Durable, Low-cost, Improved Fuel Cell Membranes

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Project Objectives

- To develop a low cost (vs. perfluorosulfonated ionomers), durable membrane.
- To develop a membrane capable at 80°C at low relative humidity (25-50%).
- To develop a membrane capable of operating at 120°C for brief periods of time.
- To elucidate membrane degradation and failure mechanisms.

Technical Barriers Addressed

- Membrane Cost
- Membrane Durability
- Membrane capability to operate at low relative humidity.
- Membrane capability to operate at 120ºC for brief period of times.

Technical Targets

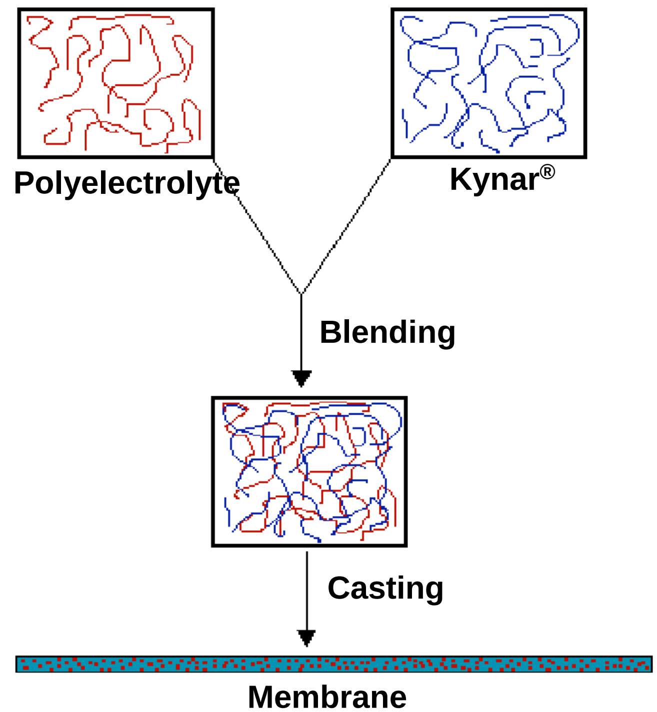
Characteristic	2004 DOE Targets	Arkema 2006 Status	2010 DOE Targets
Operating Temperature	?80°C	80°C (w/120°C excursions)	?120°C
Inlet water vapor partial pressure	50 KPa_{abs}	50 KPa_{abs}	?1.5 KPa_{abs}
Membrane Conductivity at inlet water vapor partial pressure and: Operating Temperature Room temperature -20°C	 0.10 S/cm 0.07 S/cm 0.01 S/cm	 0.10-0.14 S/cm[g,h] 0.07-0.085 S/cm[h] (not available)	 0.10 S/cm 0.07 S/cm 0.01 S/cm
Oxygen cross-over[a]	5 mA/cm^2	0.8 mA/cm^2 (w/ 25 μm membrane)	2 mA/cm^2
Hydrogen cross-over[a]	5 mA/cm^2	1.0 mA/cm^2 (w/ 25 μm membrane)	2 mA/cm^2
Area Specific Resistance	0.03 ohm cm^2	0.022 ohm cm^2	0.02 ohm cm^2
Cost [b]	65 $/m^2 [c]	≤ 65 $/m^2	(40$/m^2) 20$/m^2
Durability with cycling At operating temp ?80°C At operating temp >80°C	 ~2000 hr [d] (not available)[f]	 2100 hr[i] (not available)	 5000 hr [e] 2000 hr
Unassisted start from	-20°C	(not available)	-40°C

(a) Tested in MEA at 1 atm O_2 or H_2 at nominal stack operating temperature.
(b) Based on 2002 dollars and costs projected to high volume production (500,000 stacks per year).
(c) Based on 2004 TIAX Study that will be periodically updated.
(d) Durability is being evaluated. Steady-state durability is 9,000 hours.
(e) Includes typical drive cycles.
(f) High-temperature membranes are still in a development stage and durability data are not available.
(g) At 70ºC.
(h) In liquid water measured by EIS.
(i) Steady state at 0.5 A/cm^2; 60ºC; H_2/O_2, 100% RH, 0 KPag.

ARKEMA

Arkema's Approach

- Use polymer blend system to decouple H^+ conductivity from other requirements
  - **Kynar® PVDF**
    - Engineering thermoplastic
    - High chemical resistance
    - High electrochemical stability
    - No H^+ conduction
  - **Polyelectrolyte**
    - Water absorption
    - H^+ conduction
    - Physical properties unimportant



- A very flexible fabrication process
- Lower cost approach compared to PFSA
- M31 membrane demonstrated feasibility

Summary of Major Findings for First Generation (M31)

I. Membrane

- High conductivity achieved (close to PFSI).
- Excellent mechanical properties.
- Superior barrier properties to hydrogen and oxygen.
- Process scaled up to pilot plant up to the film step.

II. MEA

- Beginning of Life performance comparable to PFSI MEA at 60°C.

III. Durability

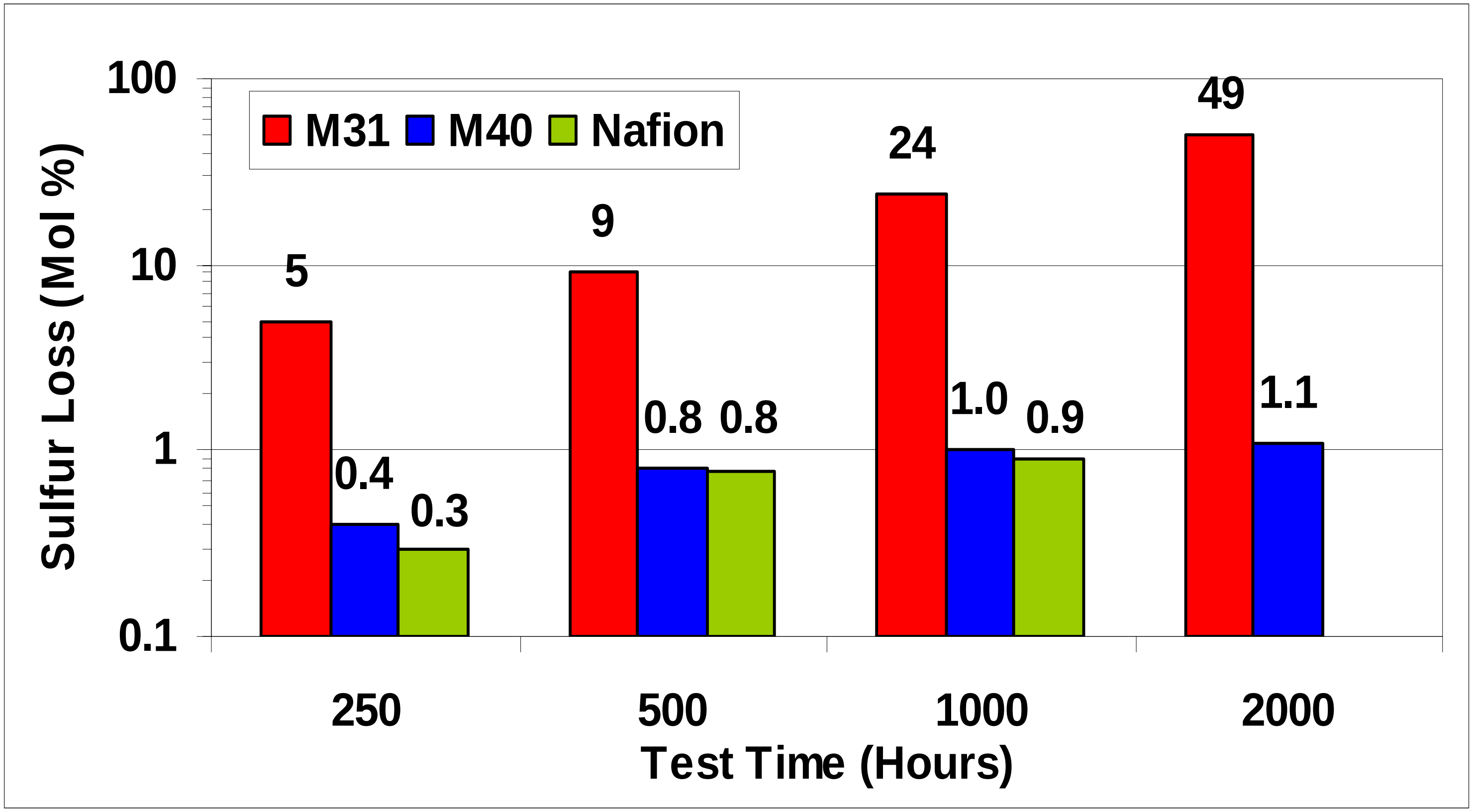
- Passed 2000 hours but long-term durability is not sufficient.
- Rapid performance drop at 80°C.
- Degradation mechanism identified: related to sulfur loss.

Kynar® PVDF with Various Polyelectrolytes

Polyelectrolyte	Conductivity (mS/cm)
• Model materials	
• P(AMPS)	90-120
• Sulfonated Polystyrene	50-90
• Materials for membrane evaluation	
• Generation A (M31)	120-150
• Generation B	120-140
• Generation C	60-120
• Generation D (M40)	100-140

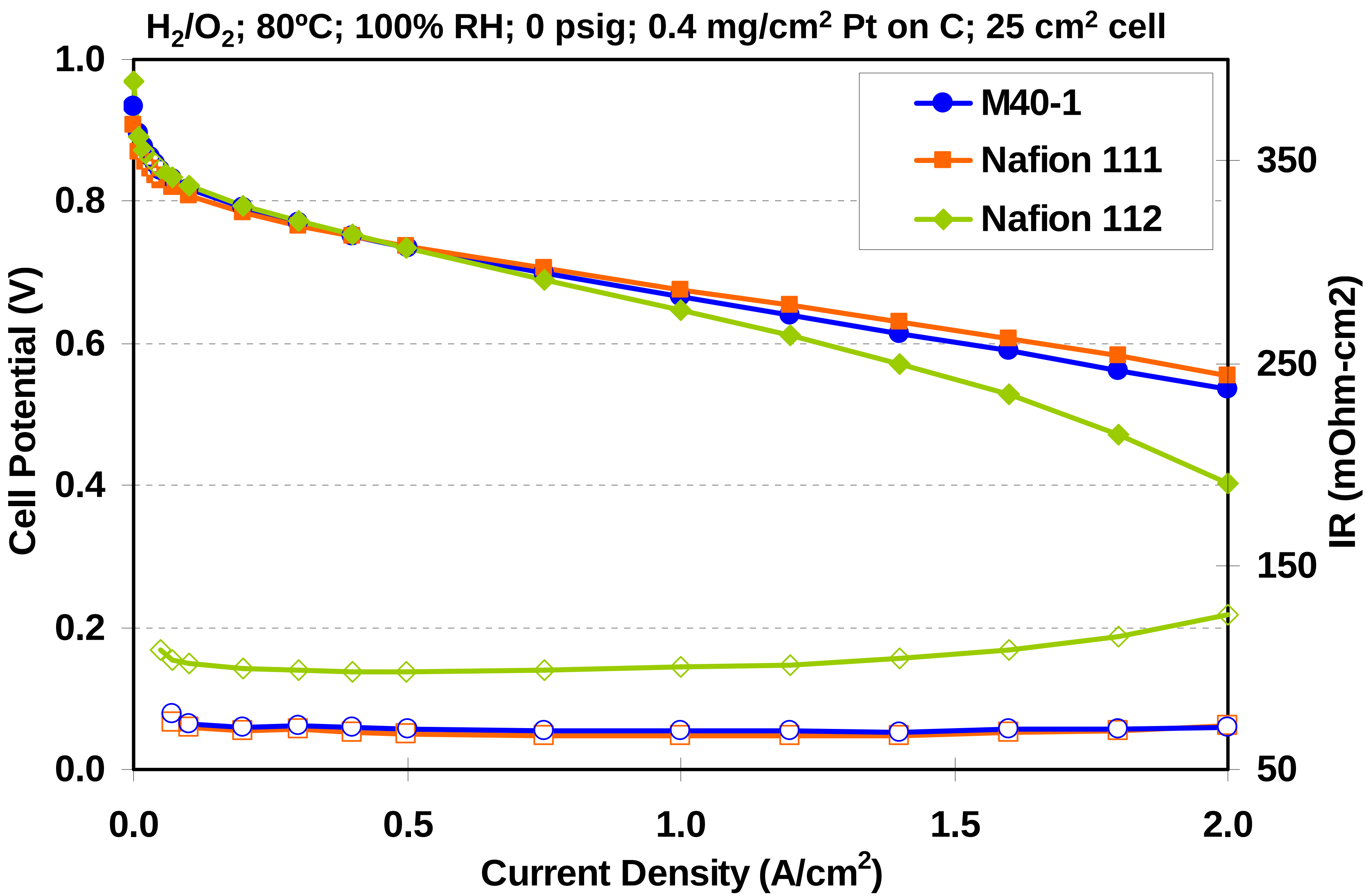
Kynar® blending process is generally applicable for highly protogenic polymers

Ex-situ Membrane Sulfur Loss Test



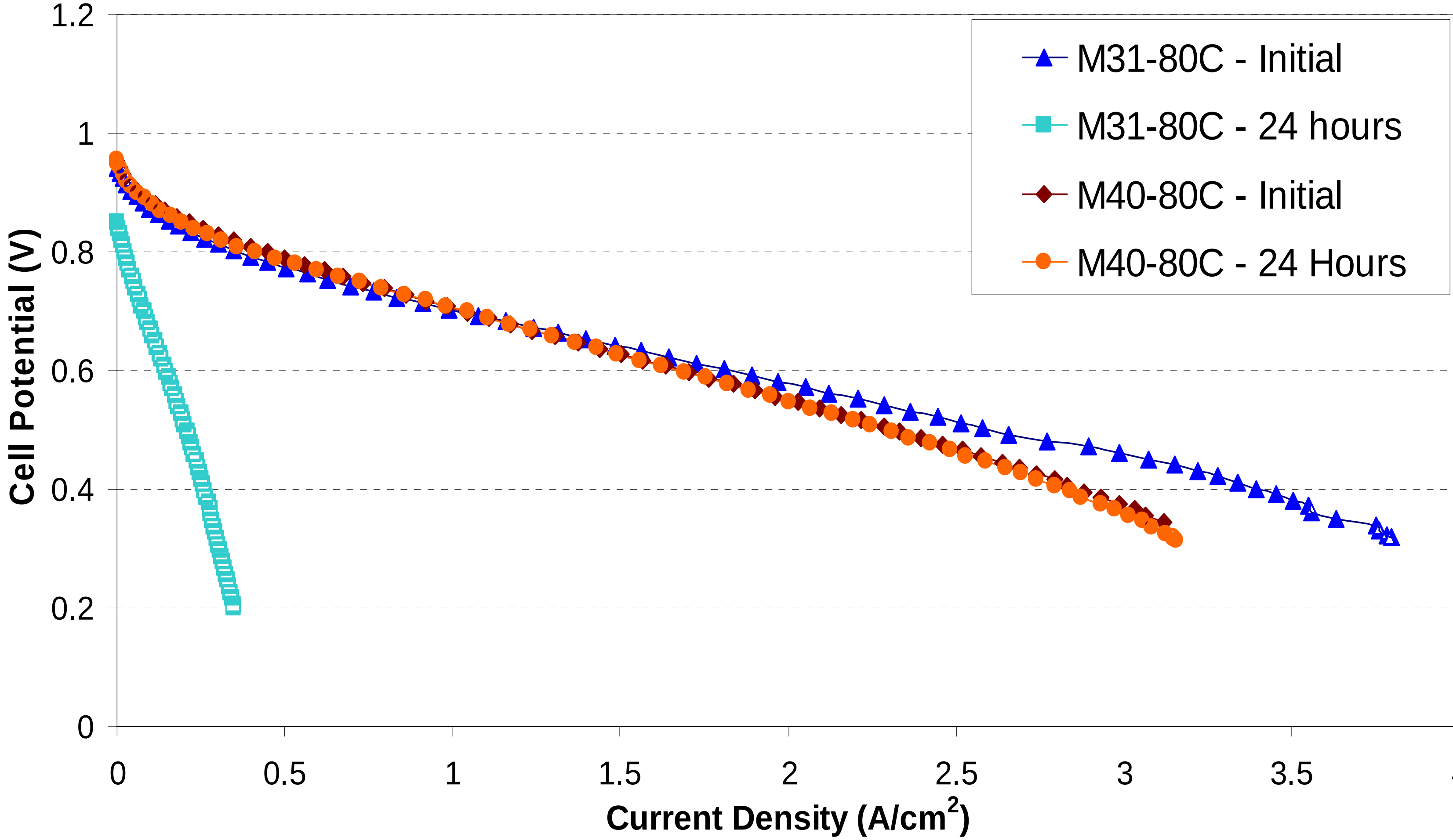
- M31 showed ~50% sulfur loss after 2000 hours due to chemical degradation
- M40 (Gen. D) shows 1% small molecule sulfur loss over 2000 hours

Beginning of Life Performance



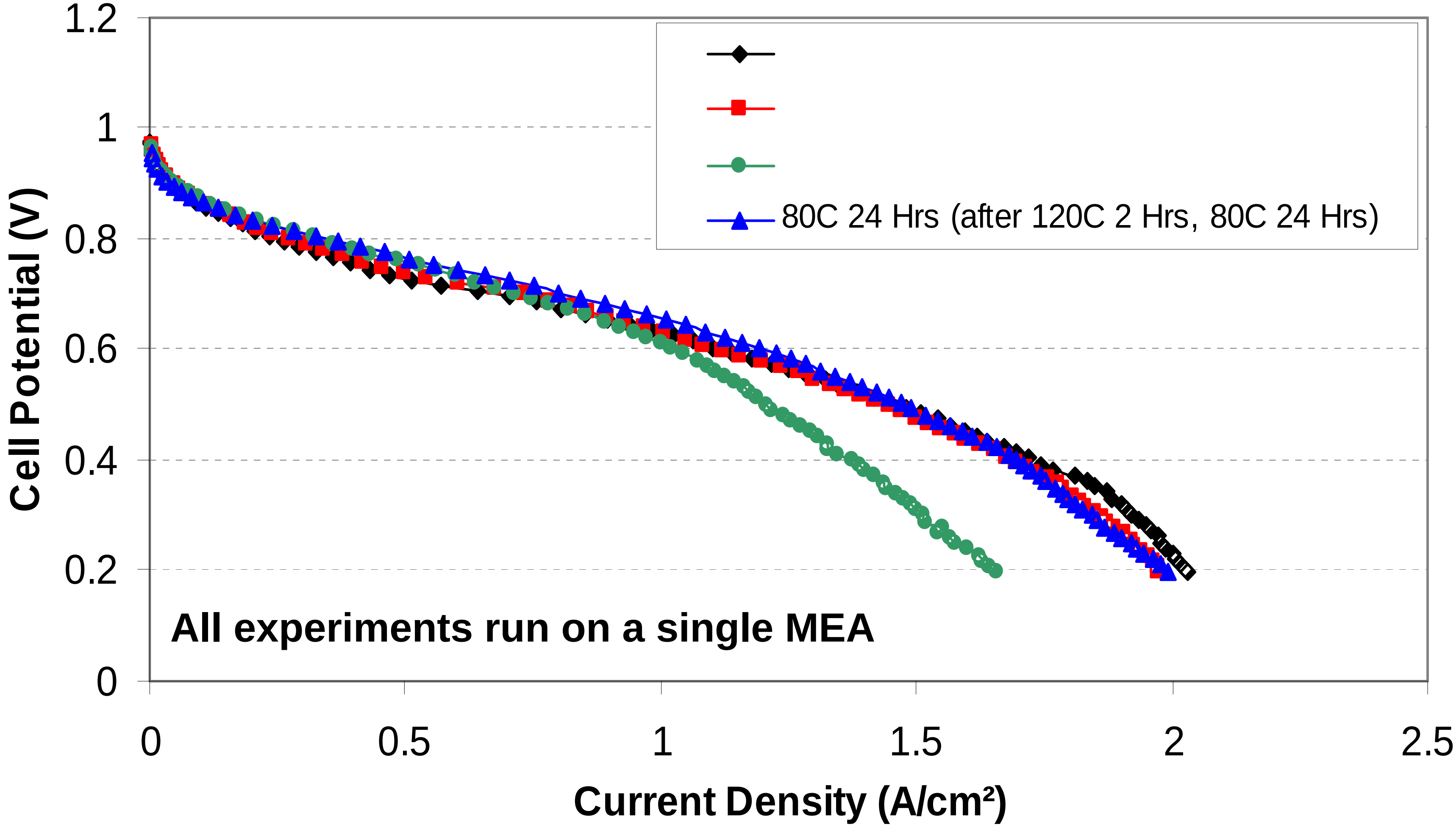
M40 vs. M31 at 80°C

H_2/O_2 - 80ºC – 100% RH – 0 psig. – 0.4 mg Pt on C – 25 cm^2 cell

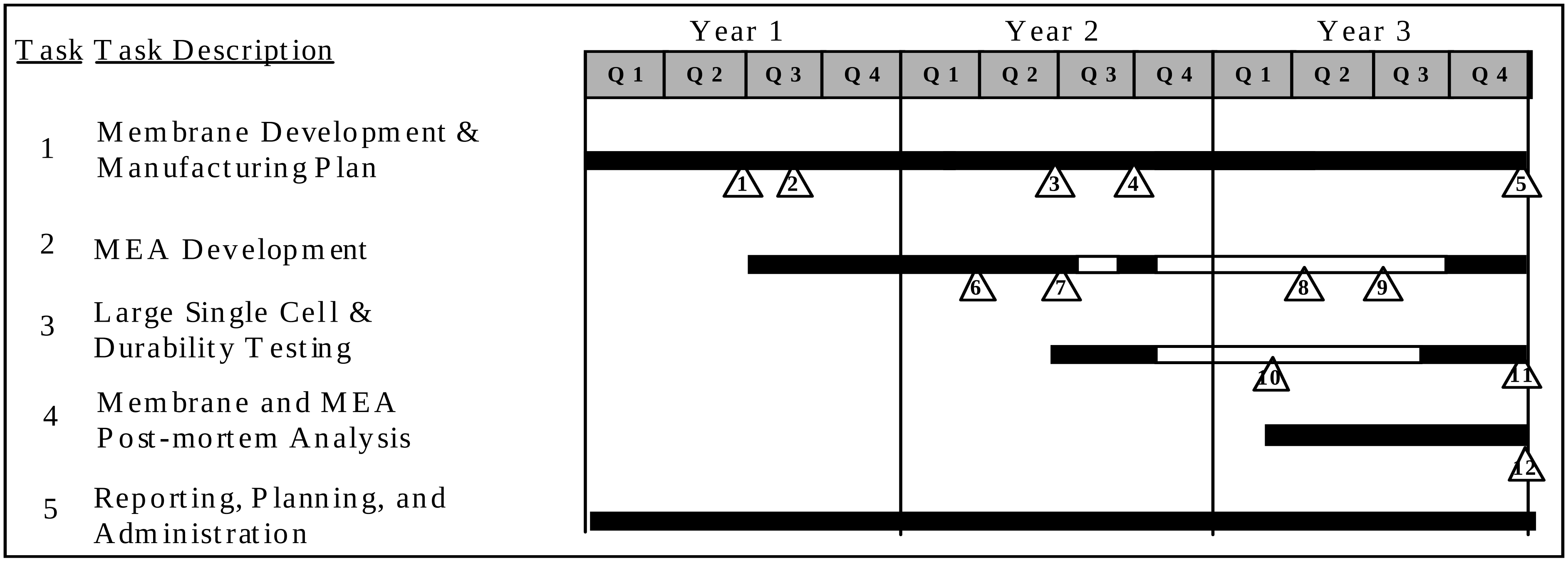


M40 High Temperature Excursion

H_2/Air; 80ºC (100% RH); 120ºC (40% RH); 0.4 mg/cm^2 Pt on C; 25 cm^2 cell



Project Time Line



Project Milestones and Decision Points

Task #	Milestone #	Title	Project Months	Project Deliverable	Go/No-Go Decision
1	1	Membrane meets 80°C requirements	6		X
	2	80°C membrane delivered to JMFC	8	X	
	3	Membrane meets > 100°C requirements	18		X
	4	> 100°C membrane delivered to JMFC	21	X	
	5	Membrane manufacturing plan complete	36	X	
2	6	MEA meets 80°C requirements	15		X
	7	Large MEAs 80°C delivered to HNEI	18	X	
	8	MEA meets > 100°C requirements	27		X
	9	Large MEAs > 100°C delivered to HNEI	30	X	
3	10	80°C MEAs perform per DOE requirements	27		X
	11	> 100°C MEAs perform per DOE requirements	36		X
4	12	Post-mortem analysis of MEAs complete	36	X	
5	N/A	Reporting, Planning, Administration	As Required		

Project Team

- Arkema (Leader)
- Johnson Matthey Fuel Cells
- Virginia Polytechnic Institute and State University
- Oak Ridge National Laboratory
- The Hawaii Natural Energy Institute of the University of Hawaii

Budget

Year 1	$2,369,000
Year 2	$2,651,000
Year 3	$2,827,000
Total	$7,847,000
DOE Share	$6,277,000

Inputs/Needs

- Arkema technology appears to be transparent to the polyelectrolyte used in the membrane.
- Arkema is open to evaluate polyelectrolytes from other parties.