Complex Coolant Fluid for PEM Fuel Cell Systems

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Project ID #
FCP 6

Overview

Timeline

For SBIR Phase I & II Project

- Project start date: 07-14-2004 (Phase I)
- Project end date: 07-12-2007
- Percent complete: 83% (Phase II)

Barriers

- Barriers addressed
  - System thermal management

Budget

- Total project funding
  - DOE share: $847K (Phase I & II)
  - Contractor share: $100K (to Lehigh Univ.)
- Funding received in FY06: $415K (Phase II)
- Funding for FY07: $242K (expected)

Partners

- Interactions/ collaborations:

Lehigh University (Subcontractor)
Penn State University (Subcontractor)
Plug Power (Supporting Activities)

Objectives

Overall

To develop and validate a fuel cell coolant based on glycol/water mixtures and an additive package (with corrosion inhibitors and nanoparticles) that will exhibit less than 2.0 μS/cm of electrical conductivity for more than 3000 hours in an actual PEM Fuel Cell System. Demonstrate the potential for commercializing such a coolant at a price that is acceptable for a majority of fuel cell applications (i.e., < $8.0/gallon).

2006

Optimize nanoparticle chemistry (size, surface charge, stability)
Optimize corrosion inhibitors (type, concentration, combination)
Long-term tests (1000 hours tests)

2007

Optimize nanoparticle chemistry (dispersion and thermal stability)
Long-term tests (3000 hours)
Tests in Real Fuel Cells (3000 hours)

Key Technical and Economic Questions to be Answered

- **How is the electrical conductivity of the coolant related to the properties of the additives?**
- **Will the additives influence the heat transfer and pressure drop characteristics of the coolant?**
- **Is the coolant and its additives compatible with the fuel cell cooling system components?**
- **What is the raw material and production cost for the proposed ‘Complex Coolant Fluid’?**

Approach

- **The proposed Complex Coolant Fluid consists of a base compound (glycol/water mixtures) and an additive package.**

- **The base compound mixture has a freezing point less than –40°C, is non-flammable, and can be used at temperatures up to 122°C.**

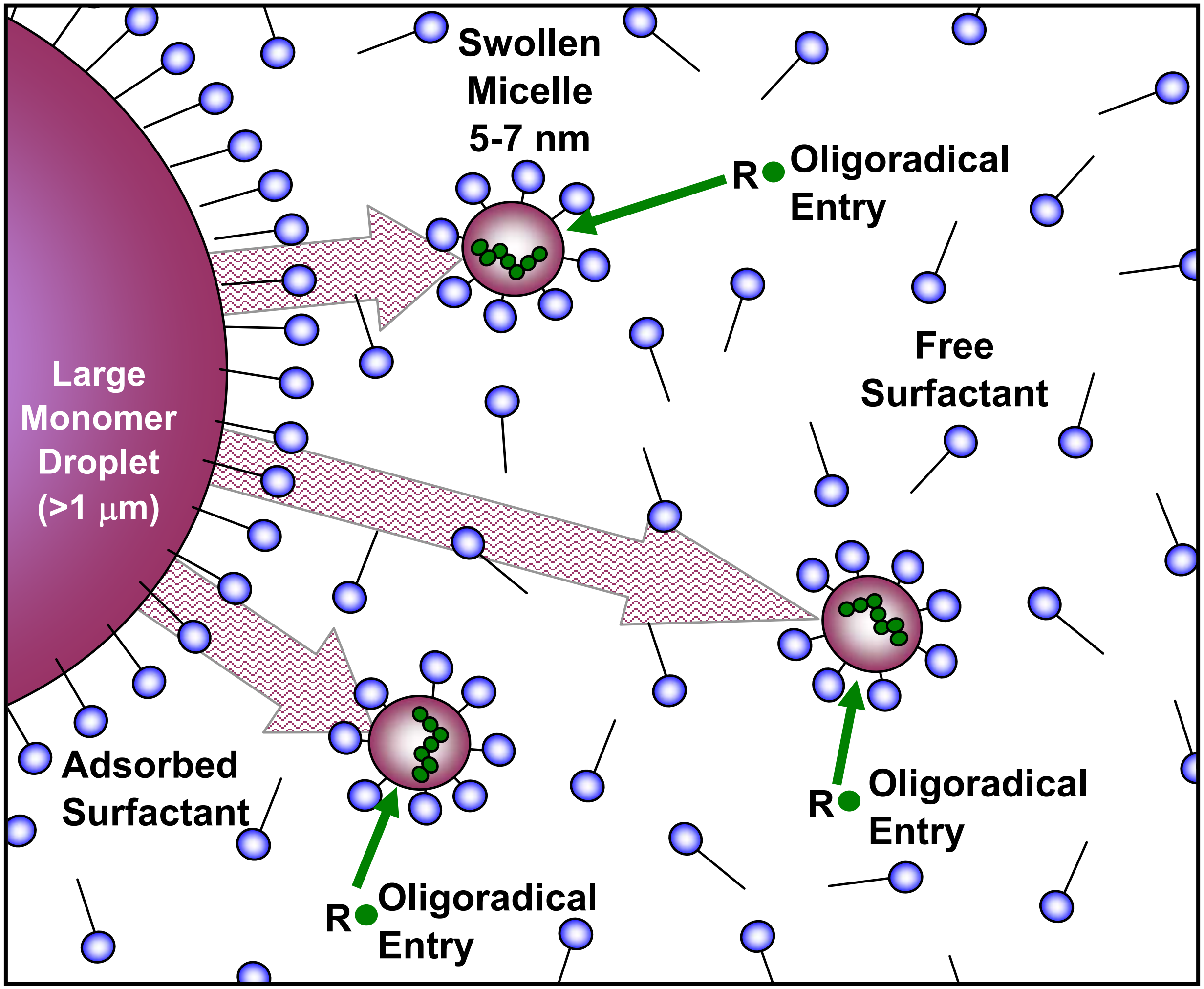
- **The additive package consists of non-ionic corrosion inhibitors and ion-suppressing compounds (ion-exchange nanoparticles) to maintain the electrical conductivity of the coolant at a low level.**

Technical Approach in Phase I

- **Development of the nanoparticles by emulsion polymerization**
  - Effect of preparation recipe on the electrical conductivity of the final coolant formulation
  - Study dispersion behavior in the coolant

- **Building a dynamic test loop (4 L)**
  - Short-term and long-term tests (electrical cond. vs. time and pH vs. time)

Emulsion Polymerization



Technical Approach in Phase II

- **Optimization of the ion-exchange nanoparticles**
  - Effect of preparation recipe on the particle size, surface charge and dispersion behavior
  - Study dispersion behavior in the final coolant formulation

- **Short-term and long-term tests**
  - Electrical conductivity and pH vs. time

Characterization of Nanoparticles

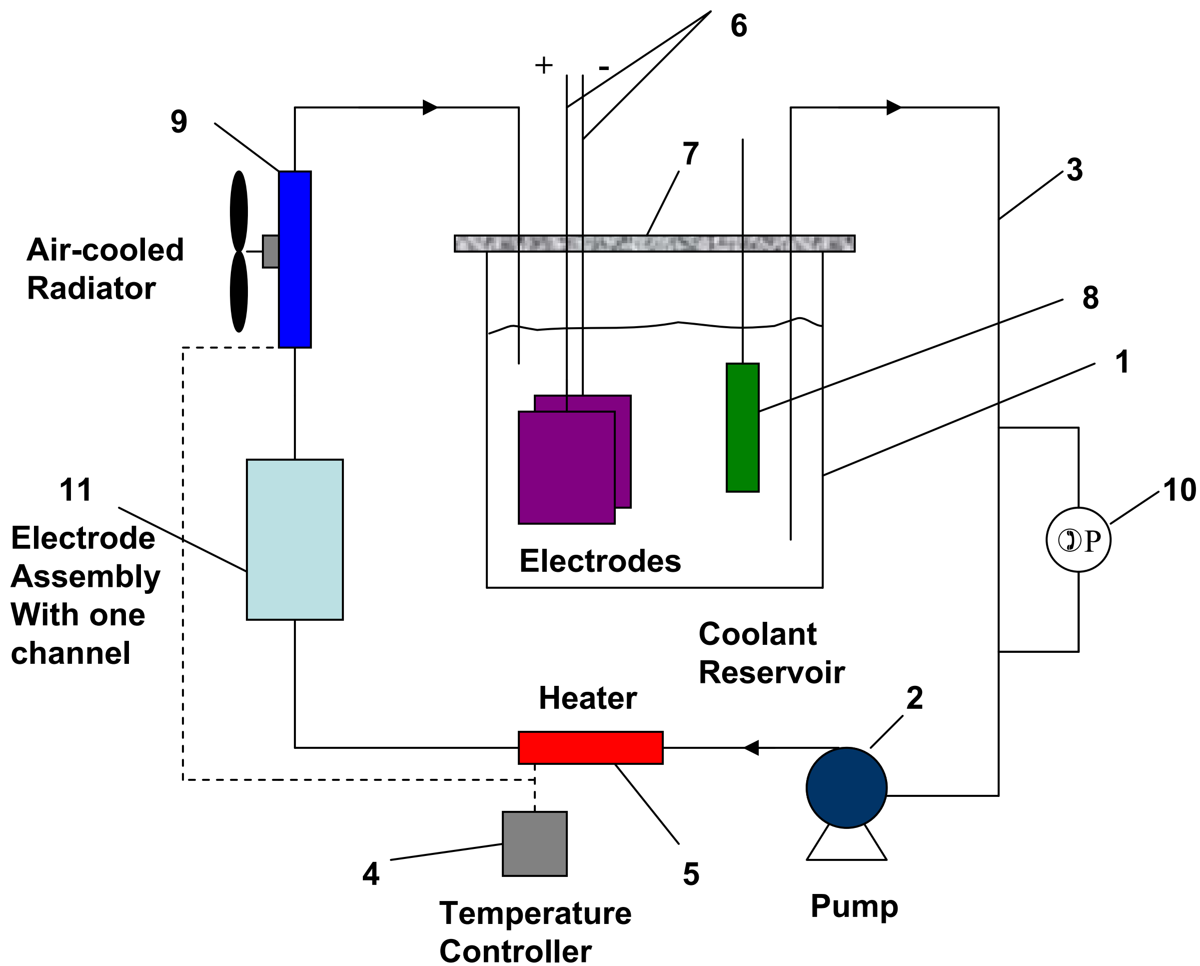
- Conversion
  - Gravimetric Analysis

- Particle Size
  - Dynamic Light Scattering (Nicomp)
  - Capillary Hydrodynamic Fractionation
  - TEM

- Cleaning
  - Serum replacement
  - Ion exchange resin (mixed bed)

- Surface Charge Density
  - Conductometric titration

Dynamic Test Loop for Coolant Testing



1: Reservoir

2: Pump

3: Piping

4: Temp. Controller

5: Heater

6: Electrodes

7: Reservoir Head

8: Probes

9: Radiator

10: Diff. Pressure Gauge

11: Electrode assembly

Dynamic Test Loop for Coolant Testing

Simulation of one channel electrode assembly

pH probe

Heater

Reservoir for the coolant

Cond. probe

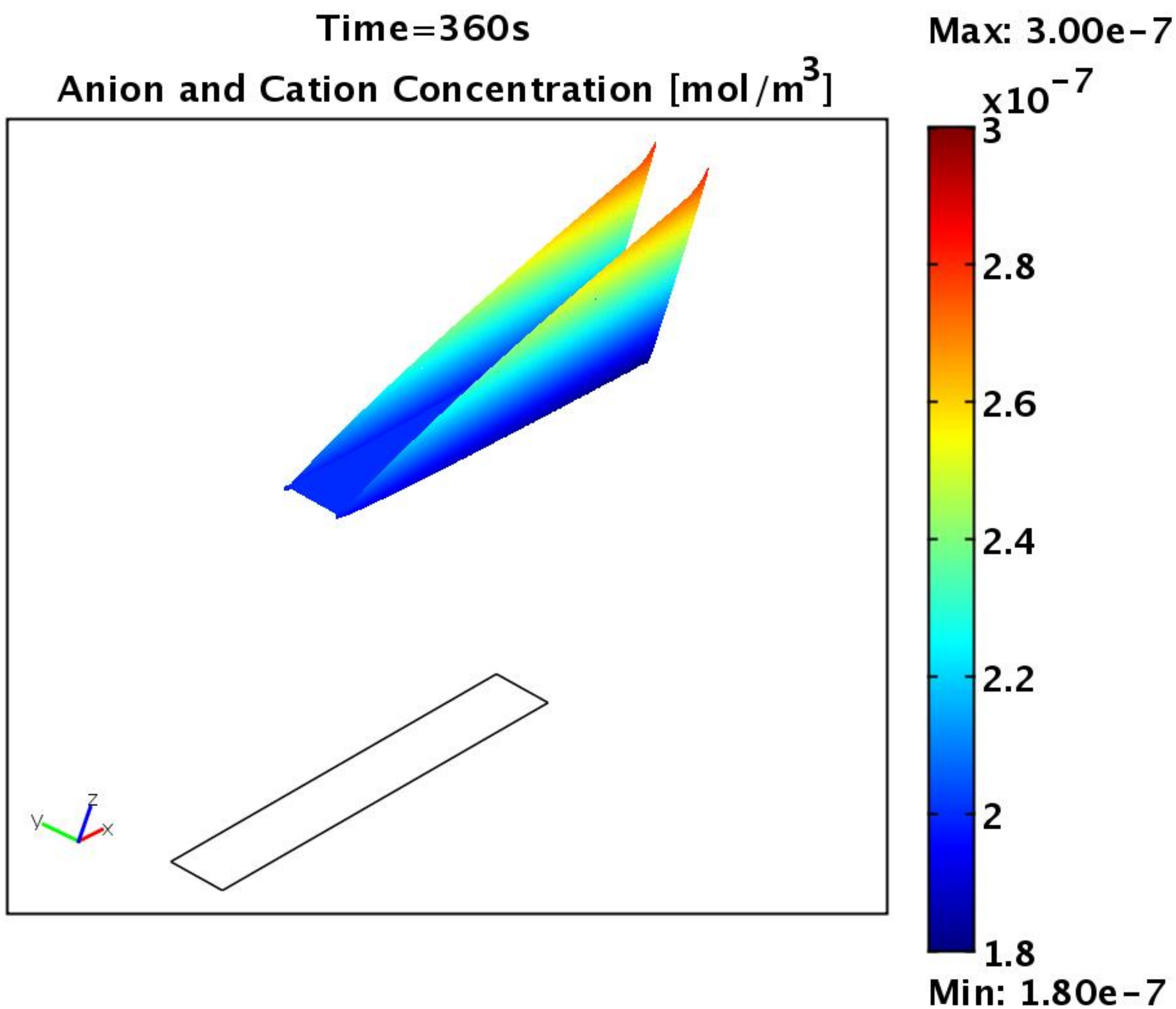
Radiator

Results from Phase II

Table 1: **Particle size and surface charge for both anionic and cationic nanoparticles**

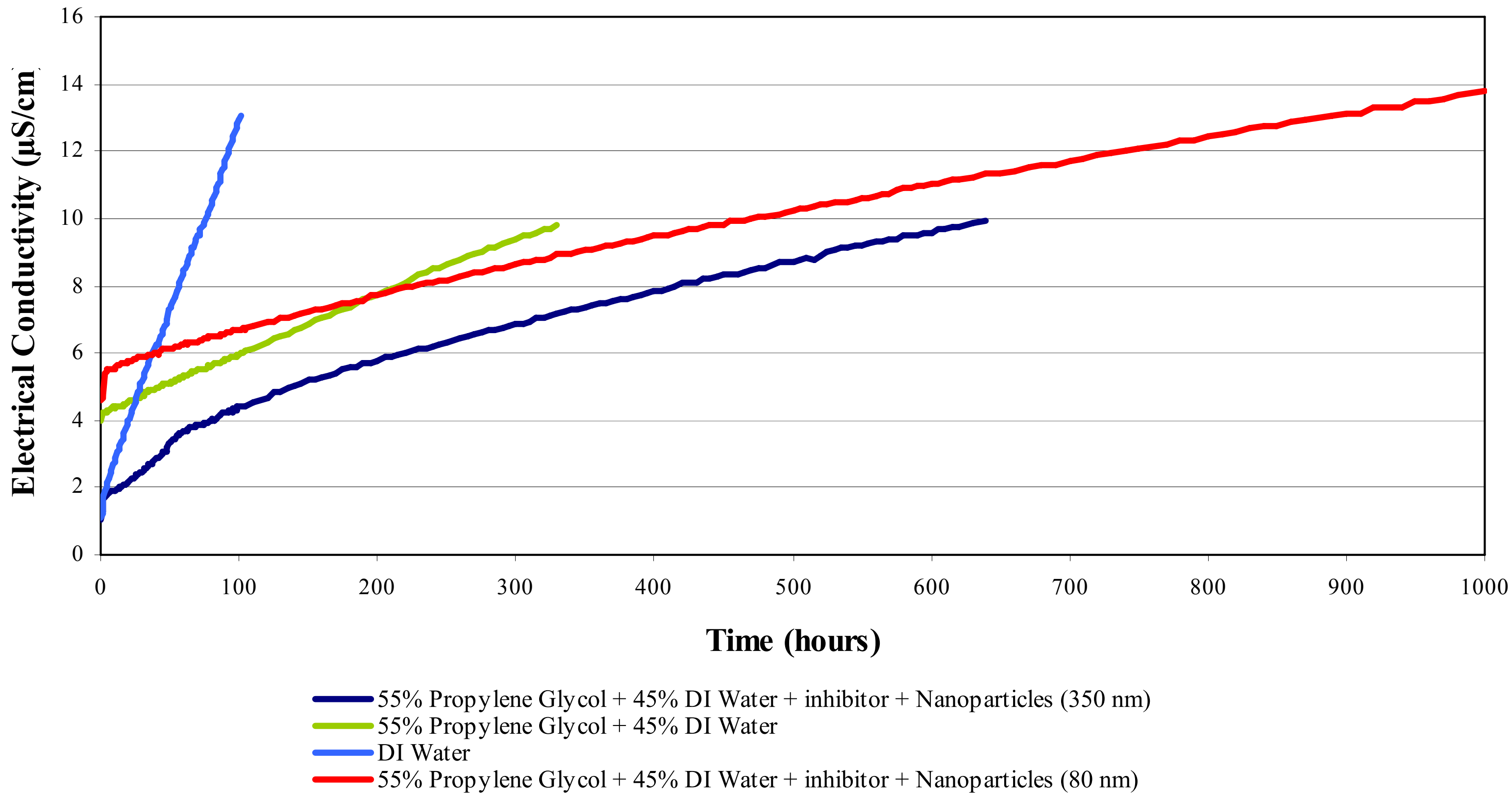
Nanoparticles	Average Size (nm)	Surface Charge by Titration (μeq/g)
ANPS 30403	80	454
CATPS 60211		743
CATPS 6	350	956
ANPS 6		28

Results from Phase II



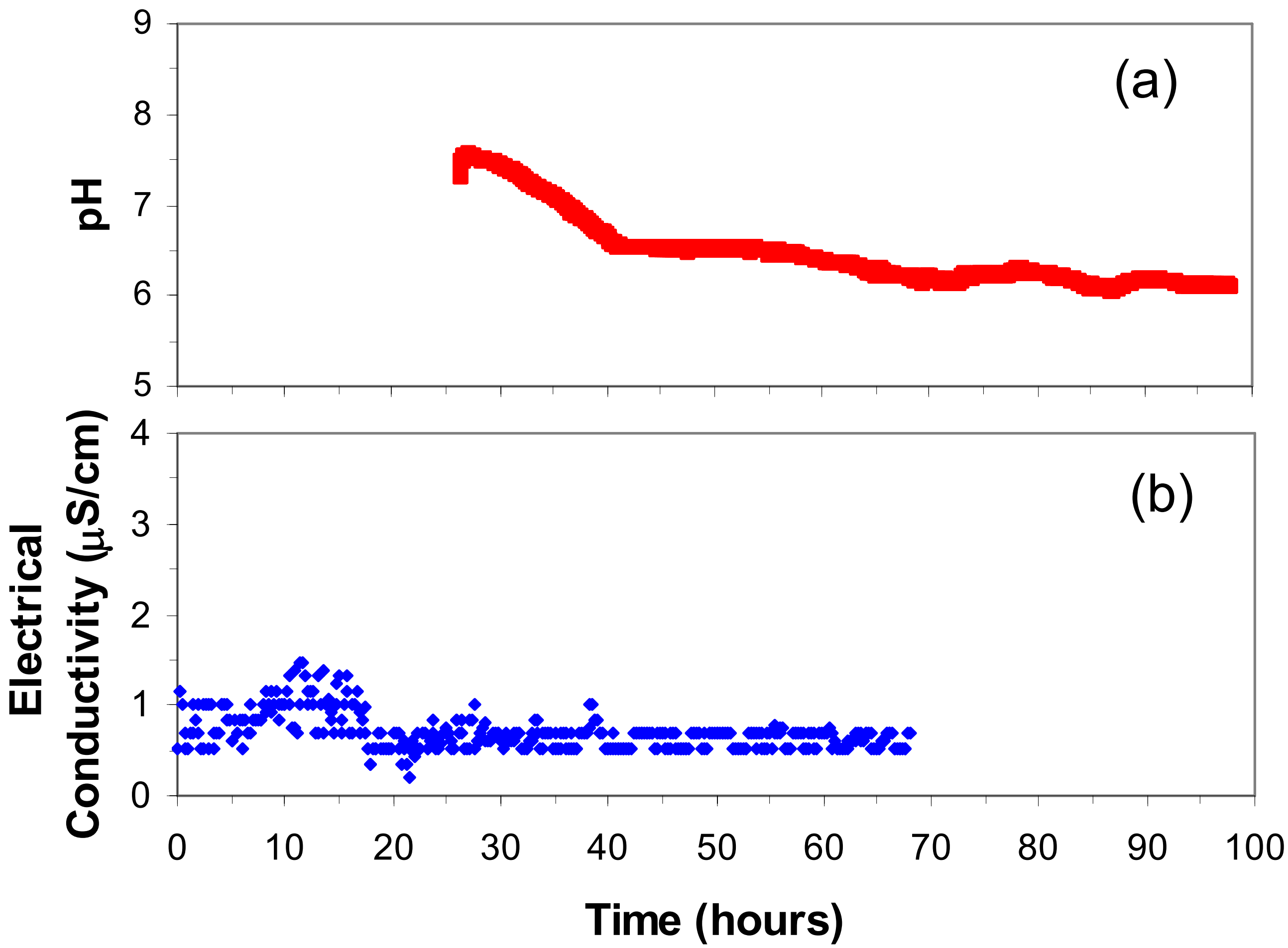
Particle deposition on channel walls due to electrostatic attraction

Results from Phase II



Electrical conductivity of coolant formulations as a function of time in the 4 L dynamic test system at 70 °C

Results from Phase II



(a) pH and (b) electrical conductivity of an optimized coolant formulations as a function of time in the dynamic test system

Discussion and Conclusions

- **Uniform particle size distribution of the nanoparticles has been obtained by optimizing the recipe.**

- **High surface charge density (> 700 μeq./g) can be obtained with cationic particles. More optimization needed for anionic particles.**

- **Coolant formulations with non-ionic corrosion inhibitor and nanoparticles have lower rate of increase in electrical conductivity than DI water, glycol/water, and glycol/water/inhibitor mixtures.**

Future Work

- In 2007, the nanoparticles will be optimized further to reduce coagulation
- Electrodeposition rate of additives on the electrode surfaces will be determined experimentally
- Material compatibility tests will be carried out
- Optimized coolant will be tested in real fuel cell systems
- Cost of the coolant will be evaluated

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