



The Hydrogen Generation.

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# Development of Piper10N membranes and ionomers

Yushan Yan, Co-founder and CEO

May 2021

AMR 2021

ARPA-E 0002

# Project Summary



**Title:** Development of PiperION membranes and ionomers

**Award Number:** DE-AR0001149

**Funding:** \$4.4M including \$1M cost-share

**Duration:** 9/13/2019 – 9/12/2022; 36 months

**Performer:** Versogen LLC

# Project Objective

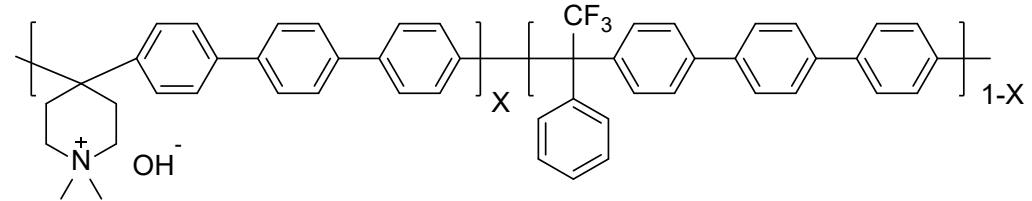
- Polymer production
  - 100L reactor (>5kg/batch)
- Membrane production
  - R2R manufacturing (~100m/hr)



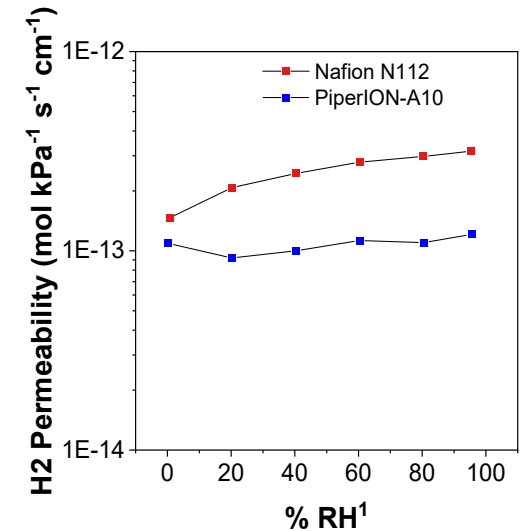
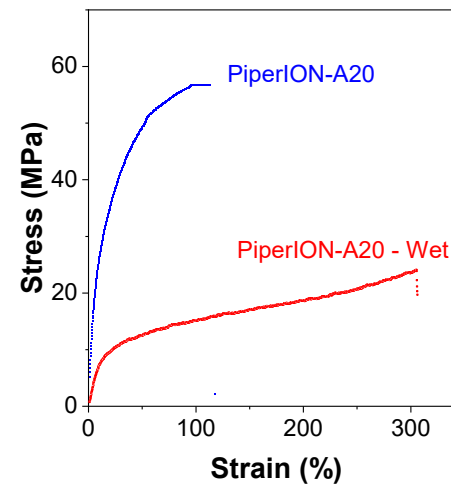
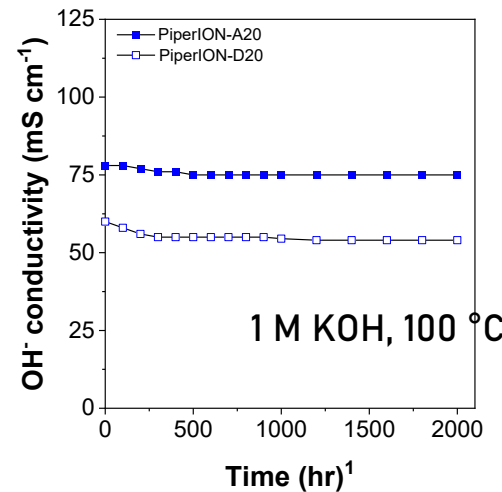
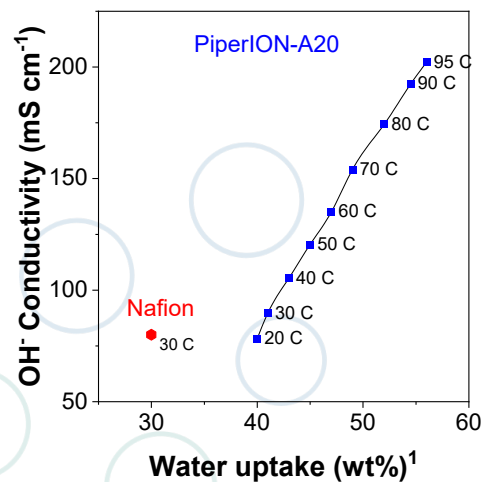
US010290890B2

(12) **United States Patent**  
Yan et al.

(10) **Patent No.:** US 10,290,890 B2  
(45) **Date of Patent:** May 14, 2019

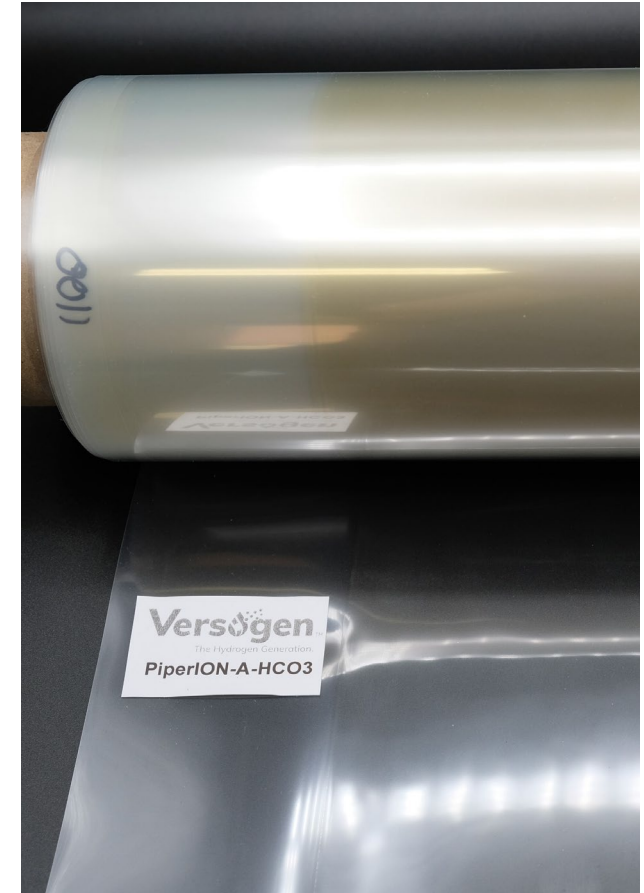


- Patent: Issued in the U.S. and being nationalized in 12 countries
- Highly conductive, alkaline stable, mechanically robust, low gas crossover



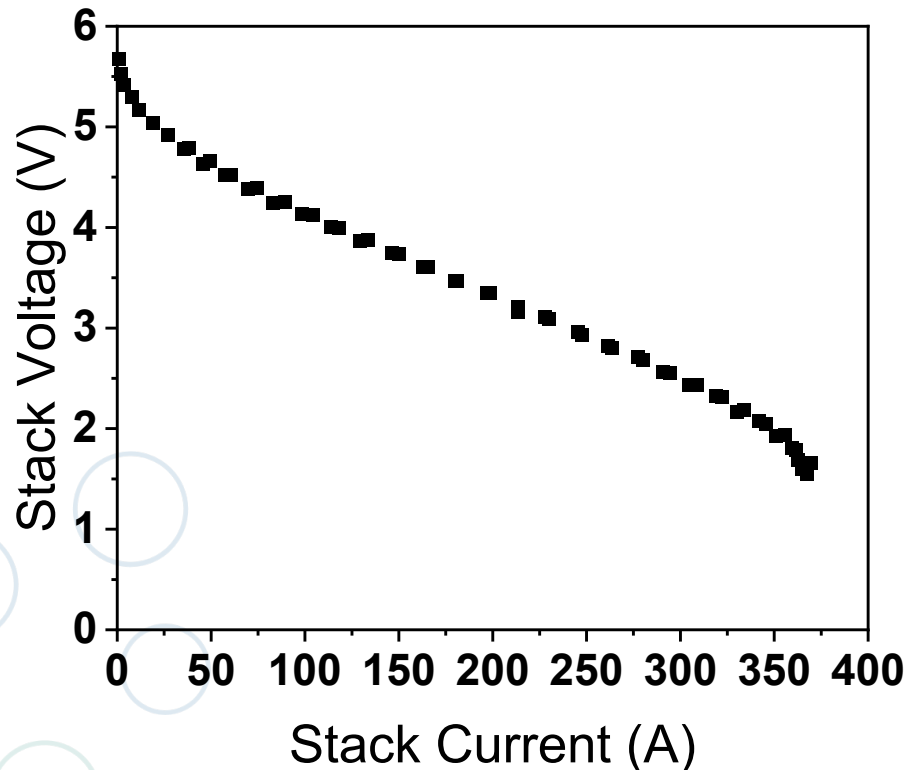
# Progress

- Polymer production
  - 100L reactor (>5kg/batch)
  - Demonstrated 2.0kg/batch
- Membrane production
  - High precision slot-die casting
  - R2R manufacturing (~100m/hr)

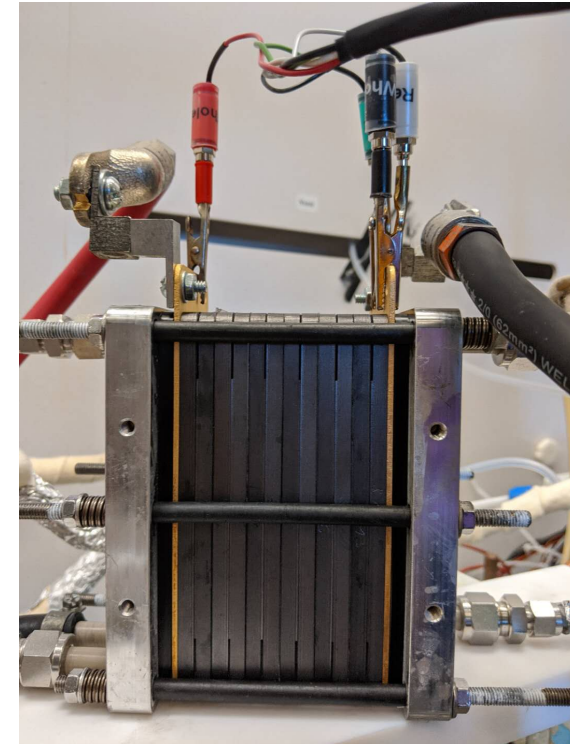


# Fuel Cells

World 1<sup>st</sup> AEMFC stack with 300cm<sup>2</sup> cells  
ARPA-E OPEN2018 project



World's 1<sup>st</sup> 75 W DAFC stack with 50cm<sup>2</sup> cells  
ARPA-E REFUEL project





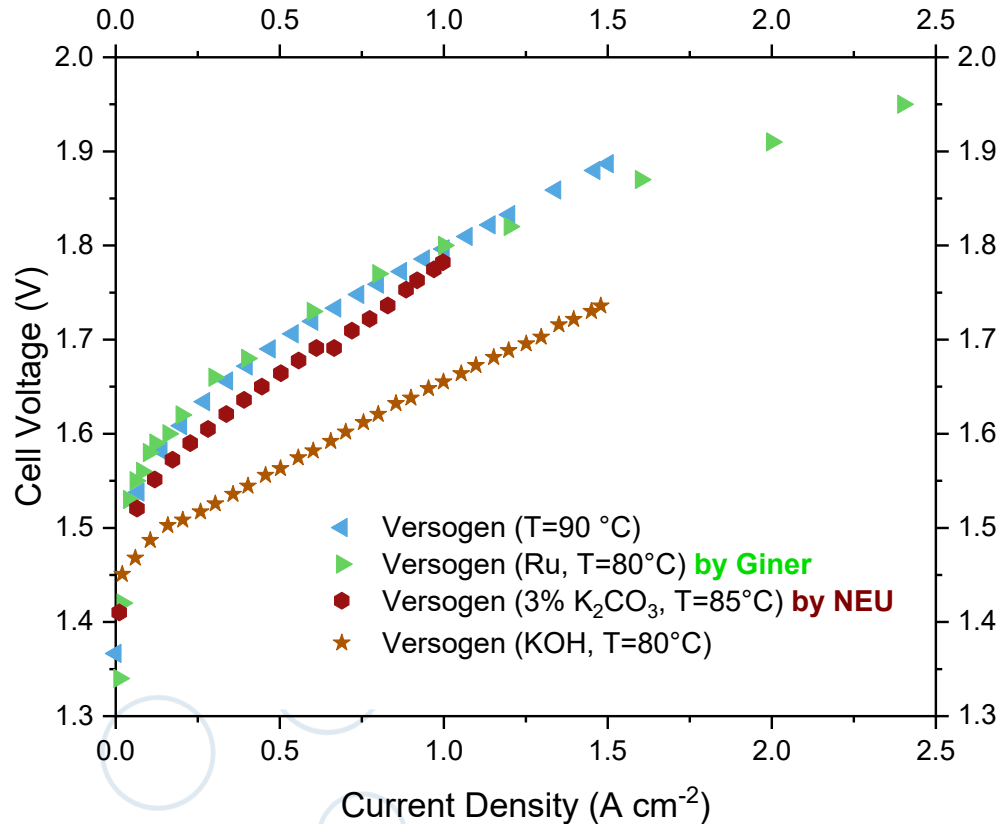
# CO<sub>2</sub> Separation/Direct Air Capture

World 1<sup>st</sup> 1kW equivalent electrochemical driven CO<sub>2</sub> separator to remove CO<sub>2</sub> from air  
ARPA-E OPEN2018 project



Sub ppm CO<sub>2</sub> one pass  
Compact  
Low-cost

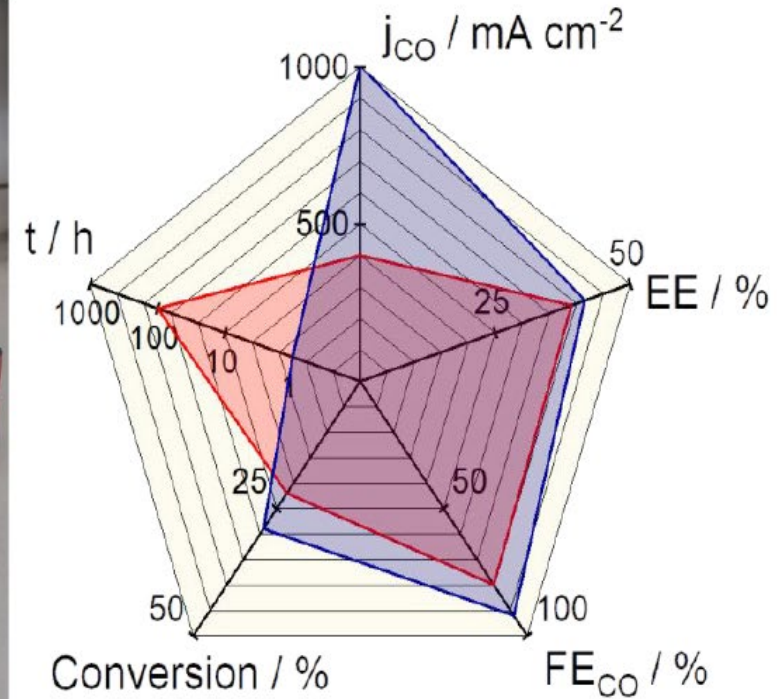
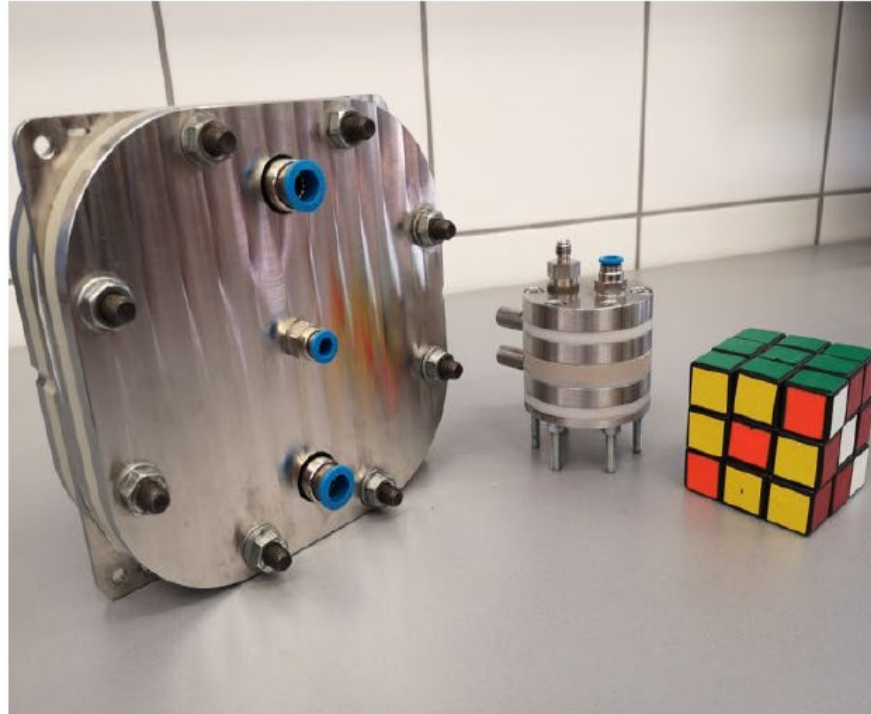
# AEM Water Electrolyzer



- Leading AEM electrolyzer performance  
    > 1 A cm<sup>-2</sup> at 1.8 V
- Pure water feed
- Anode feed
- Third party validation



# AEM CO2 Electrolyzer



- ThalesNano
  - $1 \text{ A cm}^{-2}$
  - $3.4 \text{ V}$

Energy and Environmental Science, 2020

# What We Do



- Versogen is a leader in**
- **AEMs**
  - **AEM water electrolyzers**

**AEM: anion exchange membrane**





# DELAWARE INNOVATION SPACE

AT THE EXPERIMENTAL STATION

Established 2017



Courtesy of Dr. Bill Provine, CEO of DIS

# The Experimental Station

## Bedrock of Innovation since 1903



### Small city of innovation & research

- 40+ buildings & 2.3m ft<sup>2</sup> of lab/office space
- Configured to support innovation from bench to scale-up to application development



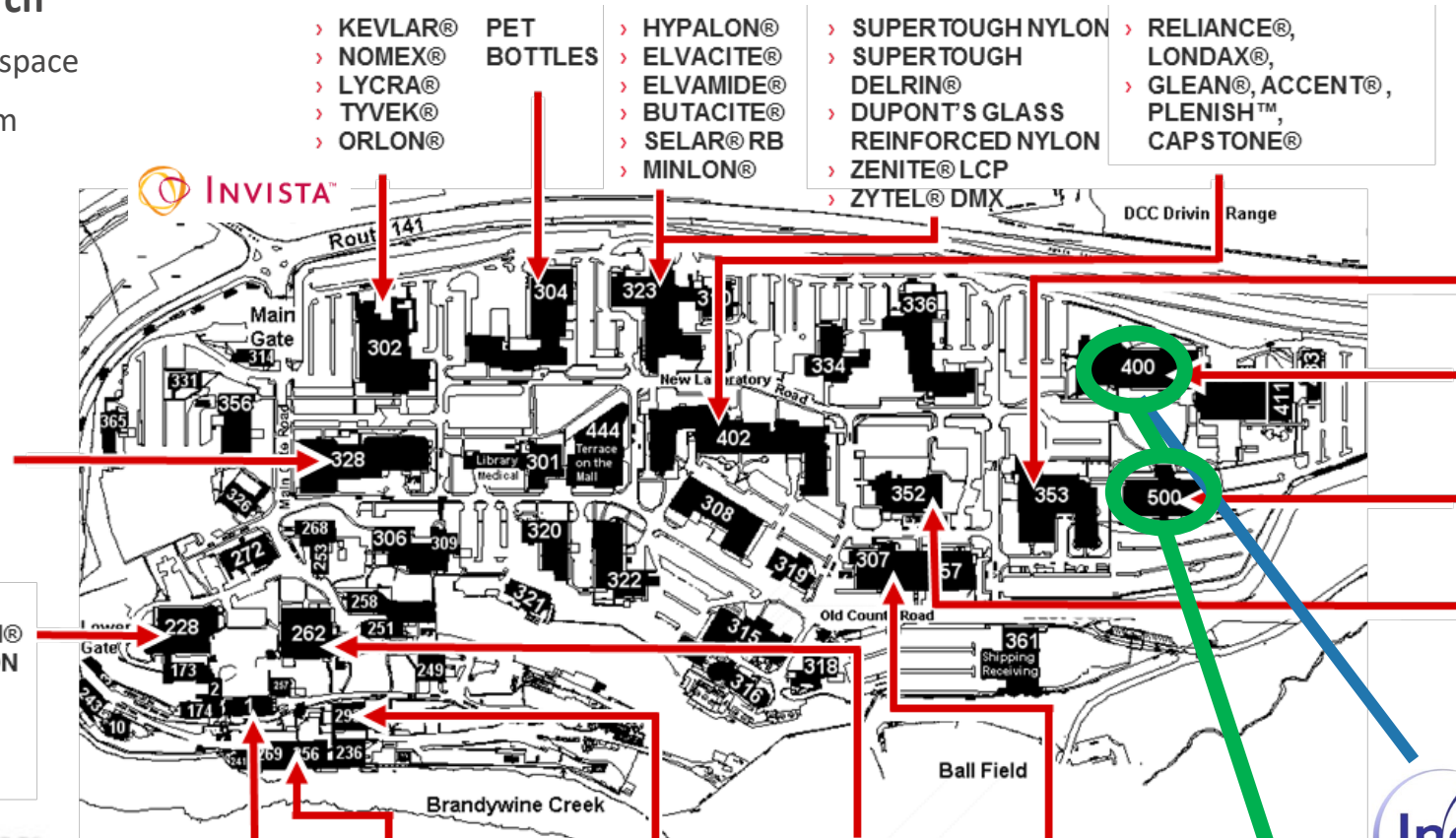
- > NYLON INTERMEDIATES
- > TiO<sub>2</sub> PROCESS
- > INK JET TECHNOLOGY
- > H<sub>2</sub>SO<sub>4</sub> PROCESS
- > NEW HARVEST™
- > SORONA®



- > NYLON, PVC, PET, NEOPRENE, DACRON®
- > TEFLON® DISPERSION
- > 2,4-D HERBICIDES
- > UREA HERBICIDES
- > COLLOIDAL SILICA
- > VAZO®



Frank Martinez



- > KEVLAR®
- > NOMEX®
- > LYCRA®
- > TYVEK®
- > ORLON®

- > PET BOTTLES

- > HYPALON®
- > ELVACITE®
- > ELVAMIDE®
- > BUTACITE®
- > SELAR® RB
- > MINLON®

- > SUPERTOUGH NYLON
- > SUPERTOUGH DELRIN®
- > DUPONT'S GLASS REINFORCED NYLON
- > ZENITE® LCP
- > ZYTEL® DMX

- > RELIANCE®, LONDAX®, GLEAN®, ACCENT®, PLENISH™, CAPSTONE®



- > NORDEL®
- > HYTREL®
- > VITON®
- > KALREZ®
- > VAMAC®
- > NOBEL PRIZE WORK CHARLIE PEDERSEN

- > COZAAR®
- > SUSTIVA®

SOLAMET® PV17

- > RISTON®
- > CYREL®



- > ALKYD RESINS
- > SURLYN®
- > TEFLON® FEP
- > ELVAX®, ELVALOY®
- > NAFION®, VESPEL®

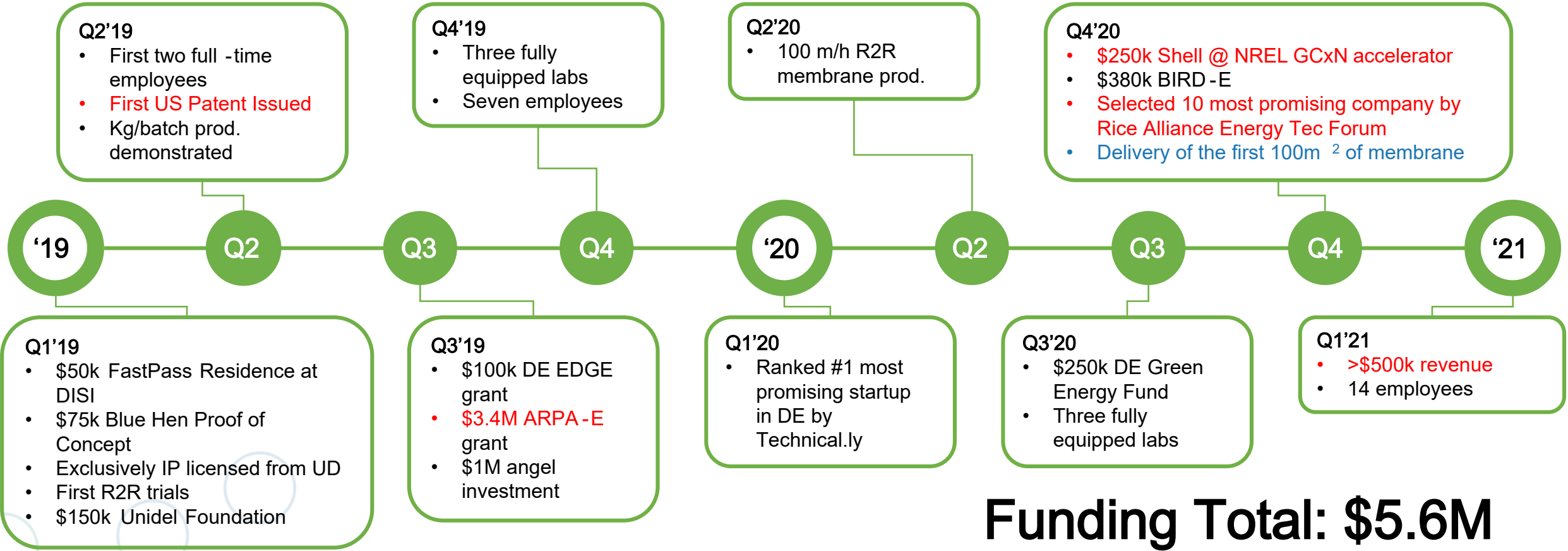
KAPTON®

- > NYLON AND POLYESTER
- > CFC ALTERNATIVES
- > QUALICON®
- > BAX®, RIBOPRINTER



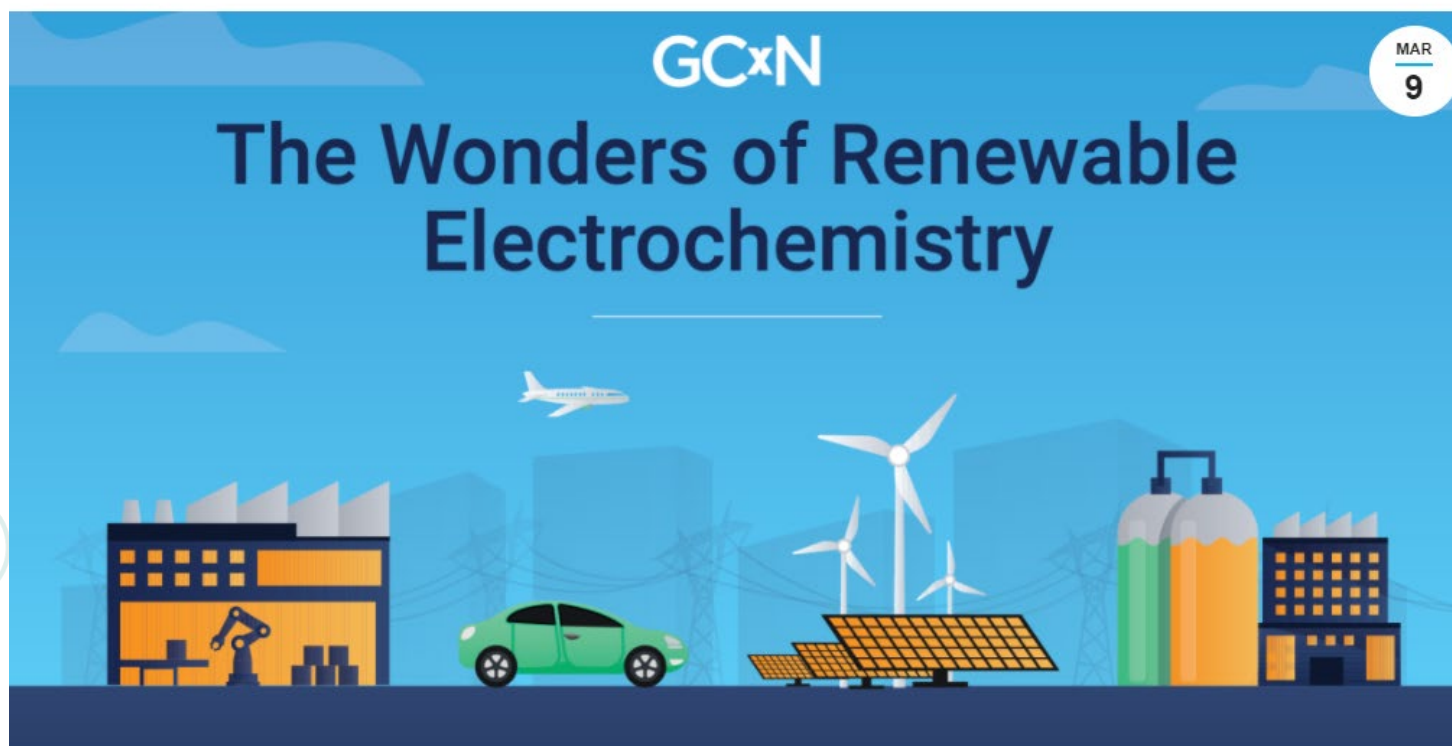


# Milestones Achieved



# Recent Grant from Shell

Shell GameChanger Accelerator powered by NREL selected Versogen as the top three most promising electrochemistry startups in 2021



Versogen “will help prove that electrochemistry technologies can replace carbon-intensive legacy processes. As renewable energy costs continue to drop, cross-industry initiatives and partnerships will prove that it's possible to cost-effectively scale these technology applications and achieve real-world impact”  
— Haibin Xu, Shell's GCxN program manager



# The Leadership Team



**Yushan Yan**  
CEO  
Ph.D., Caltech

- 20+ years of experience in fuel cells & electrolyzers
- 20+ issued US patents
- Multi-startups including nanoH2O that was acquired by LG Chemicals for +\$200m in 2014



**Santiago Rojas - Carbonell**  
COO  
Ph.D., MBA, UNM

- 11 years of experience in electrochemistry
- Breakthrough Energy Fellow Nominee
- Former CEO, Batterade



**Lan Wang**  
CTO  
Ph.D., UD

- 8 years of experience in organic/polymer chemistry
- Shell GameChanger Accelerator Entrepreneur



**Eric Rivera**  
Internal Consultant  
MBA, Yale

- Associate at Kearney
- Former Associate at Morgan Stanley



**Shimshon Gottesfeld**  
Board  
Ph.D., Technion

- 40+ years in fuel cells
- Former CTO multiple startups
- Father of modern PEM fuel cells



**Mark Mathias**  
Board  
Ph.D., UW-Madison

- 20+ years of experience in fuel cell engineering
- Former Director of GM's Fuel Cell R&D



**Producing green hydrogen at  
scale—reliably and affordably.**

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**Just add water.**



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