IONOMR INNOVATIONS

PEMION® FUEL CELL OFFERINGS

Proton Exchange Membranes & Polymers

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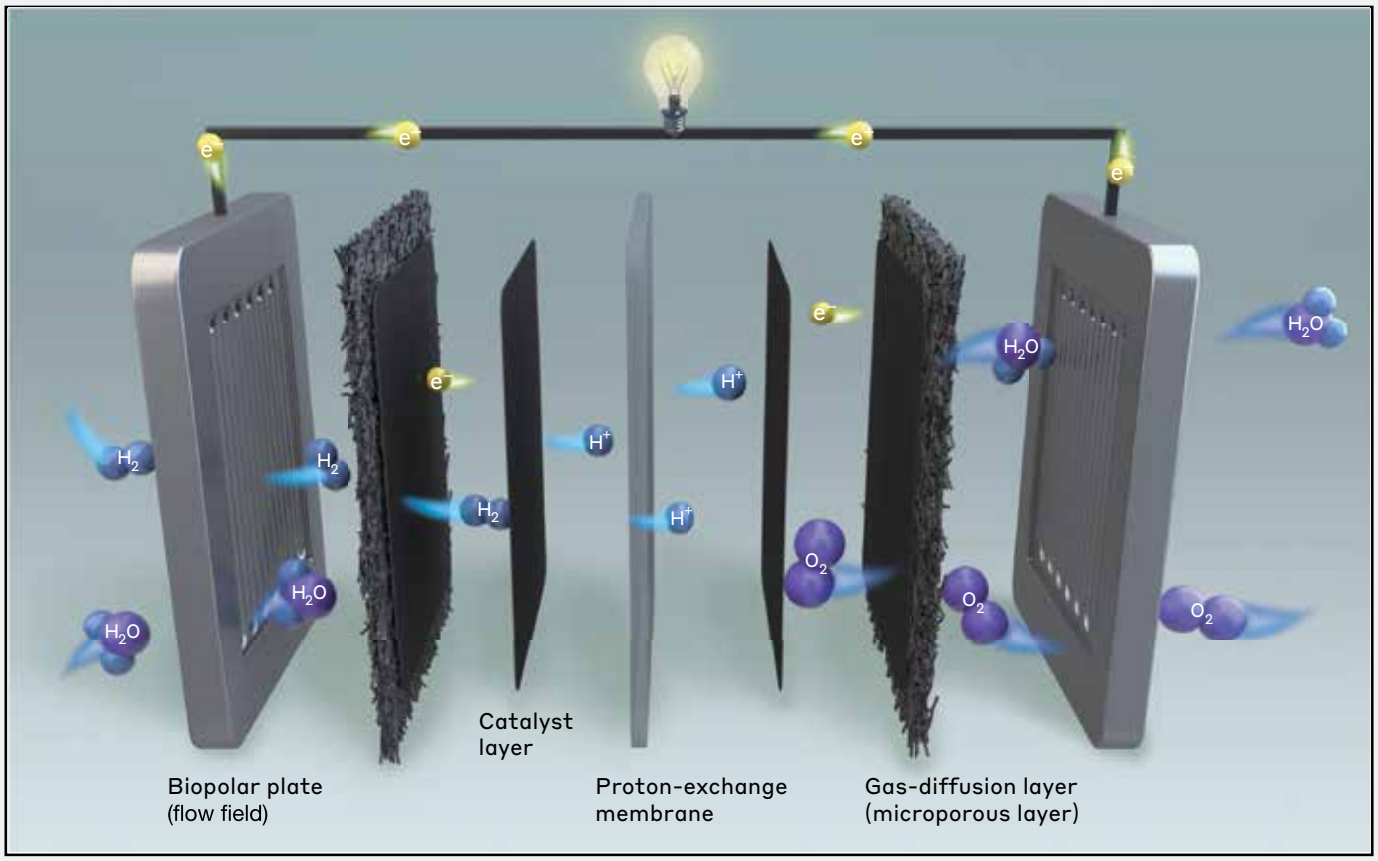

PRODUCT INFORMATION

Ionomr designs and manufactures breakthrough advanced ion-exchange materials to enable rapid growth of the hydrogen economy. Ionomr's advanced proton exchange membranes and polymers are a breakthrough in material science with a uniquely stable hydrocarbon structure, making it the only product of its kind.

Pemion® represents a fundamental shift in the approach to proton exchange technology through its migration from perfluorosulfonic acid (PFSA) chemistry to hydrocarbon materials, providing substantially lower gas crossover and addressing PFAS-related environmental and end-of-life issues at considerably higher performance.

Pemion® enables major efficiency and performance gains, while aligning with needs of the renewable economy. It is the only environmentally friendly option on the market.

Produced on reinforcement at thicknesses competitive to leading PFSA membranes in the industry, Pemion® provides leading conductance and durability without compromise.

For use in fuel cell applications including heavy duty transport & automotive, hydrocarbon based Pemion® membrane and ionomer offers several advantages over incumbent perfluorinated materials to increase the efficiency, versatility, and lifetime of fuel cell engines, including: lower gas crossover for increases to range and the lifetimes of both membrane and catalyst; higher proton conductivity for additional gains to efficiency and power density; significantly greater temperature stability to enable many system design benefits; & a substantially easier end-of-life precious metal recovery, reducing costs & eliminating the environmental concerns specific to acidic perfluorinated compounds.

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PEMION® REINFORCED MEMBRANES — PRE-PRODUCTION

Thickness and Basis Weight Properties

Membrane Type	Typical Thickness (µm)		Basis weight (g/m²)
PF1-HLF8-15-X	15		18
Physical Properties[1]	**MD**	**TD**	**Test Method**
Tensile Strength, MPa	55 - 60	50 - 60	ASTM 638
Young's Modulus, MPa	650 - 800	600 - 700	ASTM 638
Elongation to break	50 - 70%	55 - 75%	ASTM 638
Hydrolytic Properties[2]			
Water Uptake, wt%:			ASTM D570
to water soaked, 22 °C	95 - 140%		
to water soaked, 80 °C	150 - 190%		
Linear Expansion			ASTM D570
to water soaked, 22 °C	< 7%		
to water soaked, 80 °C	< 11%		
Z-Expansion			ASTM D570
to water soaked, 22 °C	< 140%		
to water soaked, 80 °C	< 200%		
Electrochemical Properties[3]			
Area Resistance	< 45 mΩ · cm²		
Hydrogen Crossover Current	< 2.0 mA/cm²		Atmospheric
	< 8.0 mA/cm²		150 kPa gauge
Measured Ex-situ Conductivity[5]	**In-plane**	**Through-plane**	
PF1-HLF8-15-X	> 90 mS/cm	> 80 mS/cm	
Reference:	**In-plane**	**Through-plane**	
NR211	60 ± 5 mS/cm	60 ± 5 mS/cm	
15 µm Reinforced PFSA	65 ± 5 mS/cm	44 ± 4 mS/cm	
Other Properties			
Specific Gravity	1.3 g/cm³		
Maximum Processing Temperature	160 °C		
Polymer Tg	> 300 °C		

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PEMION® REINFORCED MEMBRANES — PRE-PRODUCTION

Thickness and Basis Weight Properties

Membrane Type	Typical Thickness (µm)		Basis weight (g/m²)
PF1-HLF9-15-X	15		18
Physical Properties[1]	**MD**	**TD**	**Test Method**
Tensile Strength, MPa	55 - 60	50 - 60	ASTM 638
Young's Modulus, MPa	650 - 800	600 - 700	ASTM 638
Elongation to break	50 - 70%	55 - 75%	ASTM 638
Hydrolytic Properties[2]			
Water Uptake, wt%:			ASTM D570
to water soaked, 22 °C	110 - 160%		
to water soaked, 80 °C	175 - 225%		
Linear Expansion			ASTM D570
to water soaked, 22 °C	< 8%		
to water soaked, 80 °C	< 11%		
Z-Expansion			ASTM D570
to water soaked, 22 °C	< 150%		
to water soaked, 80 °C	< 250%		
Electrochemical Properties[3]			
Area Resistance	< 45 mΩ · cm²		
Hydrogen Crossover Current	< 2.0 mA/cm²		Atmospheric
	< 8.0 mA/cm²		150 kPa gauge
Measured Ex-situ Conductivity[5]	**In-plane**	**Through-plane**	
PF1-HLF9-15-X	> 95 mS/cm	> 85 mS/cm	
Reference:	**In-plane**	**Through-plane**	
NR211	60 ± 5 mS/cm	60 ± 5 mS/cm	
15 µm Reinforced PFSA	65 ± 5 mS/cm	44 ± 4 mS/cm	
Other Properties			
Specific Gravity	1.3 g/cm³		
Maximum Processing Temperature	160 °C		
Polymer Tg	> 300 °C		

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PEMION® IONOMERS: DRY RESIN

Ionomer Type	IEC[1] (meq/g)	EW (g/eq.)	Density (g/cm³)	Solubility[2]
PP1-HNN9-00	3.2 - 3.5	285 - 310	1.2	Alcohols and alcohol/water mixtures
PP1-HNN8-00	2.8 - 3.1	320 - 360	1.2	Alcohols and alcohol/water mixtures

Ionomer Type	IEC[1] (meq/g)	EW (g/eq.)	Density (g/cm³)	Solubility
Long side-chain PFSA	0.9 - 1.0	1000 - 1,100	2.0	Alcohols and alcohol/water mixtures
Short side-chain PFSA	1.1 - 1.3	770 - 910	2.0	Alcohols and alcohol/water mixtures

Notes

1 IEC of polymer powder measured as-received.
2 Refer to FM-7013 for additional information.

These are prototype materials only intended to be used for early development activities and not intended for production items. Product information is to be used as a guide only, subject to change at any time.

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1 Measured at 22 °C in atmospheric condition
2 Measured from dried to equilibrated in DI water at 22 °C
3 Measured at 80 °C via chronoamperometry, water-wet (100% RH)
4 Electrochemical properties reported for unreinforced membranes based on in-plane conductivity measurments by EIS. NR211 & Pemion measured under identical conditions.
5 Membranes measured equilibrated in DI water at 22 °C

Document ID	Title
FM-6027-C	Properties of Pemion® Hydrocarbon Proton Exchange Membrane

Revision	Prepared By	Approved By	Effective Date
C	Omid Toussi	Ben Britton	Sept. 24, 2021

This document is reviewed to ensure its continuing relevance to the systems and process that it describes.

REVISION HISTORY:

Revision	Date	Description of Changes	Approved By
A	March 12, 2021	Initial Draft	Ben Britton
B	July 26, 2021	Added new picture, PF1-HLF9-15-X	Ben Britton
C	Sept. 24, 2021	Added PF1-HLF8-15-X	Ben Britton

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