Fabricating Superhydrophobic Membranes to Improve Water Recovery from Urine

Krystle Dunn[1], Seth Pedersen[2], Qilin Li[2]

[1] NSF Research Experience for Teachers Program, Rice University, Houston, Texas, USA

[2] Department of Civil and Environmental Engineering, Rice University, Houston, Texas, USA

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Background and Problem

Life Sustaining Resources in Space

- In space there is a unique challenge to provide and sustain resources
- It would is not cost effective or feasible to do transport needed resources
- Water is an important resource that must be recycled

Vapor Compression Distillation

- Mechanical failure at 85% due to solid precipitation (Scaling)[1]

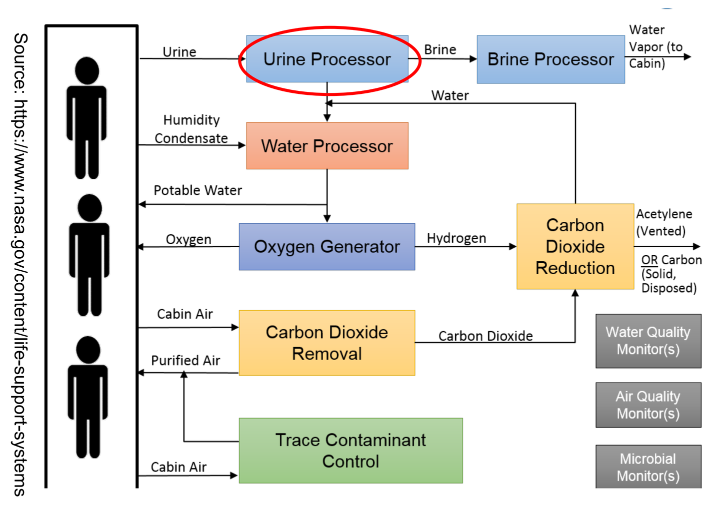

Figure 1. Water is recycled from urine and condensate.

Proposed Alternative Solution

Membrane Distillation

- Process can occur at lower temperature and ambient pressure.
- Recover 90% of water from urine

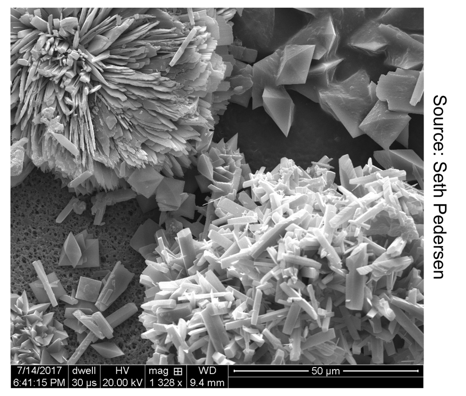

Figure 2. Scaling of a commercial **Poly(vinylidene fluoride) (PVDF) membrane** that has precipitate consisting of mainly of Ca, P, and O from membrane distillation using urine.

Our goal: Since membrane scaling is still an issue in membrane distillation, we will focus on creating a superhydrophobic membrane that resists scaling.

Surfaces with Special Wettability

What is Wettability?

- Determined by the interaction of the liquid and the solid material
- It can be quantified by measuring contact angle (CA)

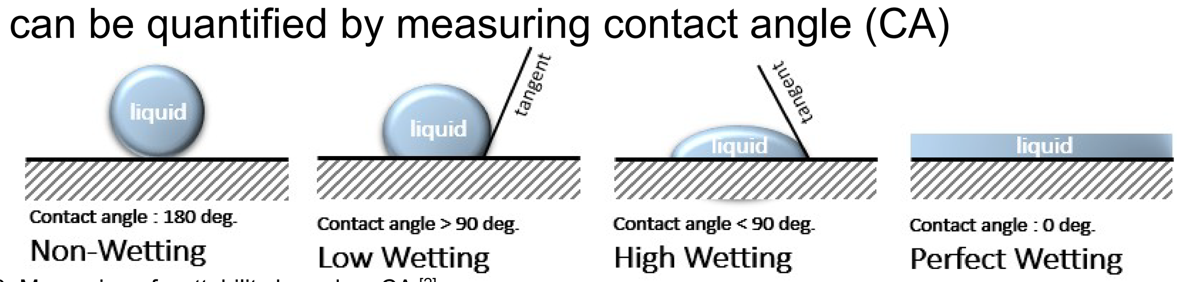

Figure 3: Measuring of wettability based on CA [2]

Superhydrophobic Surfaces [4]

- Water contact angle above 150º
- Water roll off below 10º

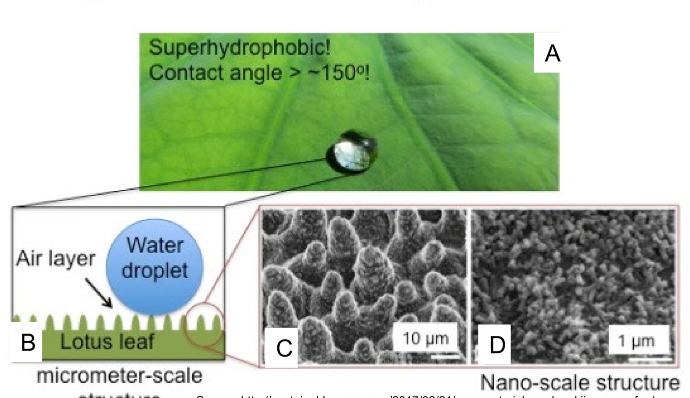

Figure 4: A. Lotus leaf B. structures on a lotus leaf create an air layer between the water droplet and the leaf surface, increasing the contact angle C. Scanning electron microscopy (SEM) image of the upper leaf side shows the hierarchical surface structure. D. An even closer look.[3]

Biomimetics

- Inspiration for self cleaning membrane
- Lotus leaf has a superhydrophobic and nonadhesive surface

Increase surface roughness

- Increases the water contact angle
- Decreases the water roll of angle (see figure 5)

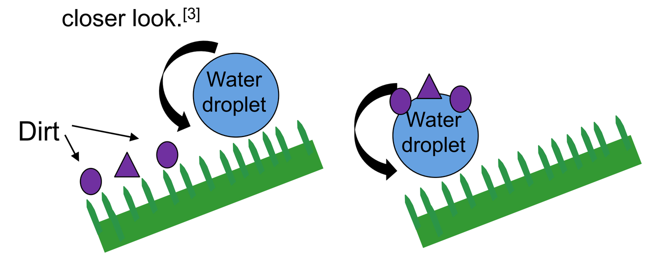

Figure 5: Rolling of a water droplet on the lotus leaf depicting the self-cleaning effect

Methods/Testing

Membranes with Hierarchal Roughness

Create super hydrophobic membrane via electrospinning (see figure 7)

- Electrospinning is a method for creating nanofibers with high porosity and roughness

Different concentrations of PVDF and PVP solution were used to fabricate membrane

- PVDF is a hydrophobic polymer with low surface energy
- PVP is a water soluble polymer

Different concentrations were tested to determine optimal hydrophobicity

- Membranes characterized by SEM images and contact angle measurements

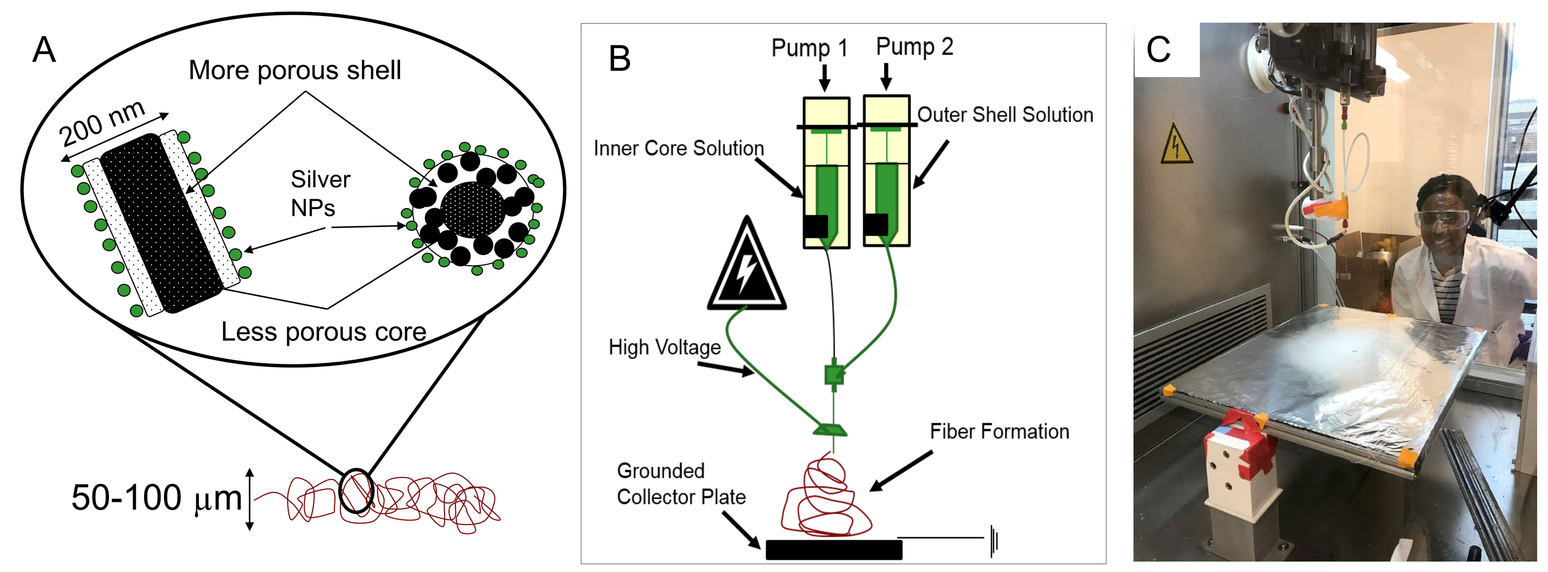

Figure 7.A. Schematic of core-shell electrospun membrane with hierarchal roughness B. Schematic of electrospinning set up C. K. Dunn observing the membrane as it electrospun

Characterization of Different Concentrations

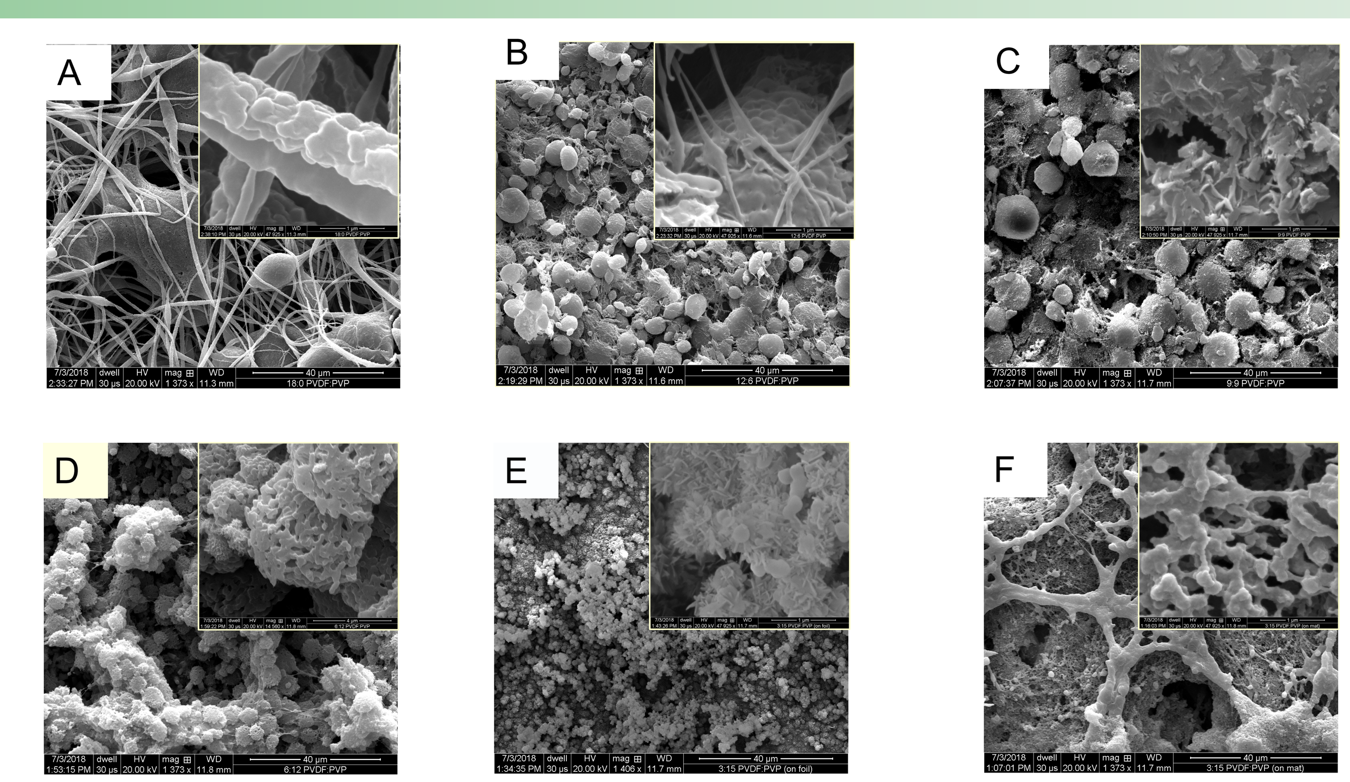

Figure 8. SEM images of samples with different concentrations: A. PVDF (18 %) B. PVDF (12%)/ PVP (6%) C. PVDF (9%)/ PVP (9%) D. PVDF (6%)/ PVP (12%) E. PVDF (15%)/ PVP (3%) (on foil) F. PVDF (15%)/ PVP (3%) (on mat)

Concentration Affect on Contact Angle

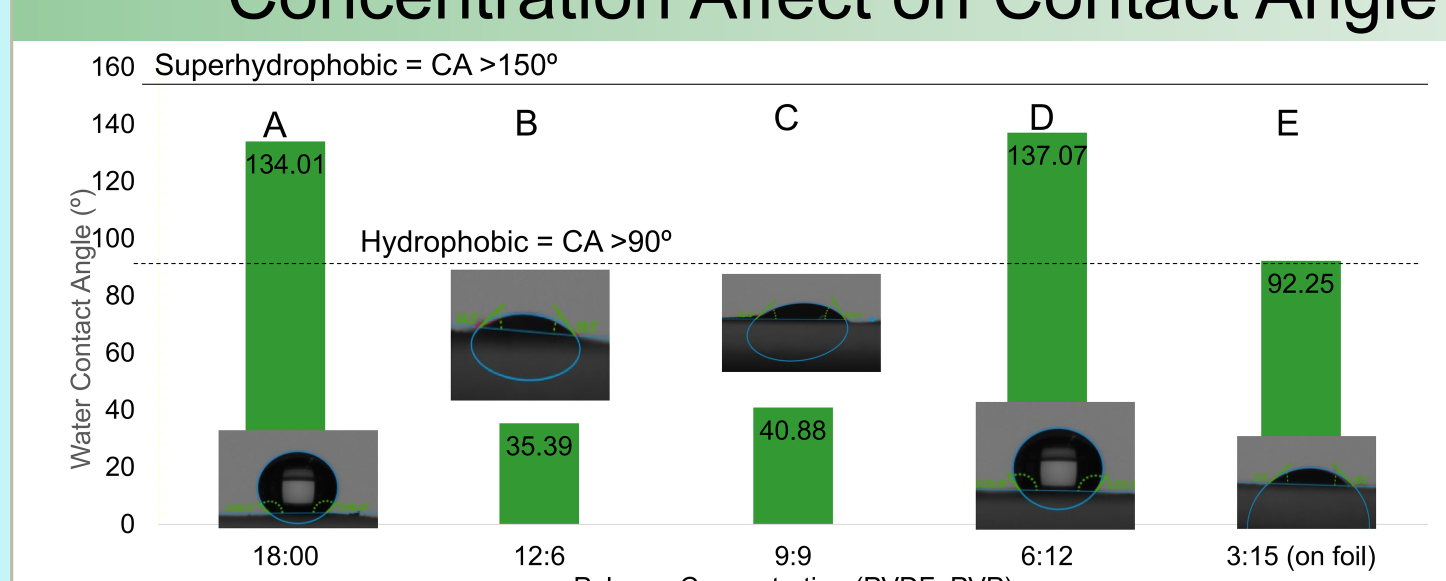

Figure 9. Graph showing 18:0 and 6: 12 PVDF: PVP concentrations are our most hydrophobic fibers and will be combined for our core shell electrospun membrane.

Results and Discussions

Core-Shell Electrospun Membrane

Core shell choice based on SEM and contact angle measurement

- 18:0 inner core for roughness and stability
- 6:12 outer shell for increased porosity (roughness)
- Post treatment
  - Not washed → washed in water→ Dried →Hot glass Pressed

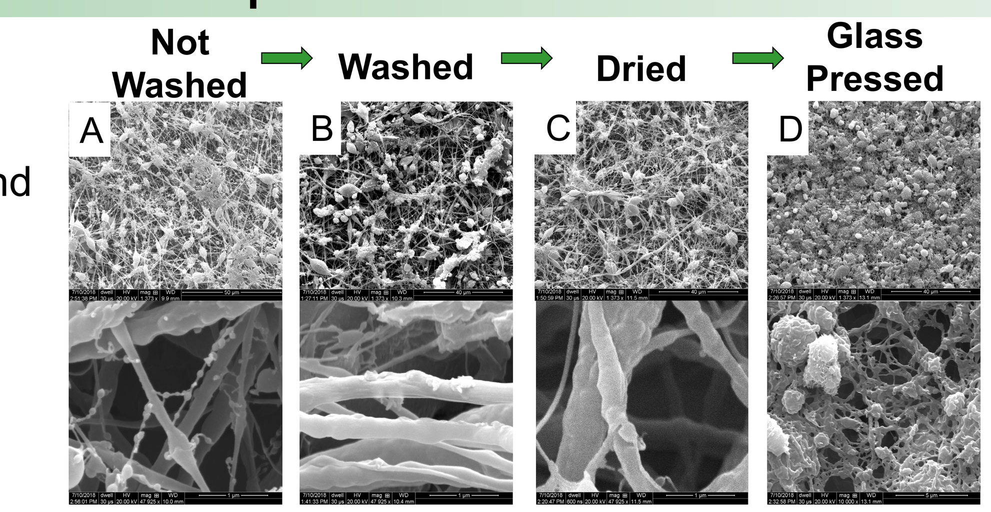

Figure 10. SEM images of core-shell electrospun membrane at different phases of post treatment A. Not washed B. washed in water C. Dried D. Hot glass pressed (Bottom: nanofiber membranes)

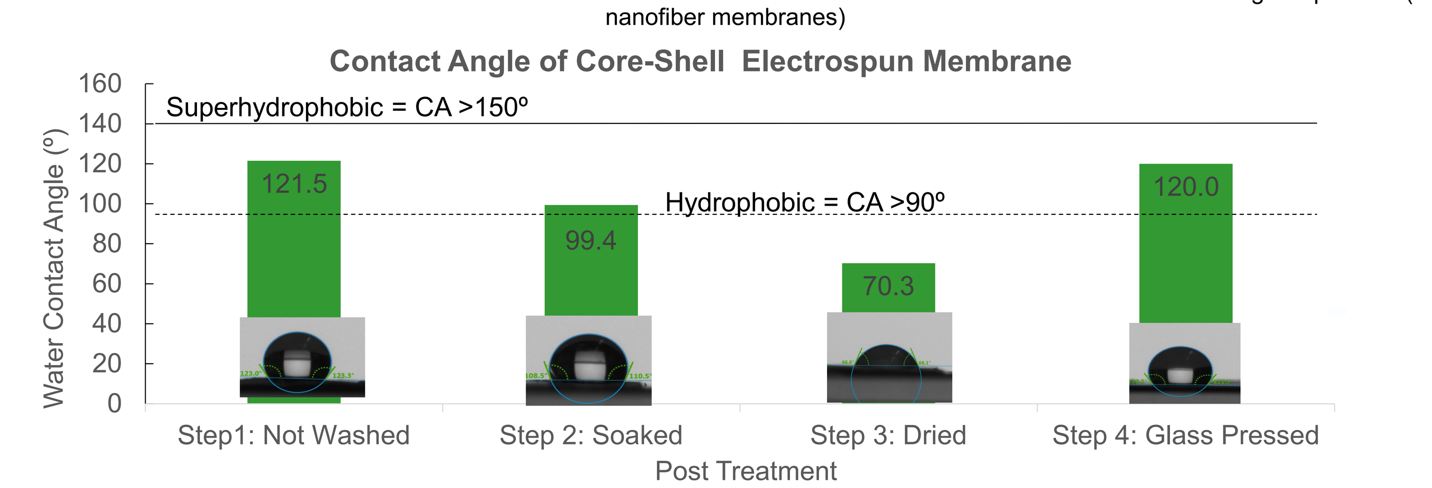

Figure 11. Graph showing 18:0 and 6: 12 PVDF: PVP core shell contact angle fluctuation during post treatment process

Conclusion

Surface Morphology

- Progression through post treatment creates mat with hierarchal roughness (Fig. 9)
- After the last step of post treatment, membrane exhibits a rough texture with polymer beads on a fibrous web (Fig. 9D)

Contact Angle (CA)

The membrane is highly hydrophobic with a CA of 120º, but not superhydrophobic

Potential Error with electrospinning core-shell polymers

Noticed the 6:12 polymer syringe was not pumping at same rate as 18:0 polymer and this may have led to inconsistency in membrane samples

Future Work

Modifications

Add silver nanoparticles to increase roughness and coat with 1-dodecanethiol to lower surface energy

Testing

Test roll off angle and water recovery using membrane distillation set up

References

[1] L. Carter, et al., "Status of ISS Water Management and Recovery." *Int. Conf. on Environmental Sys.* 47, 1-17.

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Acknowledgements

- Dr. Qilin Li and the Li Lab
- Carolyn Nichol and Christina Crawford, R-STEM
- NSF Nanotechnology Research Experience for Teachers, National Science Foundation, Grant EEC-1406885

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