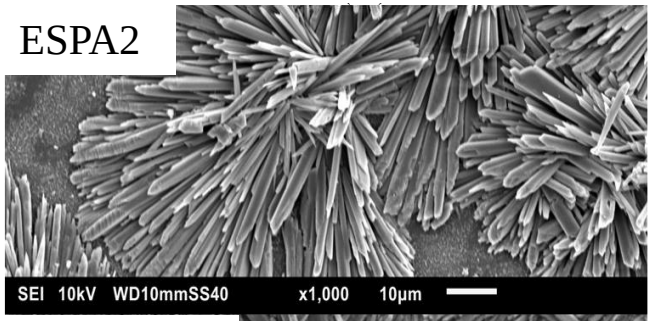


GO makes more stable crystals, due to heterogeneous nucleation (higher number of –COOH)

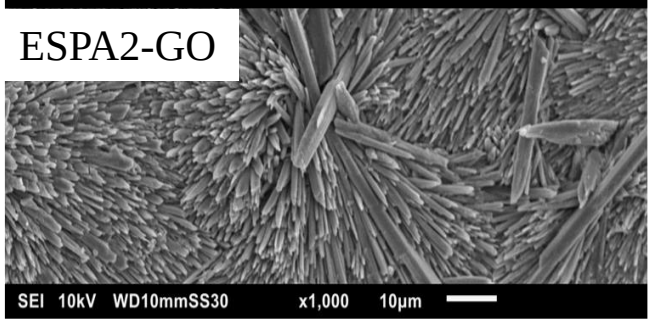
Characterization of the scales: SEM

Test 1

ESPA2

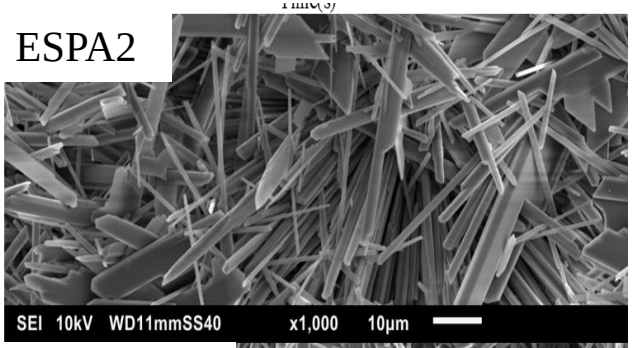


ESPA2-GO

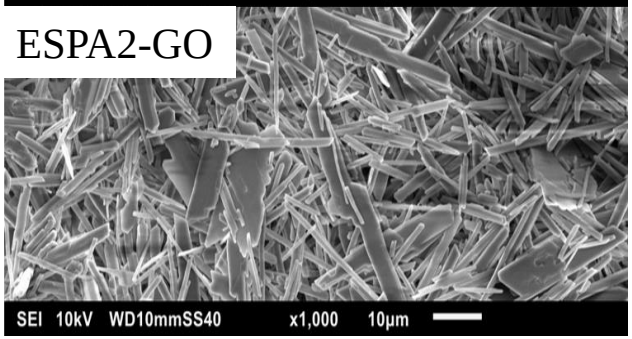


Test 2

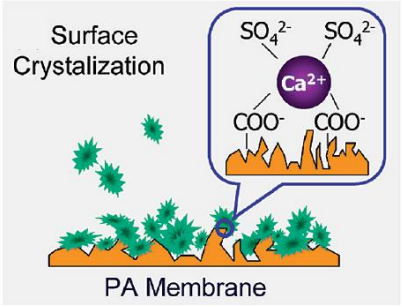
ESPA2



ESPA2-GO

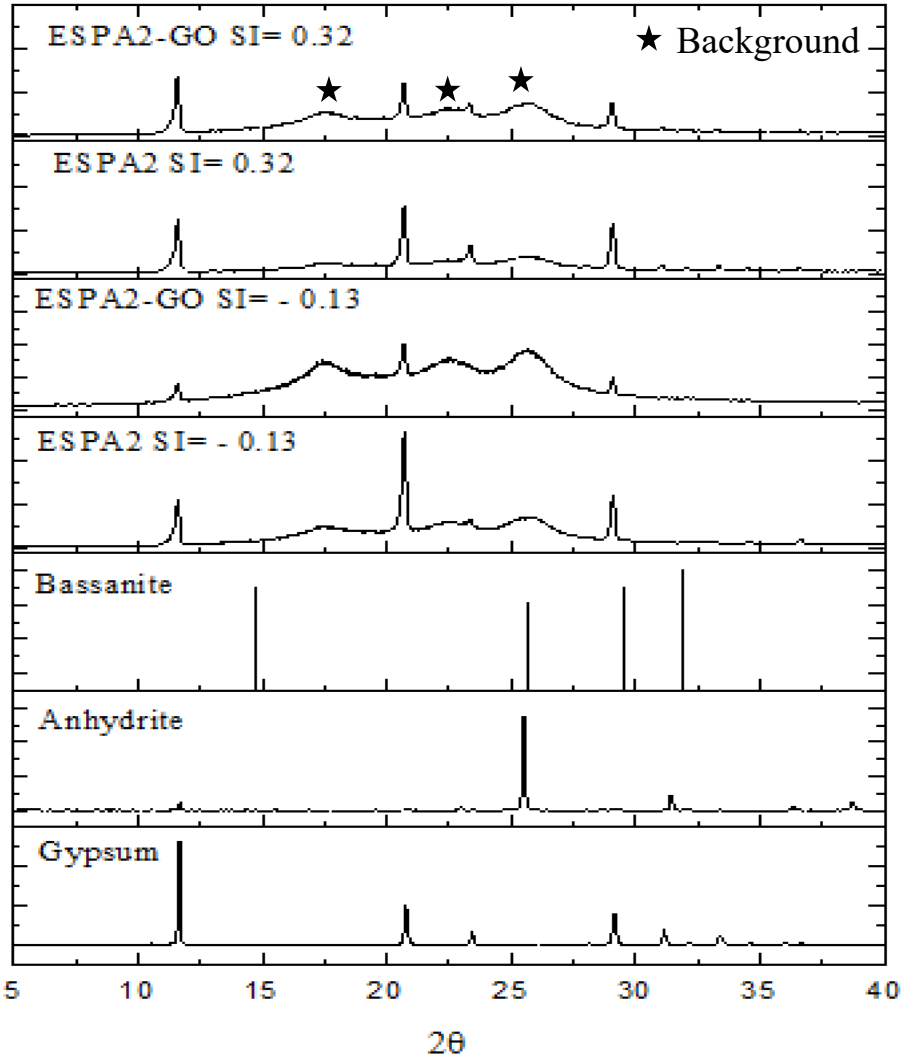


More nucleation sites on the ESPA2-GO cause smaller size crystals



VOL. 44, NO. 6, 2010 / ENVIRONMENTAL SCIENCE & TECHNOLOGY

Characterization of the scales: XRD



All the scales are in gypsum form

Conclusions

- ✓ GO coating doesn't have negative effect on permeability and salt rejection
- ✓ GO coating decreased scaling by repelling negatively charged gypsum, but decreased the flux recovery by making more stable crystals
- ✓ The size of the crystal decreased in ESPA2-GO due to increase in nucleation sites
- ✓ The scales only form in gypsum structure on both ESPA2 and ESPA2-GO

Acknowledgments

This presentation was made possible by NPRP grant # 9-318-1-064 from the Qatar National Research Fund (a member of Qatar Foundation). The findings achieved herein are solely the responsibility of the authors.

Thank you