U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Desalination by Membrane Distillation (MD) using Ceramic Membranes

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An International Collaboration

Fraunhofer USA

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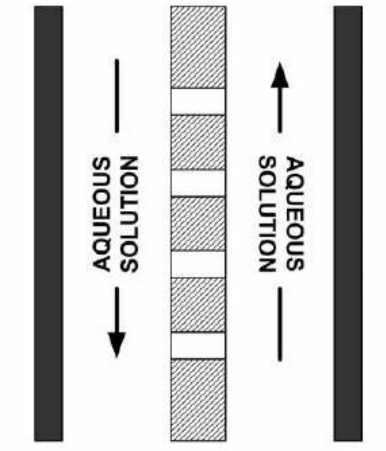
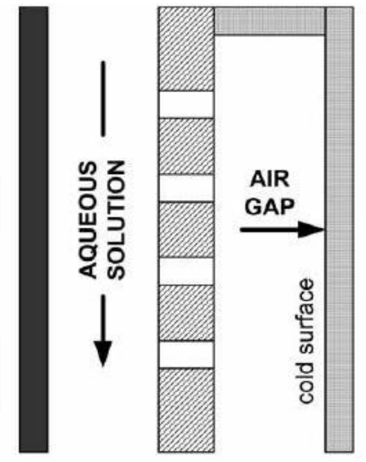
Membrane Distillation

Direct Contact MD (DCMD)



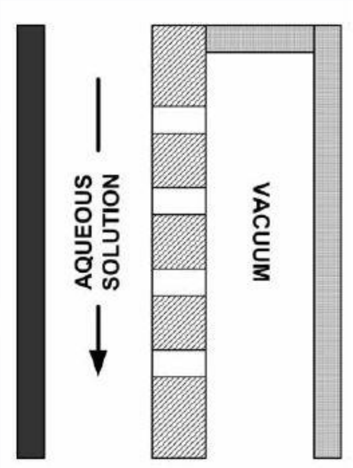
A cold downstream solution condenses vapors crossing the membrane

Air Gap MD (AGMD)



A cold condensing surface is placed some distance from the membrane on the downstream side of the membrane

Vacuum MD (VMD)



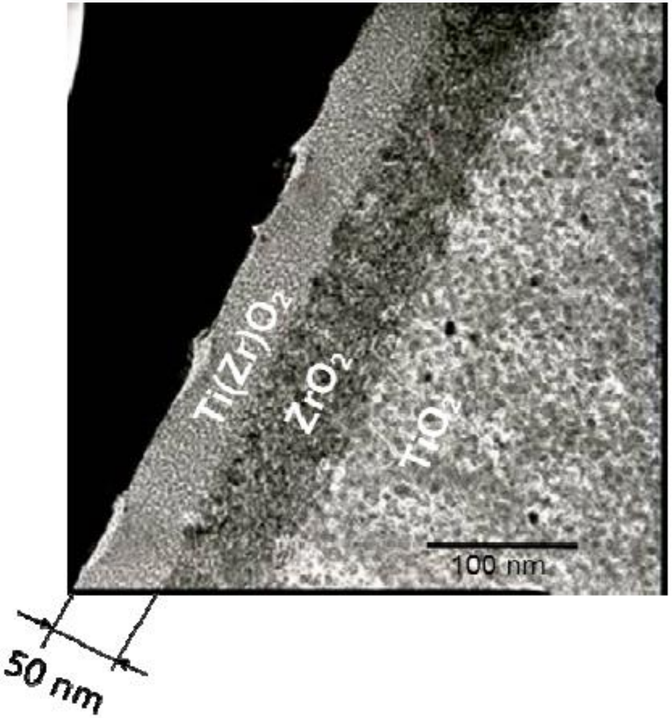
A vacuum draws vapor across the membrane where it is condensed downstream

Necessary Membrane Properties

- High porosity (to allow vapor flow)
- Hydrophobicity (to prevent wetting)
- Resiliency under thermal and chemical conditions (to prevent failure and allow cleaning)

Why Ceramic Membranes

- Ceramic membranes offer unprecedented chemical and thermal resiliency
- Still retain control of pore size and architecture
- May enable use of hot wastewaters directly



Objective

- We will develop the first ceramic-based MD membrane for use in challenging thermal and chemical environments.
- We will establish relationships between MD performance and ceramic membrane properties (pore size, material)
- We will design and build these membranes in manufacturable form factors and develop models to predict their performance to aid in element and module design

Lab-scale element

Monolithic element

Full-scale module

Early Results: Characterization of Membranes

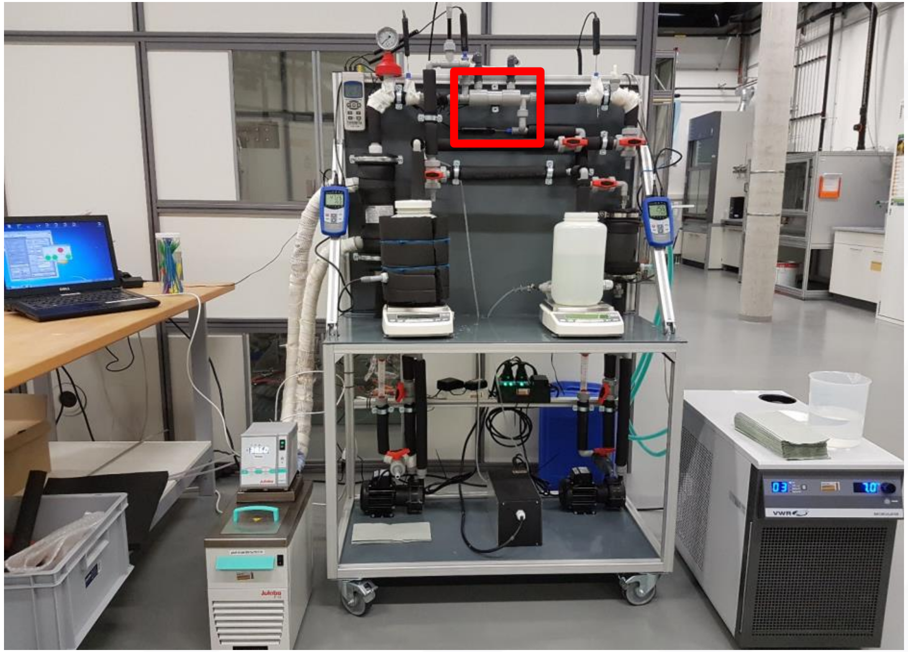
- Liquid Entry Pressure (LEP) testing quantifies the membrane's resistance to wetting
- Results show that membranes of varying pore size and PFAS coating levels resist wetting pressure of at least 2 bar
- Holds true for several relevant feed compositions

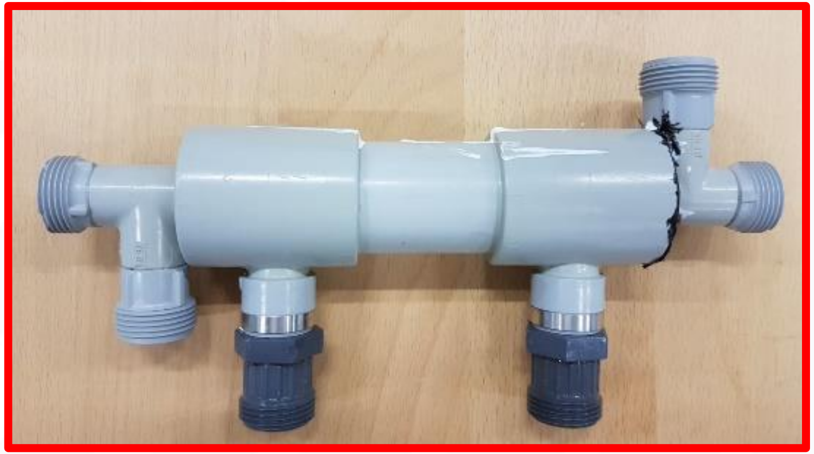
Pore Size [nm]	LEP [bar]	PFAS Coating [%]
100	5.1	1
250	3.95	1
400	2.1	1
250	2.3	0.5
250	4.1	2

Feed Composition	LEP [bar]
Demineralized Water at 20 °C	4
3 Mol NaCl/kg H_2O at 20 °C	4.4
Demineralized Water at 60 °C	4.1
2 g PEG1000/kg H_2O at 20 °C	2.4

Testing of MD Performance

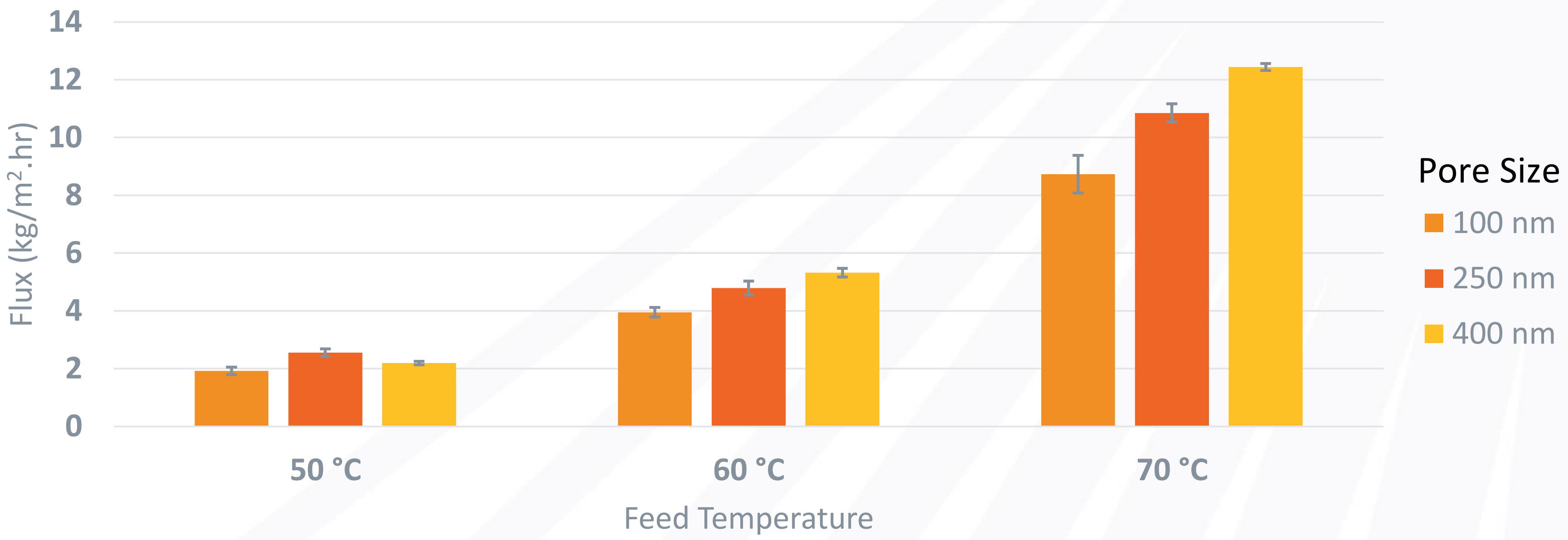
Test Rig for Lab-scale Elements





Membrane distillation module

Early Results: DCDM Performance



Condensing fluid temperature 20C
Crossflow velocity 30cm/s
Single channel 7mm ID tube (10mm OD)

Early Results: DCDM Performance

[min]	Flux [kg/m²h]	electr. Conductivity Coolant [µS/cm]
0	-	
30	5.451	12.5
60	5.105	12.5
90	5.355	12.6
120	5.489	12.1
150	5.585	12.3
180	5.393	12
210	5.374	12
240	5.317	11.9
270	5.355	11.6
300	5.317	10.9
330	5.298	11.1
360	5.489	11
390	5.662	10.8

- Conductivity of downstream solution measured
- No increase in conductivity indicates near perfect selectivity for up to 6 hours of continuous operation
- Decrease in conductivity over time caused by dilution of the receiving solution

Summary

- We have successfully synthesized a ceramic-based MD membrane that resists wetting
- This membrane has shown reasonable performance in DCMD mode with reasonable flux and exceptional selectivity
- We will continue to explore the impacts of membrane material and pore size on MD performance as we begin to design multi-channeled membranes for larger scale element and module design