Design and Development of High-Performance Polymer Fuel Cell Membranes

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GE imagination at work

Approach

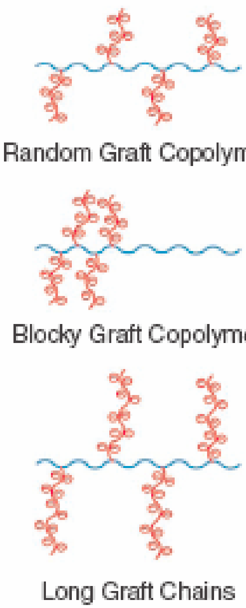
5-Year, $2 Million Program for the Development of High Temperature, Low Relative Humidity Polymer Membranes

GE Global Research
World Leader in High Performance Polymers

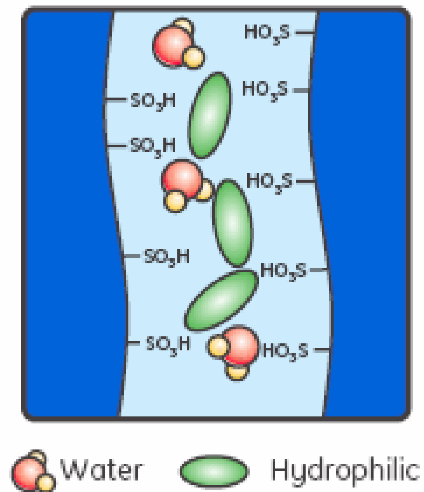
Program Rationale

Current PEM materials do not meet the performance requirements necessary for high temperature, low relative humidity operation of fuel cells

Unique Polymer Architectures



Hydrophilic Organic Additives

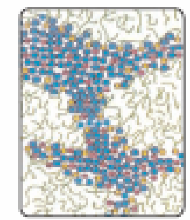


Technology Innovations

Design, synthesis, and characterization of novel ionomeric films with unique polymer architectures and hydrophilic fillers.

Program Deliverables

High performance durable membrane films
- Conductivity >0.1 S/cm at 120°C and 50% RH
- Chemical and mechanical stability



Anticipated Program Benefits

- Increased scientific knowledge to improve future generation of PEMs
- U.S. leadership in automotive fuel cell development and manufacturing
- Reduced environmental pollution
- Lower reliance on petroleum imports

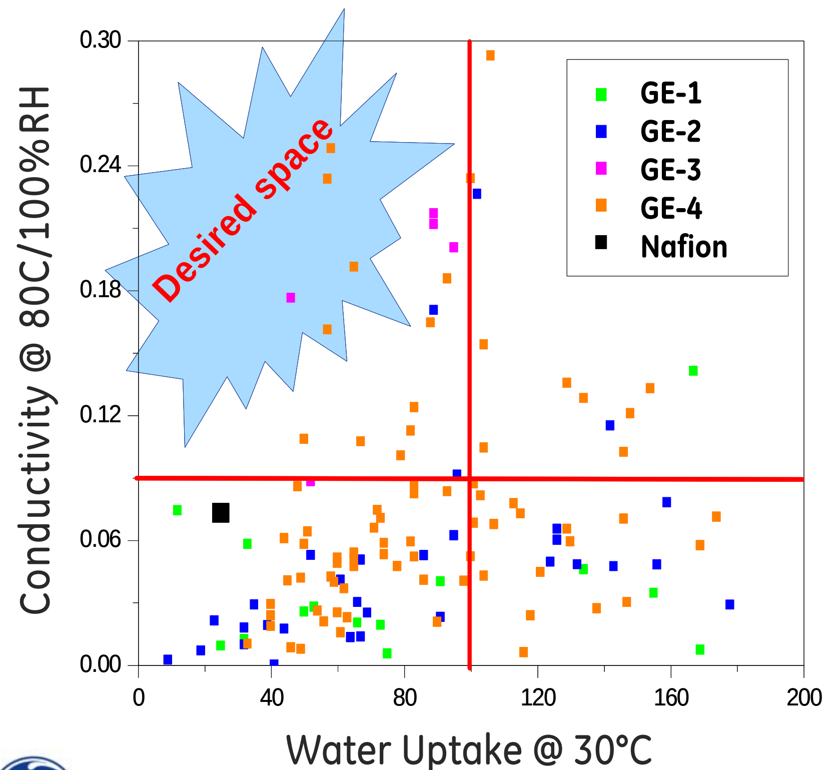
GE Progress in New Membrane Development

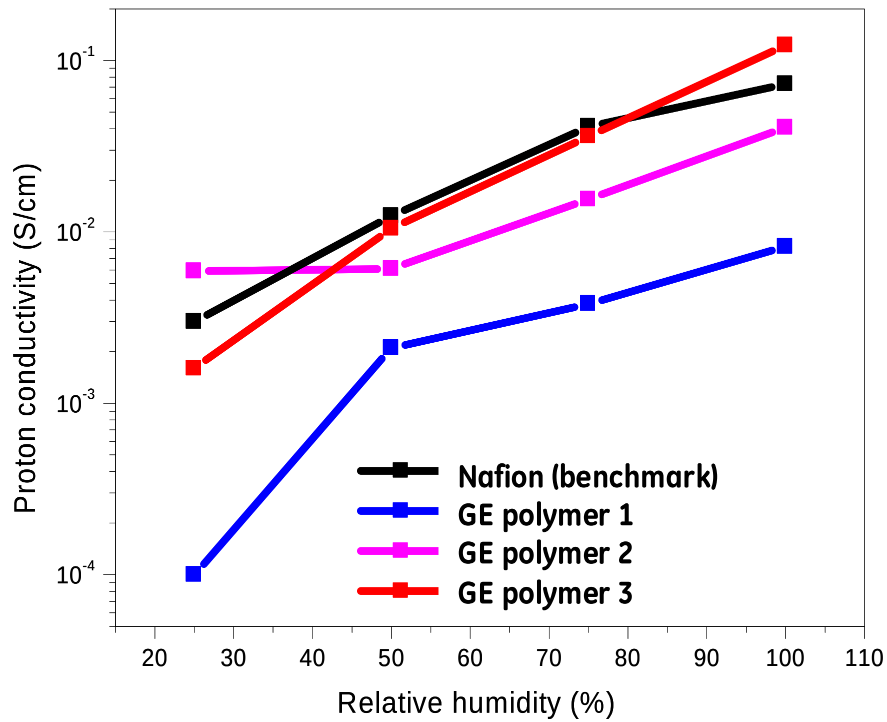
GE 1st Generation
Random copolymers

GE 2nd Generation
Block copolymers

New Concepts
Unique polymer architectures

Over 150 new materials and compositions





GE Material Design

Thermally stable aromatic hydrocarbon polymers

- Build on GE's strength and expertise in engineering polymers

No perfluorinated polymers

- Lower cost
- Benefit environment

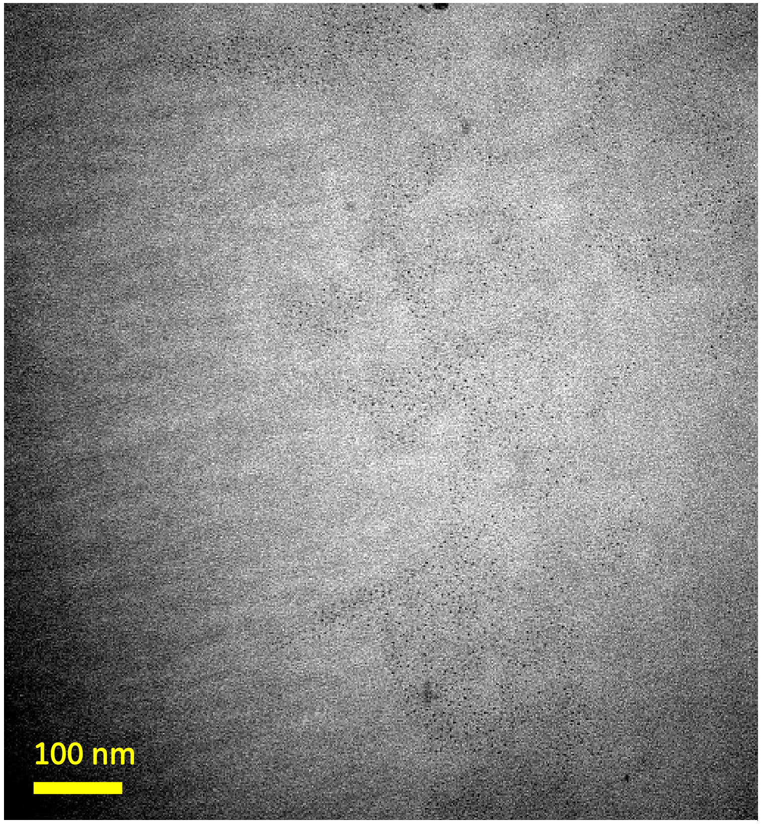
Balance proton conductivity, water uptake, and mechanical properties via material design

- Direct polymer synthesis from monomer buiding blocks
- Functionalization with acidic/basic groups, additives
- Control of membrane morphology through polymer architecture

Polymer Architecture —determines→ **Membrane Morphology** —controls→ **Balance of proton conductivity and water uptake**

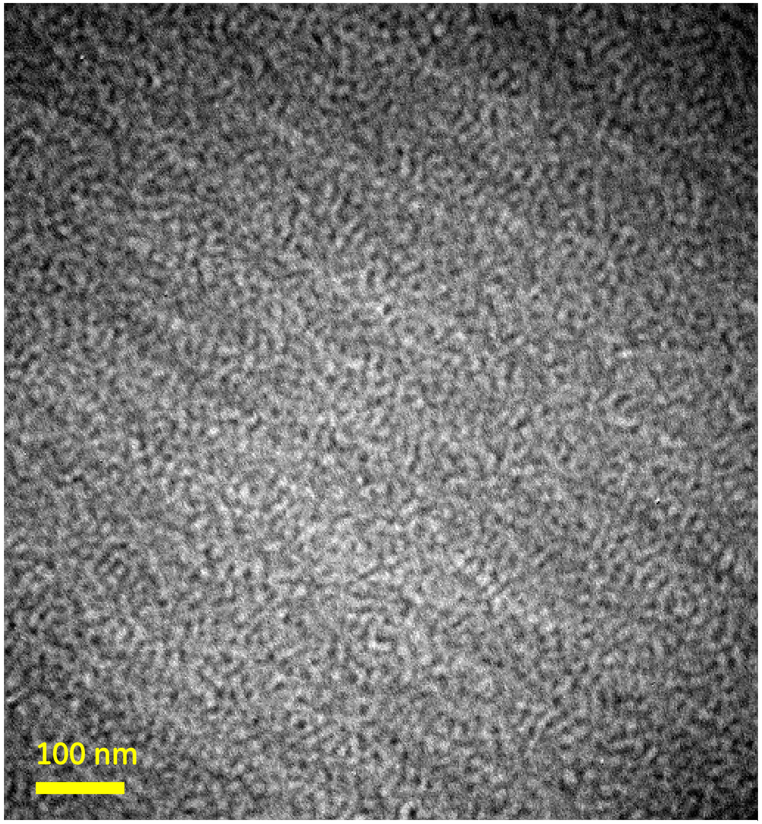
Increasing Proton Conductivity

More open, connected membrane morphology → Higher proton conductivity



Random Copolymer

$\sigma \sim 10^{-3}$ S/cm (50 %RH)



Block Copolymer

$\sigma \sim 10^{-2}$ S/cm (50 %RH)

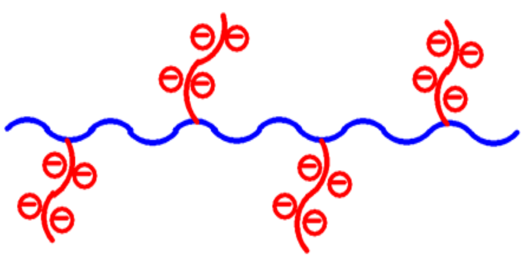
Improving Performance, Cost, and Durability

Optimize membrane morphology: New concepts in polymer chain design

- Promote phase separation and ionic aggregation
- Higher proton conductivity with good balance of water uptake properties

- **Design: Graft copolymers**
  - Higher concentration of acidic groups on pendant chains
  - More efficient proton conductivity due to enhanced phase separation
  - Neutral polymer backbone provides better mechanical support when hydrated
- **Materials: Aromatic hydrocarbon polymers**
  - Unprecedented architectures in aromatic hydrocarbon polymers
  - Synthesis is non-trivial

- **Current status:**
  - Several synthetic approaches developed
  - Synthesis in progress



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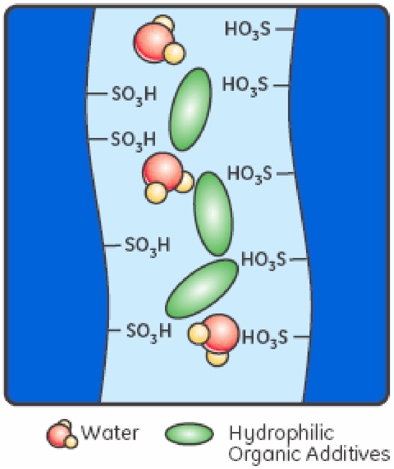
Improving High Temperature, Low RH Performance

Additives to maintain high T, low RH performance:

- Water retention at low RH
- Water supplement/replacement (with participation in proton conduction)

- **Design: Additives**
  - Hydrophilic/hygroscopic
  - Thermally, hydrolytically stable
  - May participate in proton conduction
- **Materials: Organic compounds**
  - Simple and versatile synthesis



- **Current status**
  - Designed and synthesized several additive candidates

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Future Work

Materials synthesis

- Demonstrate feasibility of synthetic approaches to making new aromatic hydrocarbon polymer structures
- Design, synthesize, and characterize new monomers, polymers, and hydrophilic organic additives

Membrane evaluation

- Evaluate membrane properties (proton conductivity, water uptake, mechanical properties)
- Study membrane morphology to understand the effect of variations in polymer architecture on membrane performance