Connecticut Center for Applied Separations Technologies

Connecticut
Department of Economic and Community Development

CAST
CONNECTICUT CENTER FOR APPLIED SEPARATIONS TECHNOLOGIES

UCONN

About The Director

UCONN TECH PARK

- Centennial Professor, UConn Department of Chemical & Biomolecular Engineering
- Executive Director, Connecticut Center for Applied Separations Technology
- Deputy Topic Area Lead for the National Alliance for water Innovation

Education

UNIVERSITY of DAYTON

B.S. Chemical Engineering 2002

Yale

LUX ET VERITAS

Ph.D. Chemical and Environmental Engineering 2008

Industrial Experience and Awards

- Global Water Summit Technology Idol Winner
- Faculty entrepreneur and startup founder
- 3M Nontenured Faculty Award
- Young investigator awards from DuPont and Solvay
- Technical Group Leader of a university spinout
- Consultant for companies ranging from startups to Fortune 500 companies on membrane technology
- Scientific Advisory Board member for several startups
- Manage rapidly growing contract R&D organization

Academic Performance

- 100+ refereed articles
- 6 issued/pending patents
- 100+ invited seminars, keynotes and webinars
- 200+ conference presentations
- $12M+ in external funding
- Director of REU Program
- 10 PhD students graduated
- Manage 10 student researchers and staff

Scientific Service and Accolades

- Member of the Connecticut Academy of Sciences and Engineering (CASE)
- President, North American Membrane Society (NAMS)
- Area Chair and Separations Division Director, American Institute of Chemical Engineers
- EPA Early Career Award
- FRI/John G. Kunesh Award for Separation Science
- Editorial Board of *Journal of Membrane Science* and *Desalination*

NAWI National Alliance for Water Innovation

AIChE®

CAST CONNECTICUT CENTER FOR APPLIED SEPARATIONS TECHNOLOGIES

nams NORTH AMERICAN MEMBRANE SOCIETY

What we do

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We serve the State of Connecticut by identifying opportunities to implement membrane and other advanced separation technology into various industrial and manufacturing processes in order to lower energy use, reduce carbon footprint, limit waste, and prevent adverse environmental and health impacts.

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Opportunities for Separations Technology

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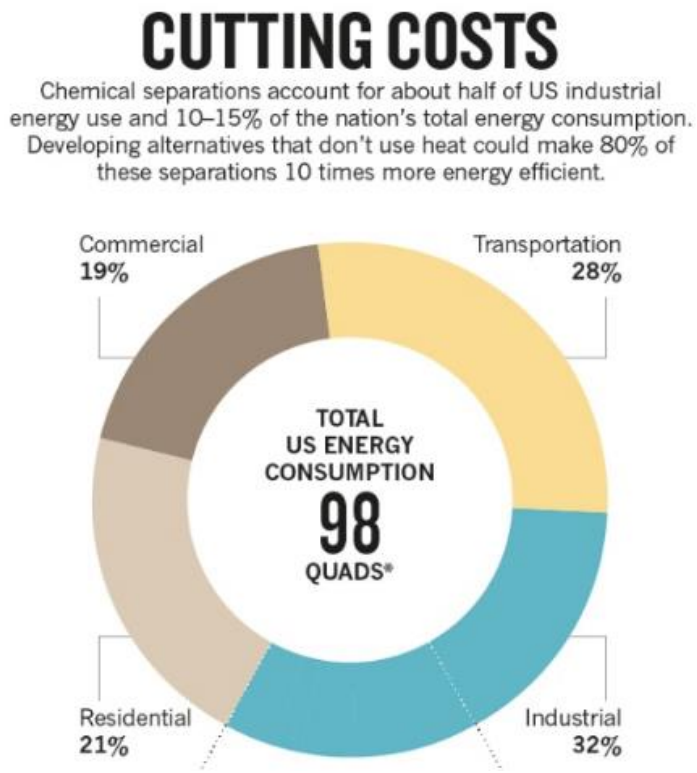
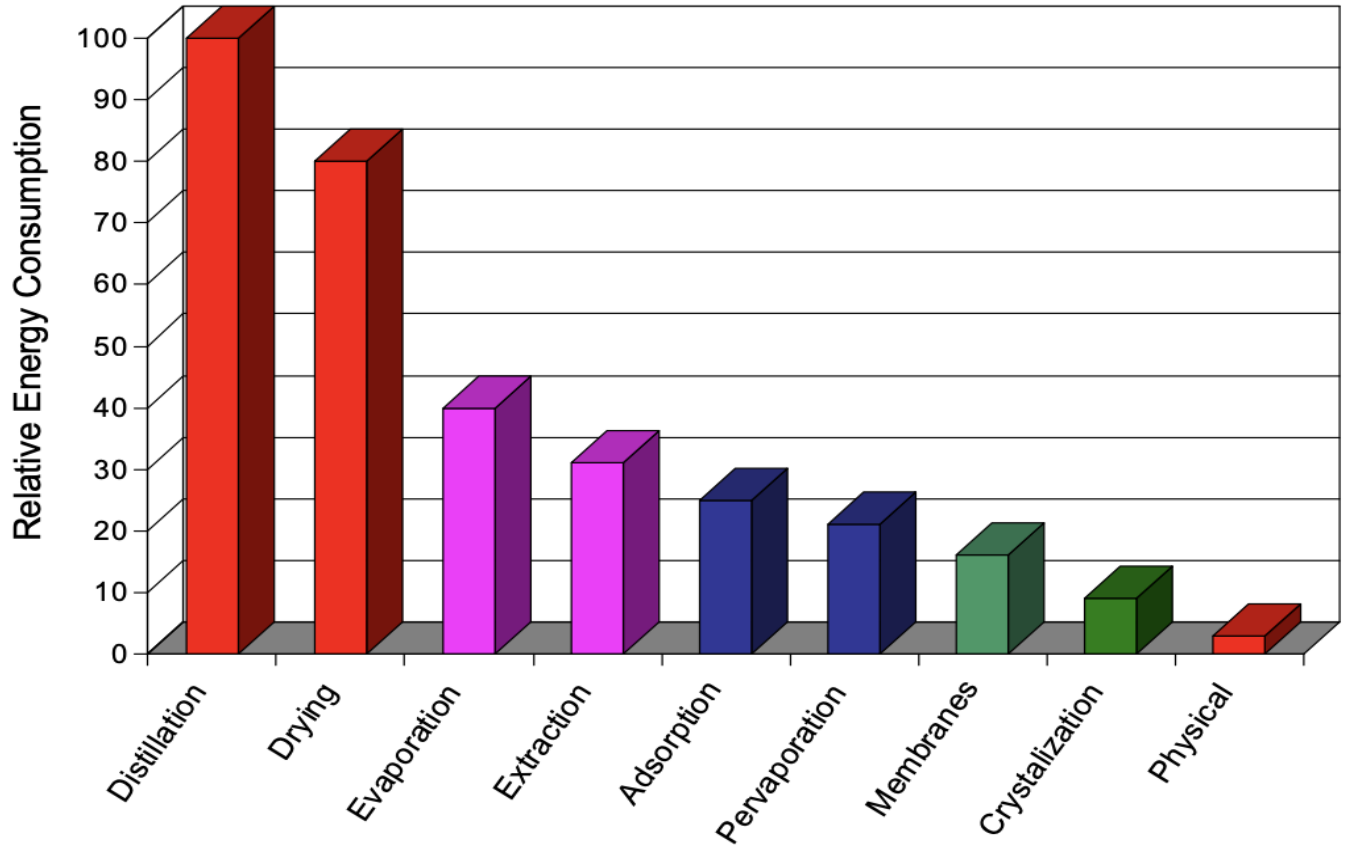


Sholl, D., Lively, R.P., "Seven Chemical Separations to Change the World", *Nature* 532, 2016, 435-437



There is a demand to move away from carbon-intensive thermal separations to electrically driven processes

Oak Ridge National Laboratory. Materials for Separation Technologies: Energy and Emission Reduction Opportunities (2005)

Our Capabilities

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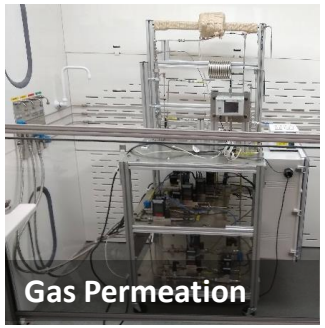
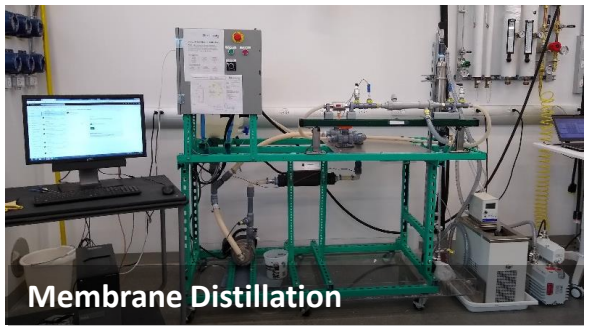

Gas Permeation


Membrane Distillation


PPE/Mask Testing

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Pervaporation


Organic Solvent NF


4040 Element-scale RO

From the lab to protype to pilot, CCAST provides a wide range contract research services for membrane processes related to energy efficient separations for all fluids


Bench-scale RO


1812 Element Testing


Vapor Permeation

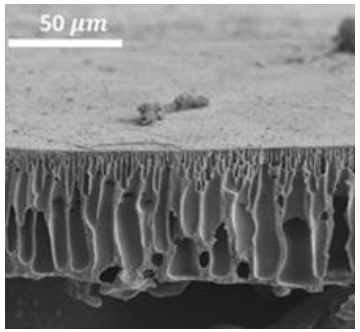
Using bench- to element-scale testing equipment, we can perform testing and 3rd party evaluation of new technologies and applications

Membrane Manufacturing Capabilities

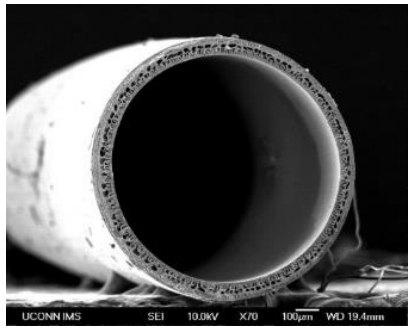
UCONN TECH PARK

We can fabricate membranes at small scale for testing and technical diligence

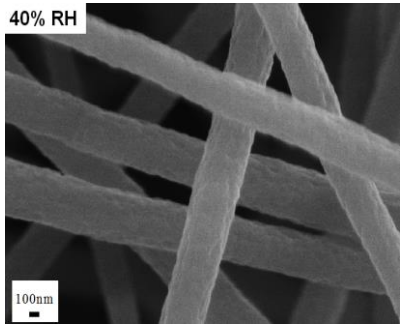
Flat Sheet



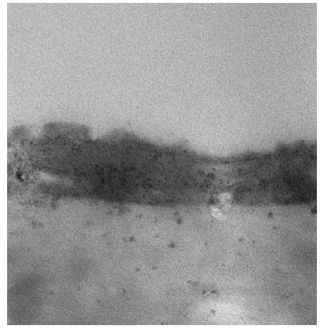
Hollow Fiber



Nanofiber

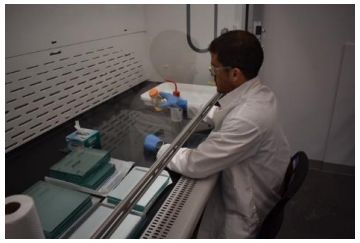


Printed Thin Film Composite



Scaled up electrospinning/electrospraying

Hand Casting



Fiber Spinning

Electrospinning/Electrospraying

Develop, Demonstrate & Deploy Separation Technologies across Various Industrial Sectors

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Manufacturing
- Gas separations
- Wastewater
- Energy recovery and storage

Oil & Gas
- Produced waters
- Oil removal
- Brine dewatering
- CO_2 removal

Agriculture
- Biofuels
- Wastewater
- Anaerobic digestion
- Food processing

Food and Beverage
- Dewatering
- Clarification
- Process water

Utilities and Power
- Gas purification
- Energy storage
- Water reuse

Healthcare and Pharmaceuticals
- Drug purification
- Molecular separation / testing
- Wastewater

Separation Expertise

- Membrane Technology (Organic & Inorganic & Mixed Matrix)
- Membrane Modules and Systems
- Liquid Separations
- Gas Separations / Vapor Permeation
- Particle Separations in Gas/Liquid
- Separations for Energy Efficiency and Production

Services Offered by CCAST

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- Contract research and specialized consulting
- 3rd party validation of new technology
- Pilot-scale demonstration system design and fabrication
- Customized membrane and process testing services
- Membrane fabrication and characterization
- New product testing and evaluation
- Modification of existing products for new applications

Access to UConn Infrastructure

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UConn Utility Plant

- 25 MW power plant
- GTCC plant with steam boiler makeup and cooling water demand
- Largest water user on campus
- Softening and deionizing water process train

Wastewater Reuse Facility

- Up to 1M MGD UV/MF tertiary treatment
- Typical operation at 400,000 GPD
- Water sent to power plant for boiler makeup and cooling water

Water Pollution Control Facility

- Up to 2.1 MGD processing capability
- Primary and secondary treatment
- Chlorination/dechlorination

Rankin Lab – UConn Seawater Intake Facility

- 2,400 square foot facility
- 250 GPM raw seawater supply
- 16 GPM filtered seawater supply
- 600 square foot dry lab for research and small classes.

Core Manufacturing Technology: Membrane Additive Manufacturing

Electrospray Additive Manufacturing

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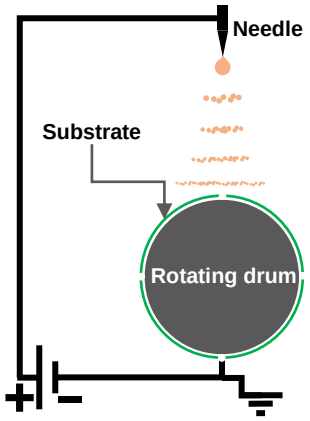

Tunable parameters

- Flow rate
- Voltage
- Tip to drum distance
- Tip configuration
- Viscosity
- Surface tension
- Electrical conductivity

Controls

- Thickness
- Chemistry
- Morphology

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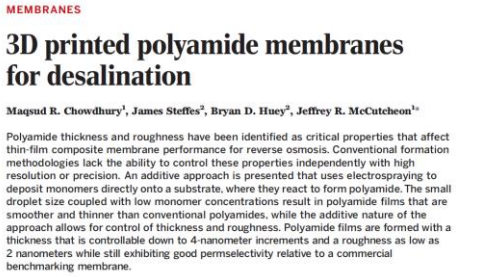
CONNECTICUT CENTER FOR APPLIED SEPARATIONS TECHNOLOGIES (CCAST)



MEMBRANES

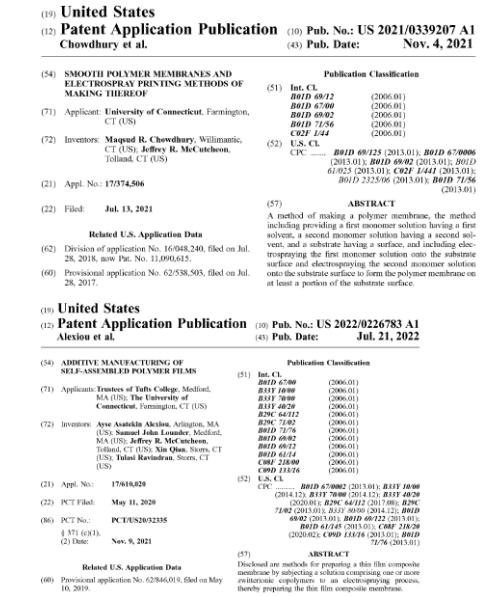
3D printed polyamide membranes for desalination

Maqsud R. Chowdhury[1], James Steffes[2], Bryan D. Huey[2], Jeffrey R. McCutcheon[1]*

Polyamide thickness and roughness have been identified as critical properties that affect thin-film composite membrane performance for reverse osmosis. Conventional formation methodologies lack the ability to control these properties independently with high resolution or precision. An additive approach is presented that uses electrospraying to deposit monomers directly onto a substrate, where they react to form polyamide. The small droplet size coupled with low monomer concentrations result in polyamide films that are smoother and thinner than conventional polyamides, while the additive nature of the approach allows for control of thickness and roughness. Polyamide films are formed with a thickness that is controllable down to 4-nanometer increments and a roughness as low as 2 nanometers while still exhibiting good permselectivity relative to a commercial benchmarking membrane.

Science AAAS

Dr. Maqsud Chowdhury



(19) United States
(12) Patent Application Publication
Chowdhury et al.
(10) Pub. No.: US 2021/0339207 A1
(43) Pub. Date: Nov. 4, 2021

(54) SMOOTH POLYMER MEMBRANES AND ELECTROSPRAY PRINTING METHODS OF MAKING THEREOF

(71) Applicant: University of Connecticut, Farmington, CT (US)

(72) Inventors: Maqsud R. Chowdhury, Willimantic, CT (US); Jeffrey R. McCutcheon, Tolland, CT (US)

(21) Appl. No.: 17/374,506

(22) Filed: Jul. 13, 2021

Related U.S. Application Data

(62) Division of application No. 16/048,240, filed on Jul. 28, 2018, now Pat. No. 11,090,615.

(60) Provisional application No. 62/538,503, filed on Jul. 28, 2017.

Publication Classification

(51) Int. Cl.
B01D 69/12 (2006.01)
B01D 67/00 (2006.01)
B01D 69/02 (2006.01)
B01D 71/56 (2006.01)
C02F 1/44 (2006.01)

(52) U.S. Cl.
CPC B01D 69/125 (2013.01); B01D 67/0006 (2013.01); B01D 69/02 (2013.01); B01D 61/025 (2013.01); C02F 1/441 (2013.01); B01D 2325/06 (2013.01); B01D 71/56 (2013.01)

(57) ABSTRACT

A method of making a polymer membrane, the method including providing a first monomer solution having a first solvent, a second monomer solution having a second solvent, and a substrate having a surface, and including electrospraying the first monomer solution onto the substrate surface and electrospraying the second monomer solution onto the substrate surface to form the polymer membrane on at least a portion of the substrate surface.

(19) United States
(12) Patent Application Publication
Alexiou et al.
(10) Pub. No.: US 2022/0226783 A1
(43) Pub. Date: Jul. 21, 2022

(54) ADDITIVE MANUFACTURING OF SELF-ASSEMBLED POLYMER FILMS

(71) Applicants: Trustees of Tufts College, Medford, MA (US); The University of Connecticut, Farmington, CT (US)

(72) Inventors: Ayse Asatekin Alexiou, Arlington, MA (US); Samuel John Lounder, Medford, MA (US); Jeffrey R. McCutcheon, Tolland, CT (US); Xin Qian, Storrs, CT (US); Tulasi Ravindran, Storrs, CT (US)

(21) Appl. No.: 17/610,020

(22) PCT Filed: May 11, 2020

(86) PCT No.: PCT/US20/32335
§ 371 (c)(1),
(2) Date: Nov. 9, 2021

Related U.S. Application Data

(60) Provisional application No. 62/846,019, filed on May 10, 2019.

Publication Classification

(51) Int. Cl.
B01D 67/00 (2006.01)
B33Y 10/00 (2006.01)
B33Y 70/00 (2006.01)
B33Y 40/20 (2006.01)
B29C 64/112 (2006.01)
B29C 71/02 (2006.01)
B01D 71/76 (2006.01)
B01D 69/02 (2006.01)
B01D 69/12 (2006.01)
B01D 61/14 (2006.01)
C08F 218/00 (2006.01)
C09D 133/16 (2006.01)

(52) U.S. Cl.
CPC B01D 67/0002 (2013.01); B33Y 10/00 (2014.12); B33Y 70/00 (2014.12); B33Y 40/20 (2020.01); B29C 64/112 (2017.08); B29C 71/02 (2013.01); B33Y 80/00 (2014.12); B01D 69/02 (2013.01); B01D 69/122 (2013.01); B01D 61/145 (2013.01); C08F 218/20 (2020.02); C09D 133/16 (2013.01); B01D 71/76 (2013.01)

(57) ABSTRACT

Disclosed are methods for preparing a thin film composite membrane by subjecting a solution comprising one or more zwitterionic copolymers to an electrospraying process, thereby preparing the thin film composite membrane.

First additive manufacturing process demonstrated to make membranes at scale

Customized Membranes for Water Treatment

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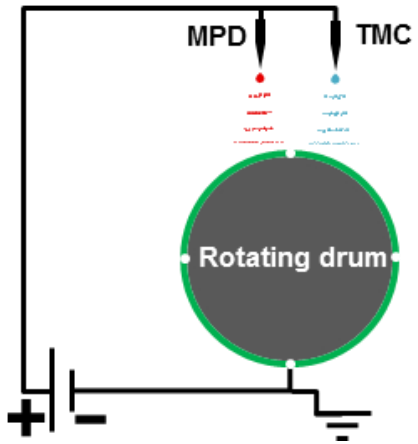
- We can apply this process to making membranes with tailored properties
- Targeted removal of specific contaminants
- Multiple research and commercialization efforts with collaborators from UT Austin, Virginia, Argonne National Labs, and industry
- ~3M+ in total funding



Polymers or monomers can be deposited into thin films to offer customized chemistries

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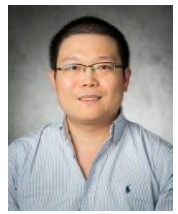
UCONN UNIVERSITY OF CONNECTICUT

TEXAS The University of Texas at Austin

Argonne NATIONAL LABORATORY

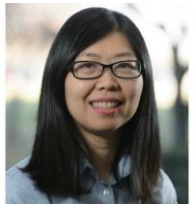

Jeffrey McCutcheon (PI)


Mayur Ostwal


Ying Li


Manish Kumar


Jamie Warner


Yuepeng Zhang

ZwitterCo

NALA MEMBRANES

Winner of the 2019 Water Technology Idol Competition at Global Water Summit

Funding

NSF

NAWI National Alliance for Water Innovation

SPARK

Printed Membranes for Biogas Upgrading

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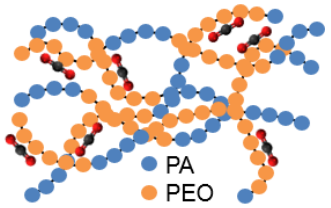
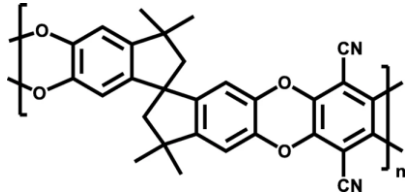
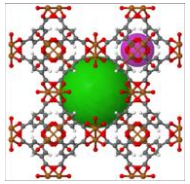
Pebax-1657



PIM-1



HKUST



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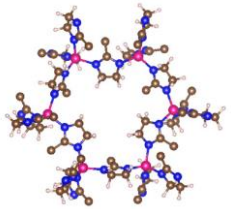

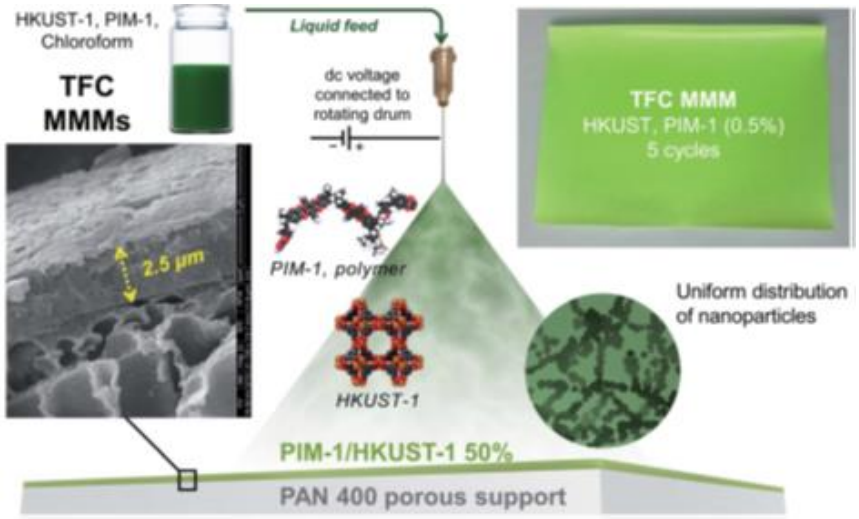

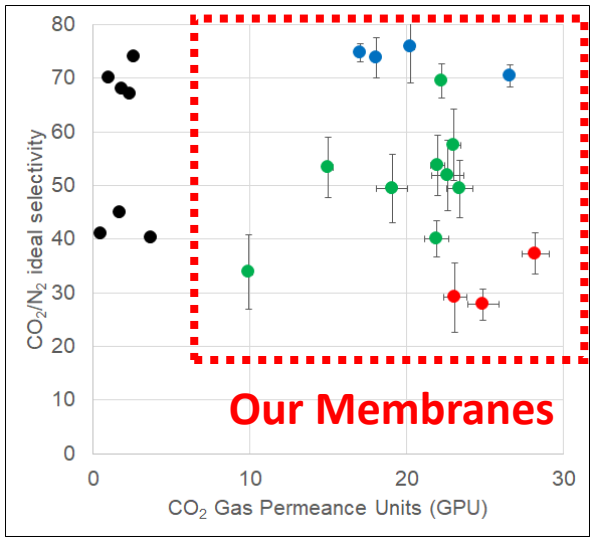

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UNIVERSITY OF CONNECTICUT

ILLINOIS INSTITUTE OF TECHNOLOGY

Jeffrey McCutcheon (PI)

Noah Ferguson

Mayur Ostwal

Sameh Elsaidi

NSF | America's SEED FUND SBIR.STTR

- We are using our manufacturing technology to make best in class membranes for biogas upgrading and carbon capture
- ~$300k in total funding

Low Cost Ion Exchange Membranes

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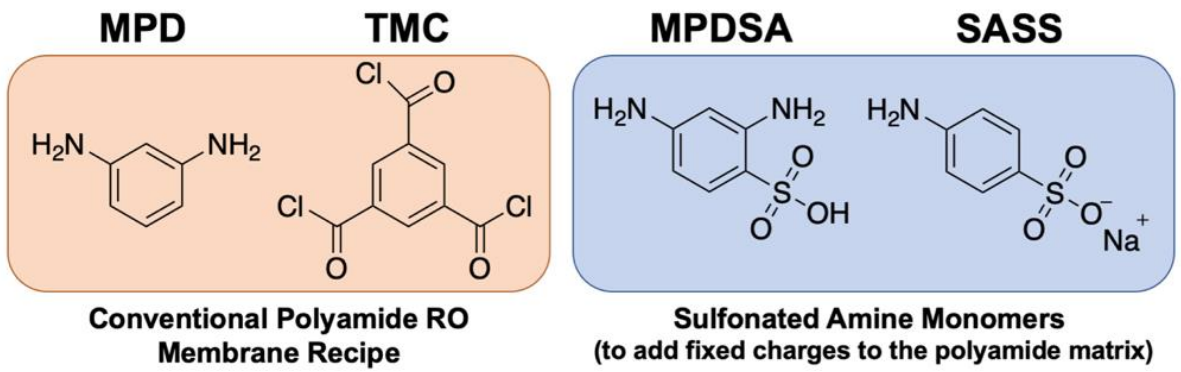

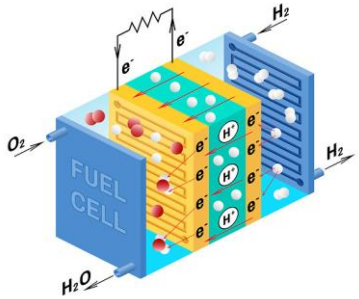

Fuel cells and electrolyzers

Electrodialysis

Printed ion exchange membranes could be 10 less expensive than conventionally manufactured membranes

UCONN UNIVERSITY OF CONNECTICUT

Jeffrey McCutcheon

UNIVERSITY of VIRGINIA

Geoff Geise

UNIVERSITY OF South Carolina

Bill Mustain

Funding

NSF

Office of Naval Research ONR Science & Technology

Conflict of Interest Statement

UCONN TECH PARK

The Director of CCAST is an equity owner of a faculty affiliated company at the University of Connecticut that is seeking to commercialize technology related to some of the work described in this talk.

Other Federally Funded Projects

Decarbonization of Wastewater Treatment with MLA Controlled Anaerobic Digestion

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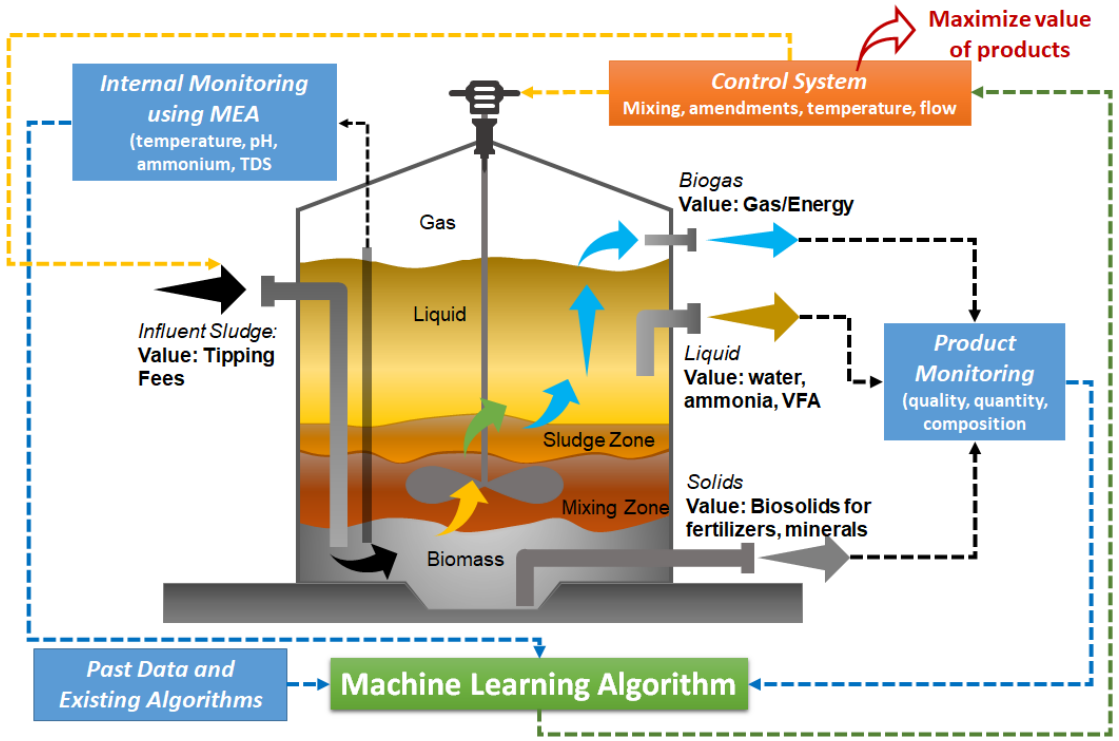

UCONN SCHOOL OF ENGINEERING

nebra North East Biosolids & Residuals Association

Greater Lawrence Sanitary District


Jeffrey McCutcheon (PI)


Baikun Li (co-PI)


George Bollas (co-PI)


Ranjan Srivastava (co-PI)


Matthew Stuber (co-PI)


Ned Beecher (co-PI)


Cheri Cousens (Municipal Collaborator)

Funding

CAST CONNECTICUT CENTER FOR APPLIED SEPARATIONS TECHNOLOGIES

- Anaerobic co-digestion is an effective means of recovering value from food waste and domestic wastewater
- We are using machine learning to develop control strategies to maximize value of products created by digestion while reducing climate-related life cycle costs of wastewater treatment
- $2.4M in total funding

Printing Ion-selective Membranes for Sensors

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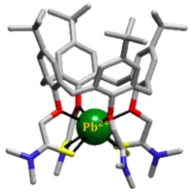
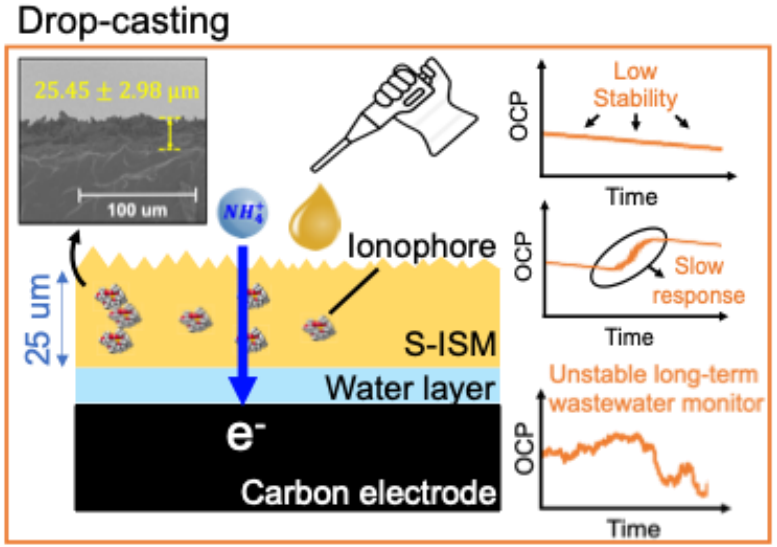
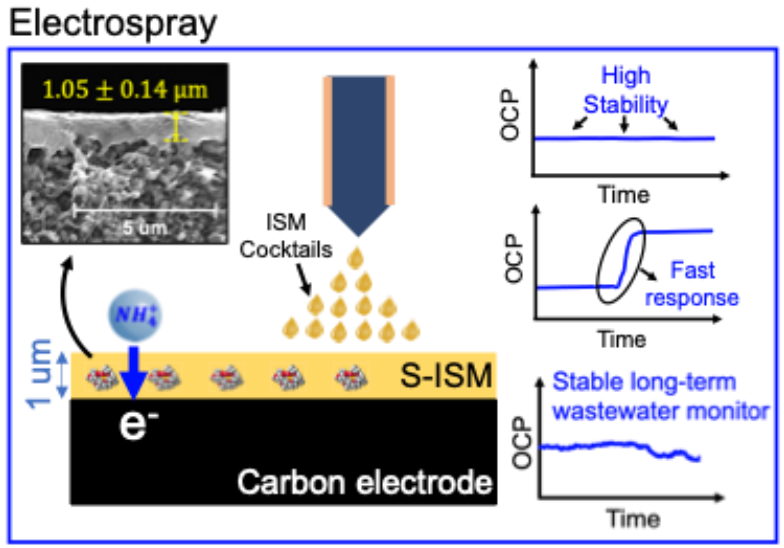
Solid-State Ion Selective Membrane Sensor (S-ISM)







New sensors cost pennies to make and offer 50% improved response time without loss of sensitivity

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UNIVERSITY OF CONNECTICUT


Dr. Baikun Li


Yuankai Huang


Dr. Yingzheng Fan

Funding

Fan, Y., Qian, X., Wang, X., Funk, T., Herman, B., McCutcheon, J.R., Li, B., "Enhancing long-term accuracy and durability of wastewater monitoring using electrosprayed ultra-thin solid-state ion selective membrane sensors", *Journal of Membrane Science* 643, 2022, 119997.

Harnessing the Sun for Solar Desalination

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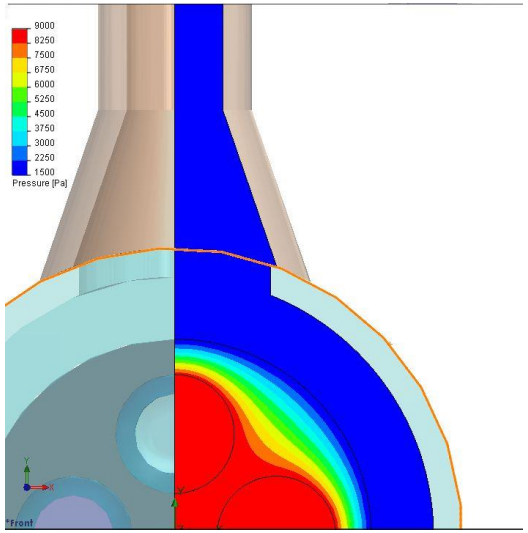
- We are developing ceramic membranes that enable solar-drive desalination
- Partners: Fraunhofer, Oak Ridge National Labs, National Renewable Energy Laboratory, Artic Solar, University of Texas, El Paso, Kay Bailey Hutchinson Desalination Plant, Rauschert North America, ALSYS
- $1.1M Project Funded by the DOE Concentrated Solar Program
- $300k in prize money for the American Made Challenges Program
- $750k in potential prize money for next prize phase



Funding

AMERICAN MADE CHALLENGES
U.S. DEPARTMENT OF ENERGY

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA ·

Examples of Industrial Client Projects

Capturing Carbon Dioxide to Make Fuel

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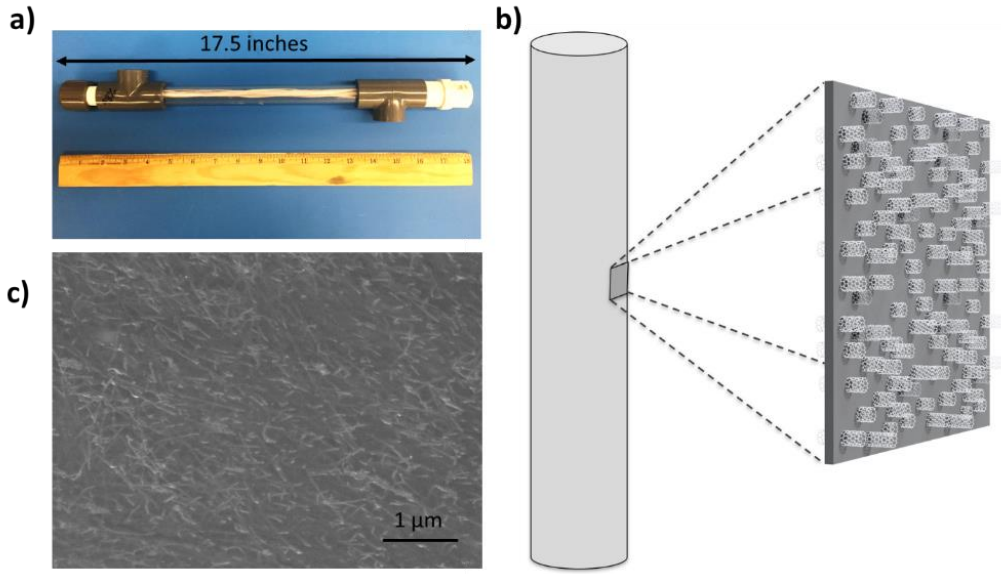
Client: Prometheus Fuels
Location: Santa Cruz, CA

- Mattershift is a former UConn TIP Company
- Mattershift spun out Prometheus Fuels, the country's first carbon neutral electrofuels unicorn
- We are evaluating their membrane technology for performance in other areas

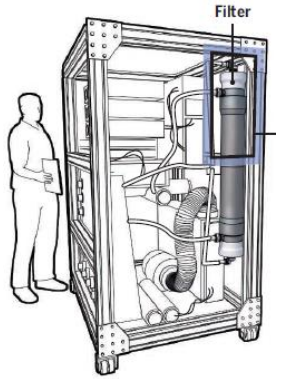


SCIENCE ADVANCES | RESEARCH ARTICLE

MATERIALS SCIENCE

Large-scale polymeric carbon nanotube membranes with sub–1.27-nm pores

Robert L. McGinnis,[1] Kevin Reimund,[1,2] Jian Ren,[2] Lingling Xia,[2] Maqsud R. Chowdhury,[2] Xuanhao Sun,[2] Maritza Abril,[2] Joshua D. Moon,[3] Melanie M. Merrick,[3] Jaesung Park,[3] Kevin A. Stevens,[3] Jeffrey R. McCutcheon,[2] Benny D. Freeman[3]*



NEWS

QUEST FOR FIRE

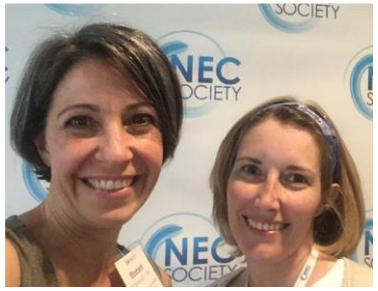
Rob McGinnis aims to use renewable energy to turn carbon dioxide and water into gasoline

By **Robert F. Service**, in San Francisco, California; Photography by **LiPo Ching**

Using Membranes to Help Premature Babies

UCONN TECH PARK

Client: Mother's Milk is Best, Inc.
Location: Boston, MA



Beth Shinkel
Elizabeth Nelson

We helped develop a new membrane devices that will gently dewater human breastmilk so that it can be ingested by premature babies.

Good sealing!

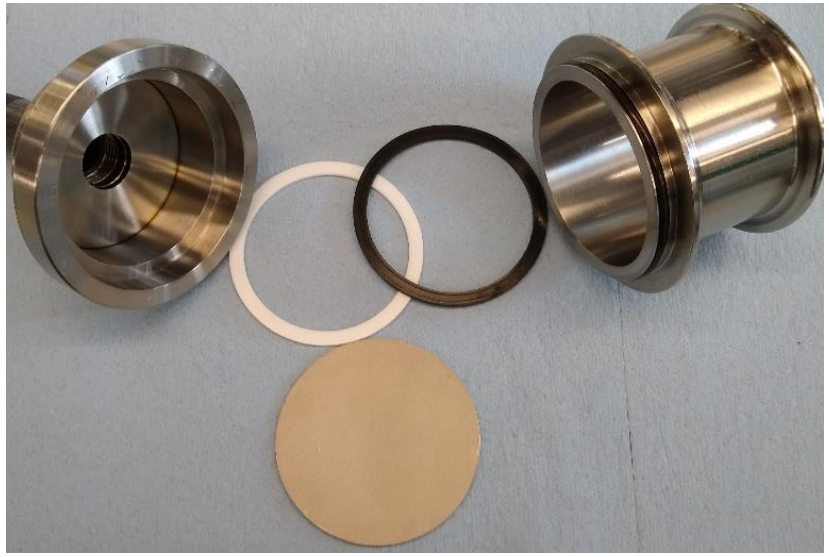
Osmotic dewatering of breastmilk enabled by membrane pouches

$35k in total funding
$100k pending

Verifying Client Marketing Data

UCONN TECH PARK

Client: Mott Corporation
Location: Farmington, CT



- Evaluated Mott's porous metal filter technology to ensure their marketing materials were accurate
- Custom built test stand with automated data collection
- Continuing work to better characterize their filter media for particle removal efficiency and cleaning potential.

Building Systems to Test New Technology

UCONN TECH PARK

Client: Henkel
Location: Rocky Hill, CT

- Built a pilot-scale reverse osmosis process to evaluate new membrane products
- Automated test rig providing long term testing of membranes rejection and productivity
- Evaluate fouling potential of new membrane materials

Mask/Materials Data and Testing

UCONN TECH PARK

Fabric Testing on TSI 8130A *by Dr Mayur Ostwal of CCAST*

Penetration Mode, 100cm^2 Membrane Area*, 2% NaCl
* All tests performed with 100cm2, except N95 Mask

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Please email mayur.ostwal@uconn.edu about testing

Flow rate of 32 lpm
Flow Rate of 85 lpm

July 15, 2020

Material	Layers	% Efficiency 0 10 20 30 40 50 60 70 80 90 100 — N95 Requirement Greater Than - - >
N95, New & NIOSH Certified	1	
Non-Medical Mask - Internally Procured Brand 1	1	
Non-Medical Mask - Procured at Gas Station	1	
Non-Medical - Internally Procured Brand 2	1	
Non-Medical Mask - Provided by R&D Center	1	
Cotton, Flannel 100%	1	
	2	
	4	
Cotton T-shirt, 100%, Used	1	
	2	
	4	
Cotton (95%) + 5% spandex	1	
	2	
	4	
Cotton (60%) + 40% Polyester, Used Bedsheet	1	
	2	
	4	
Cotton (60%) + 40% Polyester, T-shirt	1	
	2	
	4	
Coffee Filter	1	
	2	

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Mask, Respirator & Filter Testing

The **Connecticut Center for Applied Separations Technologies (CCAST)** is offering mask, respirator, and filter testing services in Storrs, Connecticut. These services can evaluate the performance of PPE as well as other filter media intended for air and gas filtration.

Mask and respirator evaluation are performed using a sodium chloride (NaCl) or dioctyl phthalate (DOP) aerosol challenge test. This is based on the National Institute for Occupational Safety and Health (NIOSH) testing protocol. These tests provide quantitative comparison to N95 and other standards using the NIOSH standards.

The NaCl aerosol test uses a widely accepted method of challenging mask or respirators with NaCl aerosol and measuring particle retention and air flow resistance. The DOP test is used to evaluate particle retention and air flow resistance properties for a variety of filtration materials such as high efficiency particulate air (HEPA) filters.

CCAST offers these tests using a commercial automated filter tester (TSI Filter Tester Model 8130A) and an in-house built testing rig. The automated tester can test masks and filter media according to NIOSH protocols while our customized testing rig offers customized "rough cut" testing for large particle sizes (300 nm and above) following NIOSH procedure.

Our testing service pricing is provided in the table below, with NIOSH certified testing offered alongside customized testing services. Discounted rates are available for State of Connecticut Government Organizations and healthcare/first responder agencies. If you are interested our services, please contact Jeffrey McCutcheon, Executive Director of CCAST, at jeffrey.mccutcheon@uconn.edu. For more information on the other services provided by CCAST at UConn, please visit our website at https://ccast.uconn.edu/.

Test	Costs
With TSI Instrument	
Basic Material Test[1]	$515
NIOSH NaCl & DOP Test[2]	$2,766
Hourly Equipment Usage Cost[3]	$142
With Customized Material Tester	
NaCl & DOP Test[4]	$470

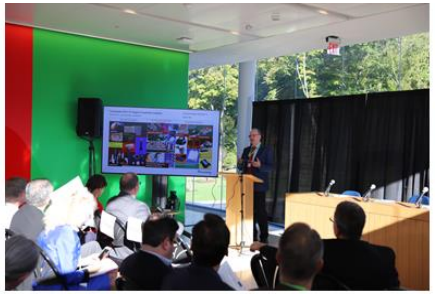
[1] Performing standard penetration NIOSH tests on one batch of sample material (useful for materials under development or with unknown efficiency)
[2] [illegible] standardized NIOSH test which requires 20 masks or 20 sample materials
[3] [illegible]th minimum of 8 hours & inclusive of labour

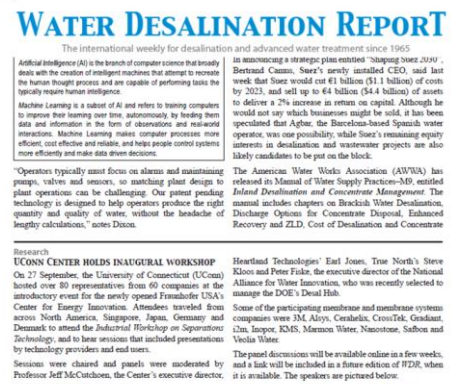
Outreach

Industrial Workshop on Separations Technology

UCONN TECH PARK

- We hosted a workshop on industrial separations technology on September 27, 2019
- 85 attendees from 60 separate businesses and entities
- Overwhelming support from attendees to have another workshop
- Featured speakers from startups to Fortune 500 companies
- 2nd workshop planned Fall 2023





DPH Connecticut Department of Public Health
Frosty Tech
Aqua Membranes
VIA SEPARATIONS
inopor
CrossTek MEMBRANE TECHNOLOGY
SAINT-GOBAIN
nerac
isle
Henkel
ECOLAB
HEARTLAND WATER TECHNOLOGY
suez Water Technologies & Solutions
GRADIANT
ExxonMobil
United Technologies
Hazen
KURITA
Pfizer
Booky Oren Global Water Technologies
ALSYS lix HEADING FOR THE FUTURE
Anfiro
evoqua WATER TECHNOLOGIES
BlueTech RESEARCH
EVONIK POWER TO CREATE
Consulate General of the Federal Republic of Germany Boston
BLACK & VEATCH
nel
SarBon Water Technology
i2m
OVIVO
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VEOLIA
TRUE NORTH VENTURE PARTNERS
PRAXAIR Making our planet more productive
P&G
MARMON
DUPONT
Next Rung Technology
3M
KOCH MEMBRANE SYSTEMS
abbvie
CLEAN MEMBRANES
ZwitterCo
nanostone water
AQUAPORIN

Past and Future Events / Outreach

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1. Invite-only Industrial Separations Workshop in Storrs: 85 attendees from 60 separate businesses and entities, September 2019
2. Upstream Oil & Gas Luncheon Roundtable in Houston, December 2019
3. WaterVent 2020 at Storrs CT, which is an international start up & investor matching forum, April 2020 (postponed indefinitely due to COVID-19 outbreak)
4. Membrane Innovations Luncheon invite only Roundtable in Boston, with BarClays & Marzarine, April 2020 (postponed due to COVID-19 outbreak)
5. 2nd Industrial Workshop on Separations Technology (April 17-18, Storrs, CT)
6. Connecticut Green Tech Venture Summit (planning post-COVID) planned with New England Water Environment Association

Work with us!

UCONN TECH PARK

Contact us:

Jeffrey McCutcheon
Director of the Connecticut Center for Applied Separations Technology
jeffrey.mccutcheon@uconn.edu

Visit our website:

www.ccast.uconn.edu

CAST
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Our Team

Our Funding

NAWI
National Alliance for Water Innovation

SPARK

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