# Operation of PEM Fuel Cells on Reformate Fuel with Ultra Low Flow Rate

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# Features of PEM Fuel Cells

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- High efficiency
- Free of toxic emissions
- Fast response
- High power density
- No noise

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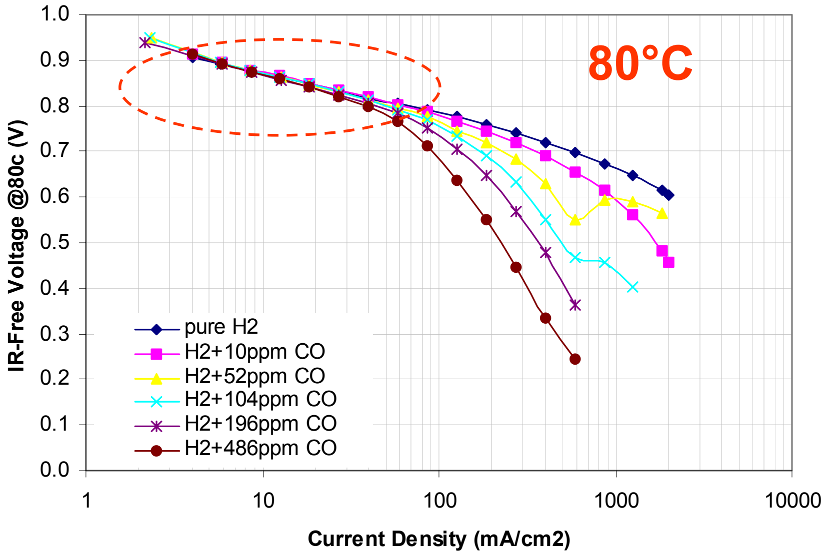
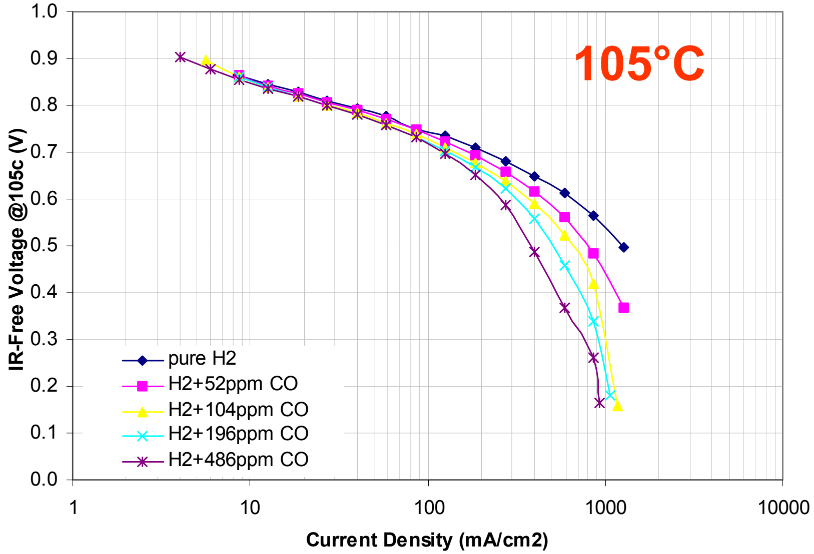
- Direct Methanol Fuel Cell
  - Methanol crossover
  - Slow methanol reaction
- Hydrogen Fuel Cell
  - Hydrogen storage?
  - Carbon monoxide poison

# Current Efforts to Improve CO Tolerance

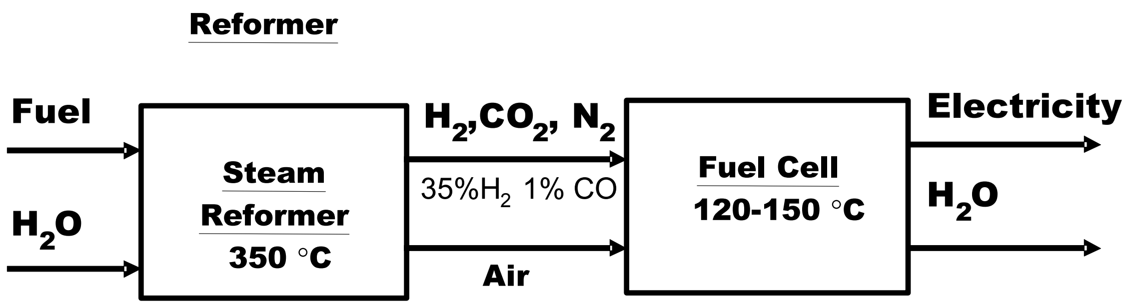
- **Air Bleeding**
  - $O_2/H_2$ ratio need to be well below the explosion threshold – 5% $O_2$ in $H_2$. Effective for low CO concentration.
- **Platinum alloy anode catalysts**
  - Pt-Ru; Pt-Sn; Pt-W; Pt-Mo; Pt-Fe; Pt-Ni; Pt-Co
- **Higher temperature operation**
  - Exothermal chemisorption of CO on Pt.
  - Increased cell resistance due to dry out effect of Nafion® membrane.

# Performance & CO Tolerance with "Normal" Fuel Flow Rate



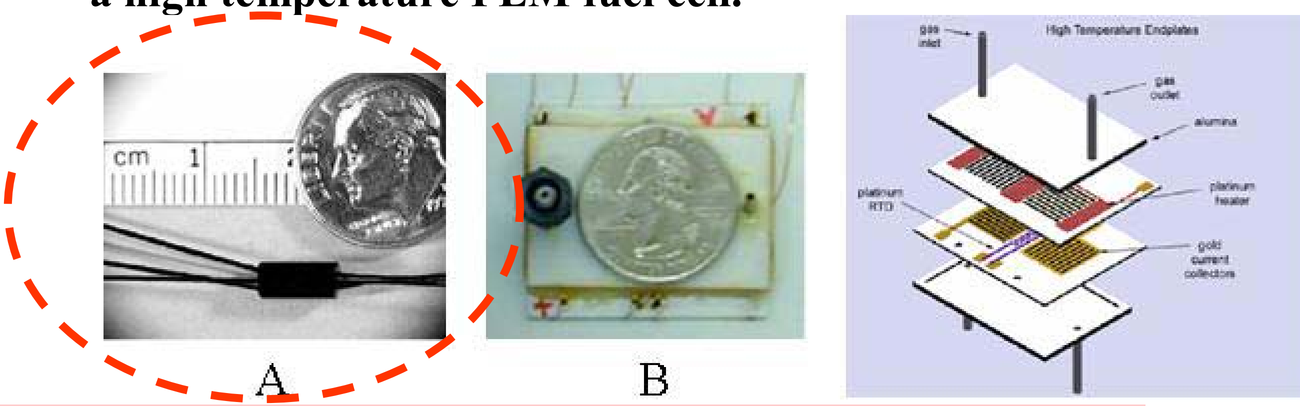

- Higher temperature operation alleviates CO poisoning.
- Performance losses due to CO poisoning effect increase with current density
- Very little performance losses at i < 100 mA/cm2




$1\ CH_3OH + 1.3\ H_2O =$

$0.23\ CO_2 + 0.005\ CO +$
$0.69\ H_2 + 0.01\ CH_3OH +$
$0.08\ H_2O$

**Figure 5. Schematic of the PNNL steam reformer using methanol and a high temperature PEM fuel cell.**




**0.1 – 1.4 cm3/min,73.8% hydrogen, 1.8% CO, and 24.4% CO2.**

maximum current densities of 40 mA/cm2

**Figure 6. Photographs of the PNNL fuel processor, Case Western Reserve University microfuel cell that uses liquid phosphoric acid as an electrolyte, and a schematic of the fuel cell components.**

# Experimental Setup

## Objectives

- PEM fuel cell performance behavior with ultra low fuel flow rate
  - Fuel flow rate
  - CO concentration in the reformate fuel
  - Cell temperature

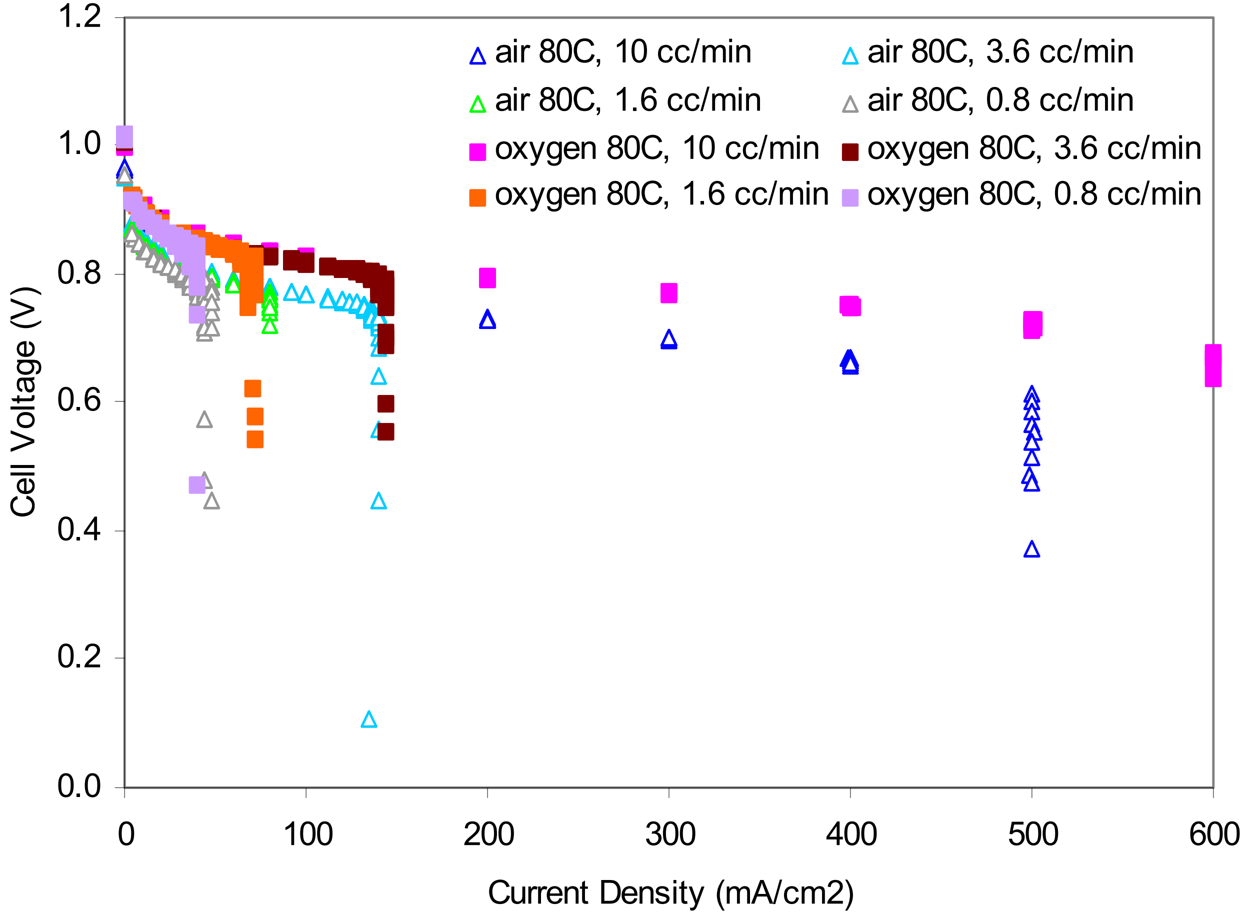
**MEAs** (5 $cm^2$ active area)

- High Temperature Membrane: Nafion®-Teflon®-$Zr(HPO_3)_4$ (25μm);
- Anode: E-TEK 40% Pt-Ru/C (Pt:Ru=1:1); 0.5 mg Pt-Ru/$cm^2$;
- Cathode: Tanaka 46% Pt/C, 0.5 mg Pt/$cm^2$;
- Gas Diffusion Layer: SGL carbon paper.

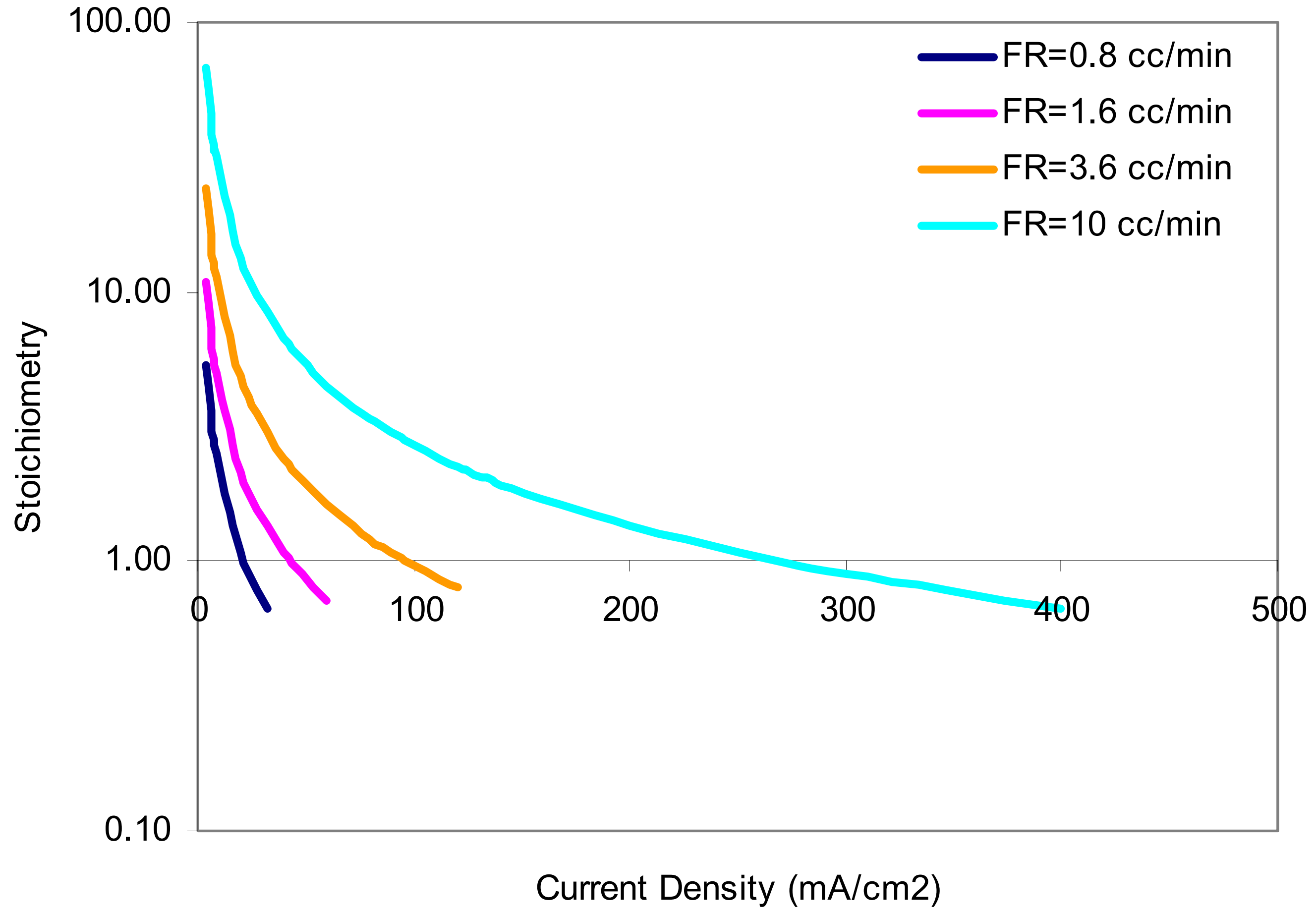
**Experimental Control**

- Anode: MSK gas flow controller (0~10 cc/min), Humidified, Ambient pressure;
- Cathode: 25% utilization for air and 5% for pure oxygen. Humidified, Ambient pressure.

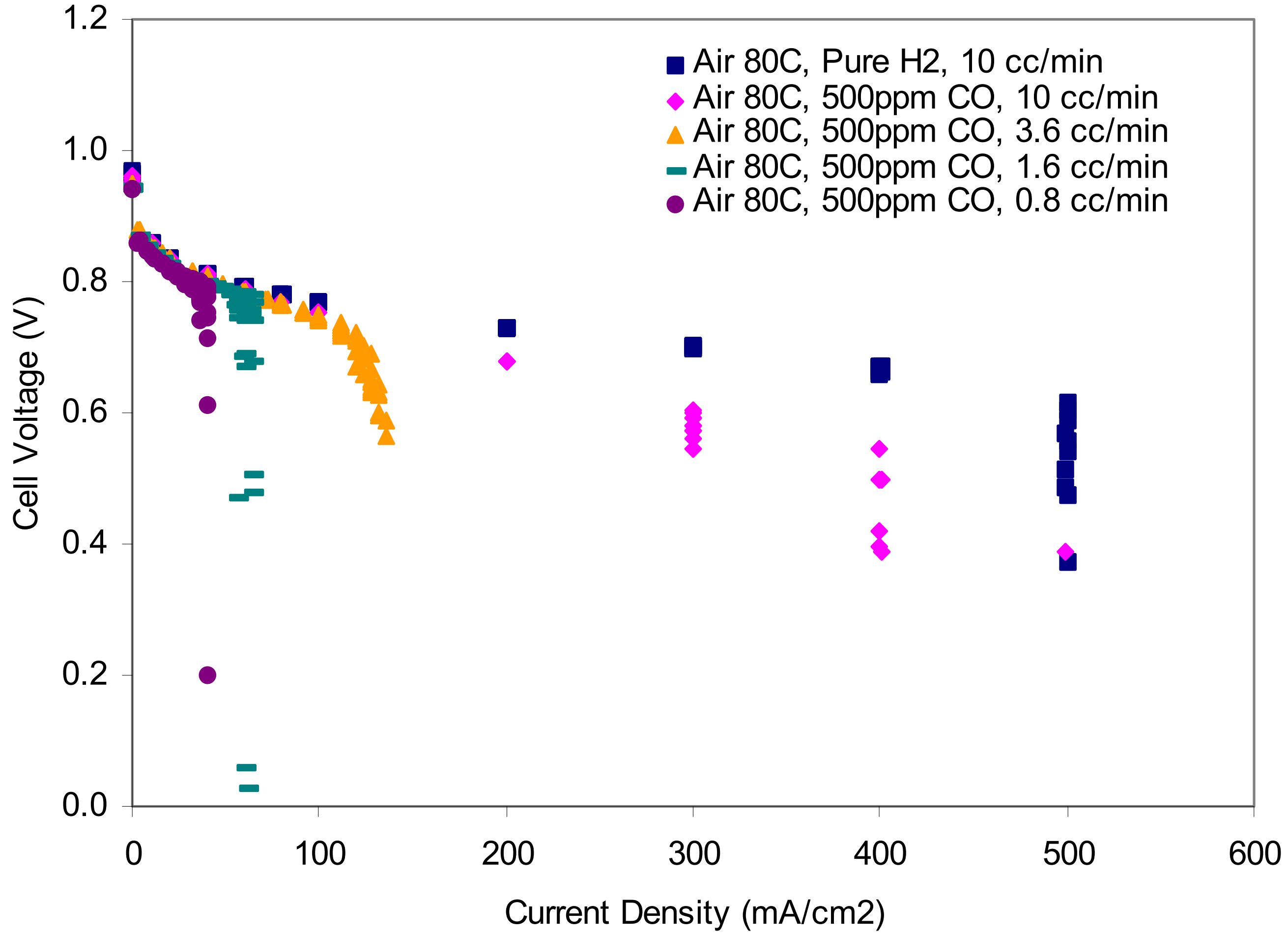
# Performances with Low Fuel Flow Rate: @ 80°C using Pure $H_2$



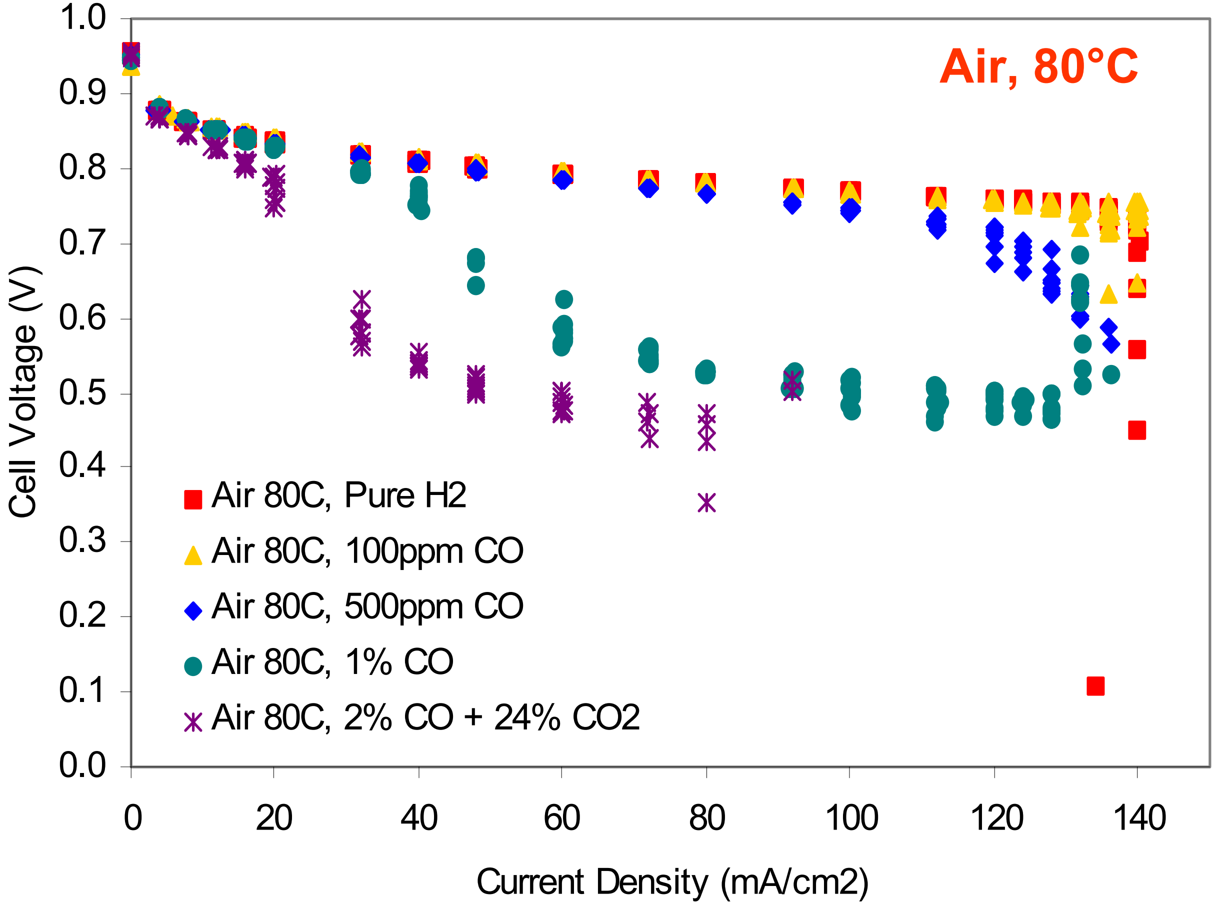
# Stoichiometry *vs.* Current Density



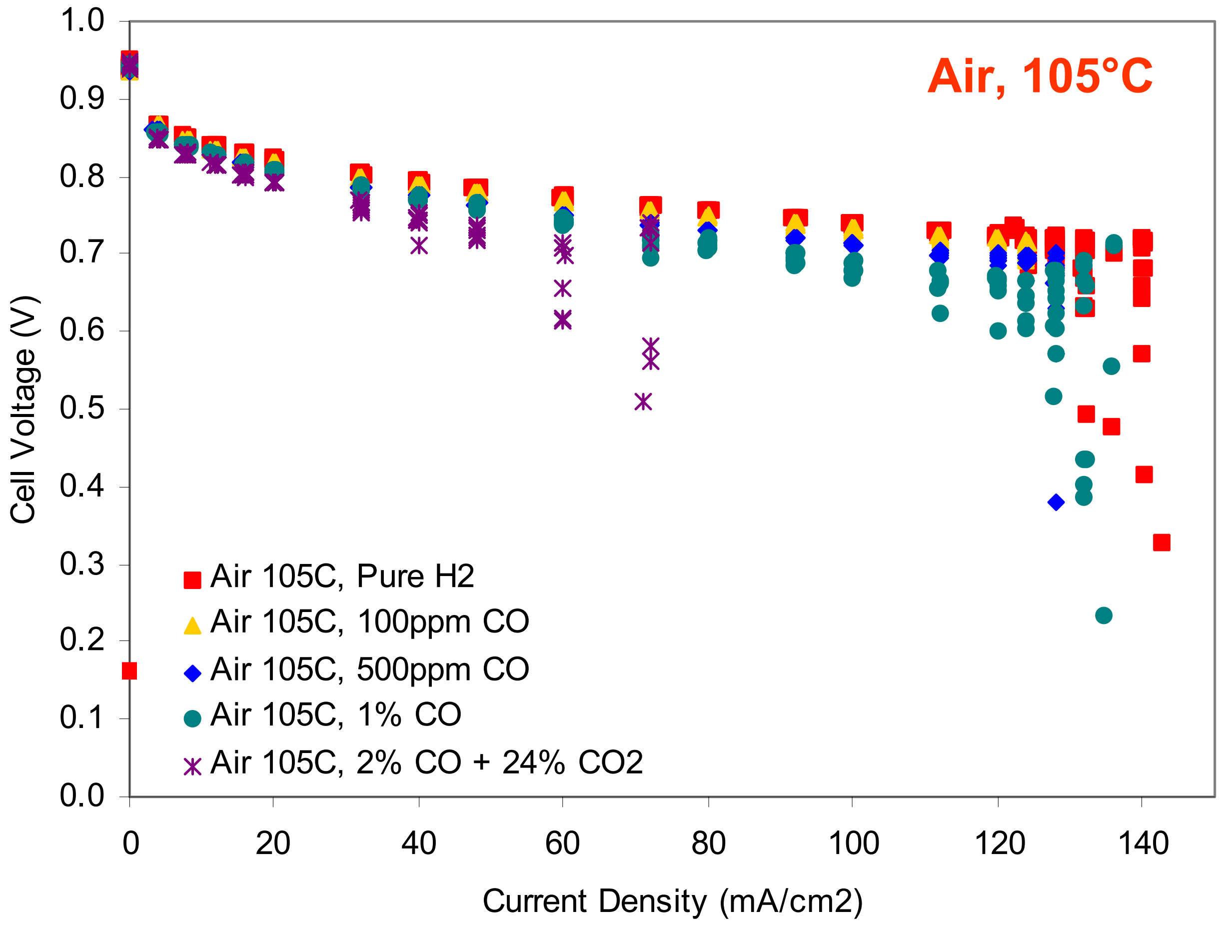
# CO Poisoning Effects @ 80°C, 500ppm CO, with Low Fuel Flow Rate



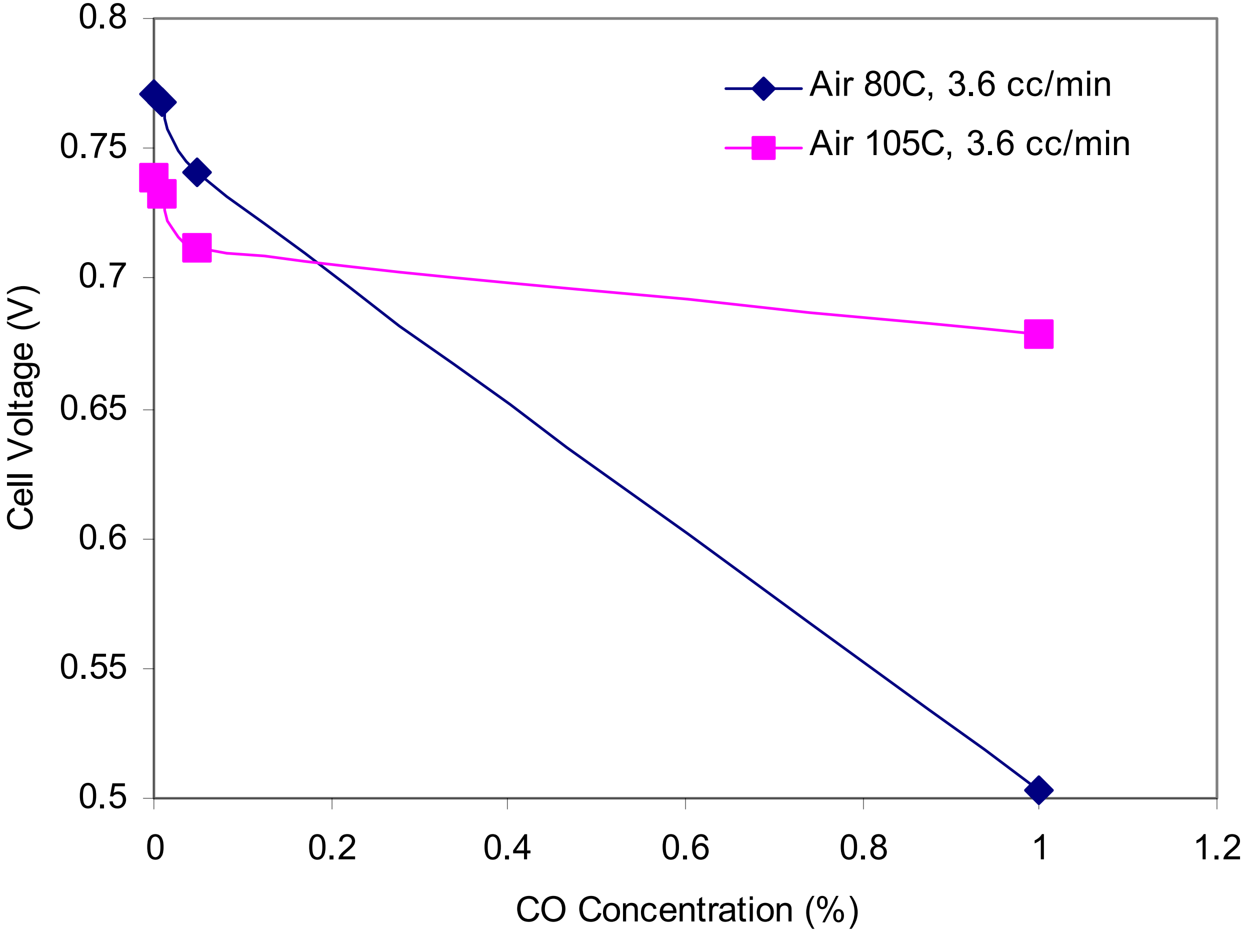
# CO Tolerance @ 80°C with 3.6 cc/min Fuel Flow Rate



# CO Tolerance @ 105°C with 3.6 cc/min Fuel Flow Rate



# Temperature Effects @ 100 mA/cm² with 3.6 cc/min Fuel Flow Rate



# Summary

- Low flow rate PEM fuel cell operation is possible for low current density requirements; and might be feasible for micro scale fuel cell systems.
- Performance losses due to CO poisoning effect increase with current density
- Excellent CO tolerance for PEM fuel cell operated with low fuel flow rate;
- Elevated temperature (105°C) operation benefits the performance using higher CO concentration (> 1%) fuel.

# Acknowledgments

- Dr. Fenton and Dr. Kunz
- Lab Mates
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