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Interests and capabilities in solid oxide fuel cell research

Tony McDaniel, Ethan Hecht, Steve Rice (08367)
Jim Miller, Ron Loehman (01815)

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Topics for discussion

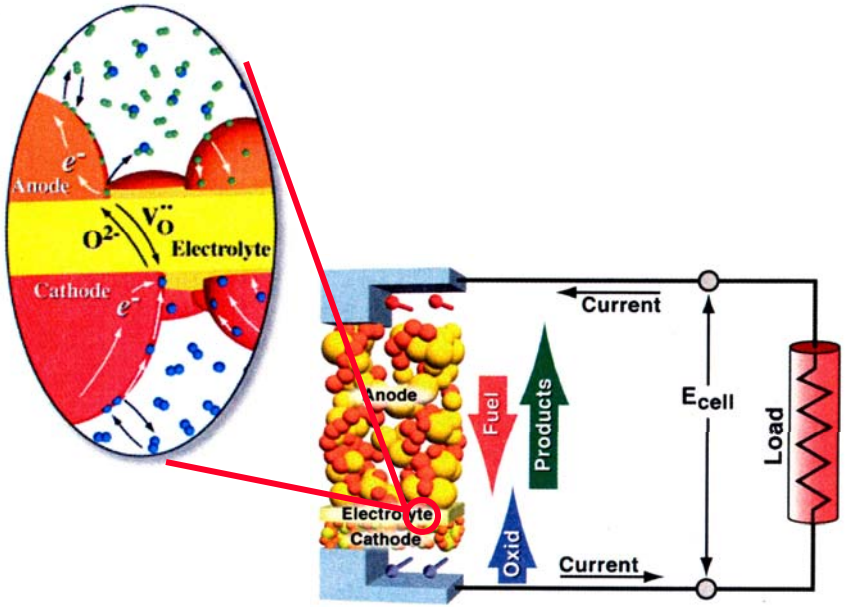
- **Current SOFC research**
  - **Electrochemical control of hydrocarbon oxidation reactions**
    - *understand the electrochemical behavior of membrane-transported O^{-2}*
    - *stable and functional anode catalyst formulations*
    - *low temperature electrolytes*

- **Ceramics processing**
  - **MEA fabrication**
    - *synthesizing powders*
    - *printing, robo-casting, firing, sealing*

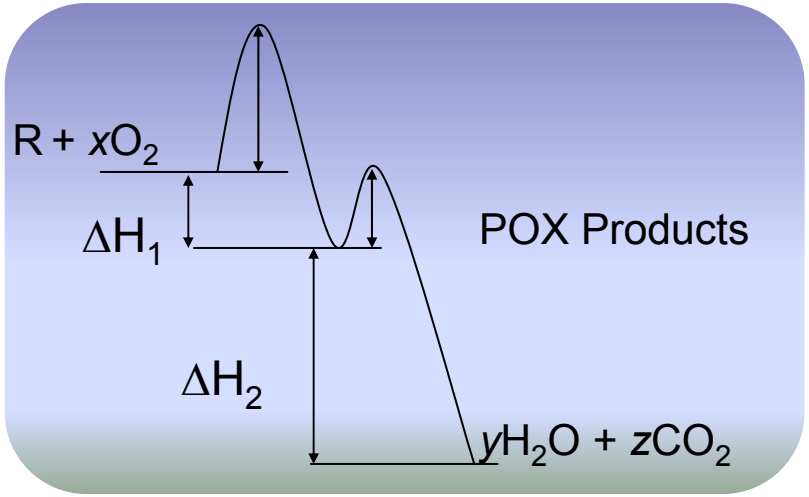
- **Diagnostics and materials characterization**
  - **Thermal chemistry of anode powders**
  - **Electrochemical performance of MEA**

The chemical nature of membrane-transported O^{-2}

- **Identify and exploit differences between chemisorbed and membrane-transported O species**
  - **Three phase boundary**
    - *complex surface and charge transfer reactions*
  - **Control the extent of oxidation**
  - **Control product selectivity**



- **Improve efficiency of hydrocarbon processing**
  - **Integrated cogeneration**
    - *better use of process enthalpy*
  - **Enhanced separation**
  - **Enhanced selectivity**



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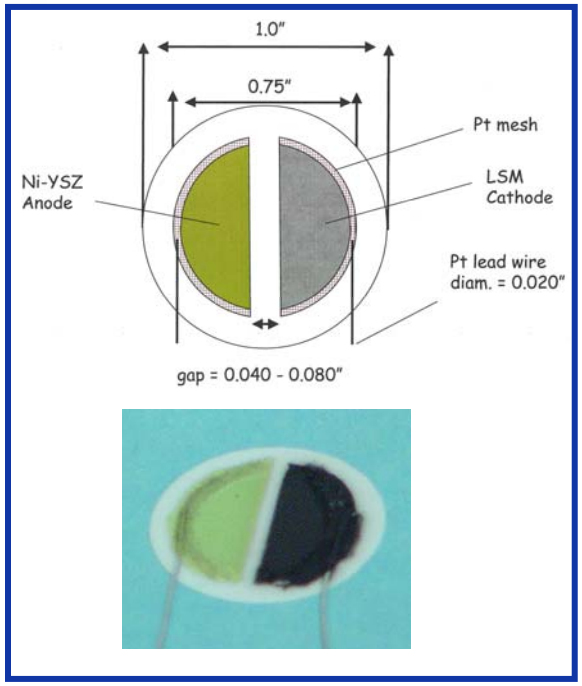
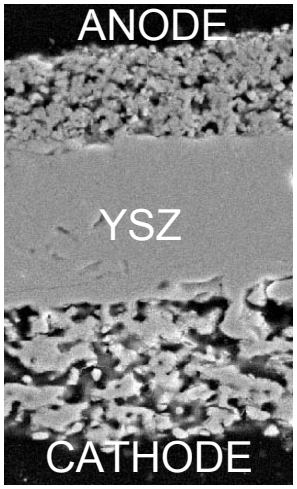
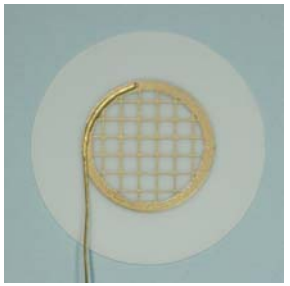
Membrane electrode assemblies and tubular reactor

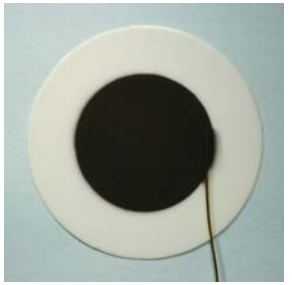


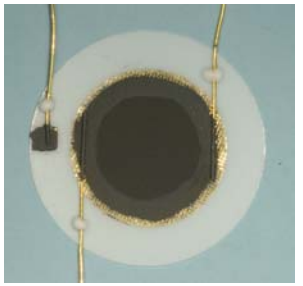


Sandia patterned gold collectors



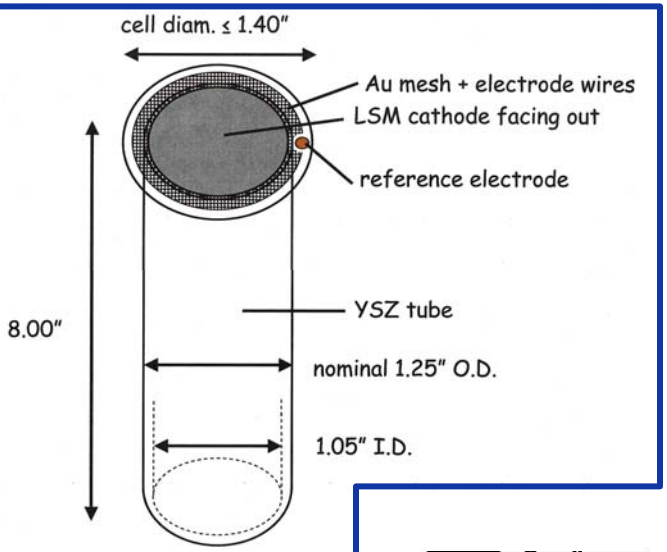
Sandia anode applied over gold





Ceramatec cathode half cell on YSZ or ScSZ

- **Sandia and Ceramatec combine to fabricate test cells**
  - **Slurries generated from anode powders and sprayed through masks**
  - **Gold collector traces printed on surfaces**
  - **Multiple firing steps, glassed onto tubes**



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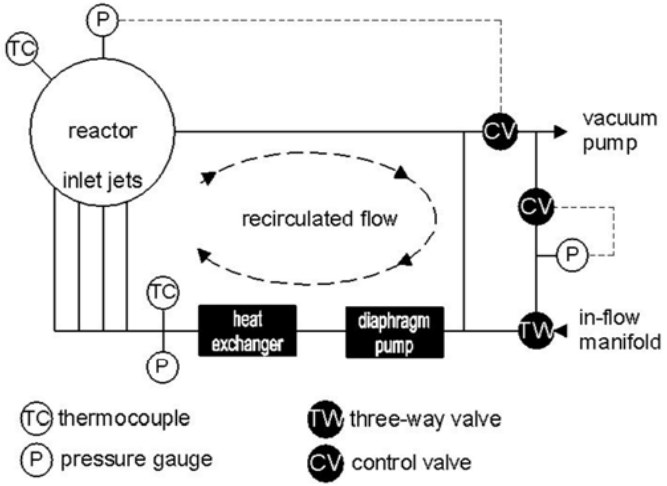
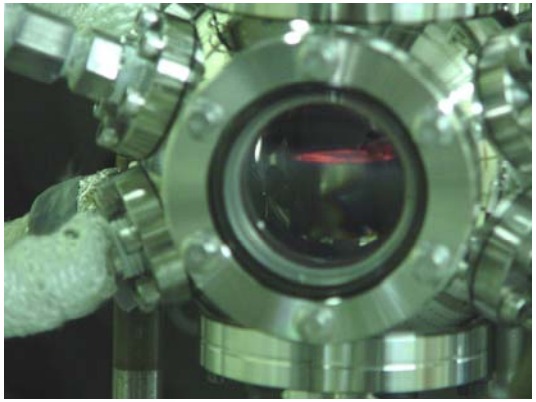
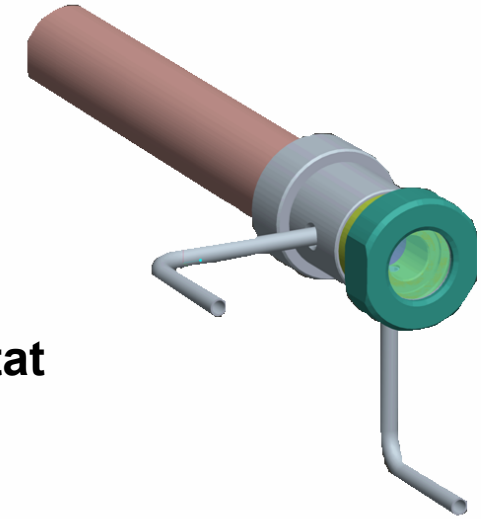
Design of experiments and diagnostics

- **Hot and cold wall reactors**
  - **Jet-stirred reactor (cold)**
    - *spherical cavity*
    - *single chamber cells*
    - *internal heated pedestal*
  - **Tubular reactor (hot)**
    - *cylindrical cavity*
    - *air-breathing cell stack*
    - *inserted into tube furnace*





- **Integrated diagnostics**
  - **Surface Raman**
  - **Gas chromatography**
  - **Mass spectrometry**
  - **CPU controlled potentiastat**
  - **Impedance spectroscopy**
  - **Dynamic load equipment**



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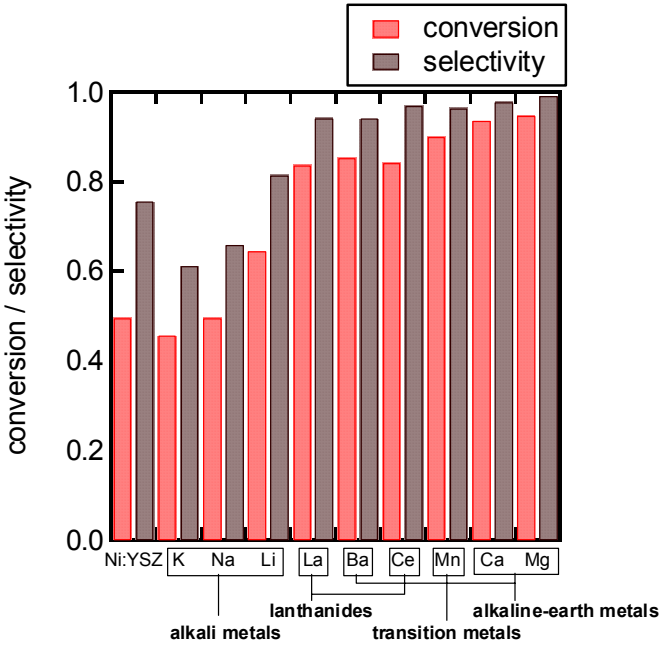
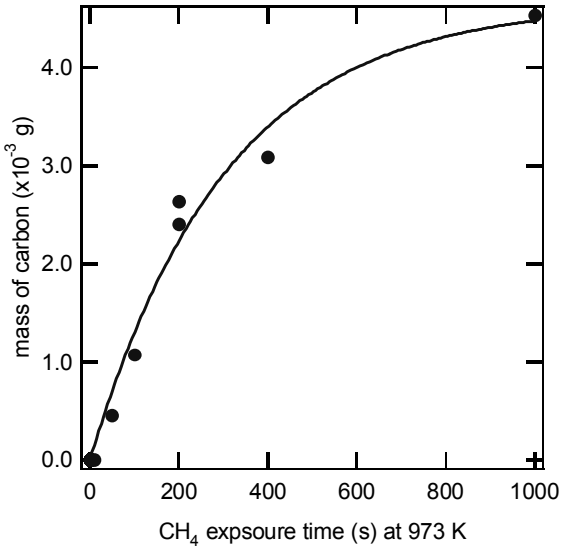
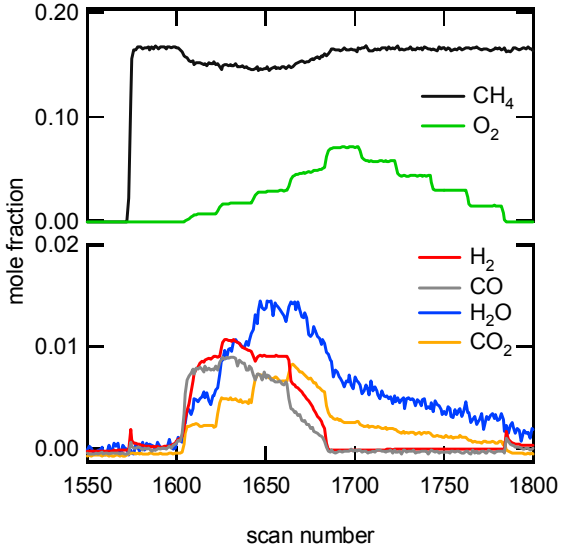
Methane partial oxidation to synthesis gas

- **Probe thermal chemistry to baseline effects of carbon and oxygen**
  - **Mn doped Ni-YSZ**
  - **$BaNiAl_{11}O_{19}$ doped Ni-YSZ**
- **Stabilize anode to carbon deposition**
  - **Maintain conversion and synthesis gas selectivity**







Example of BaNiAlO material at various fuel:oxygen ratios

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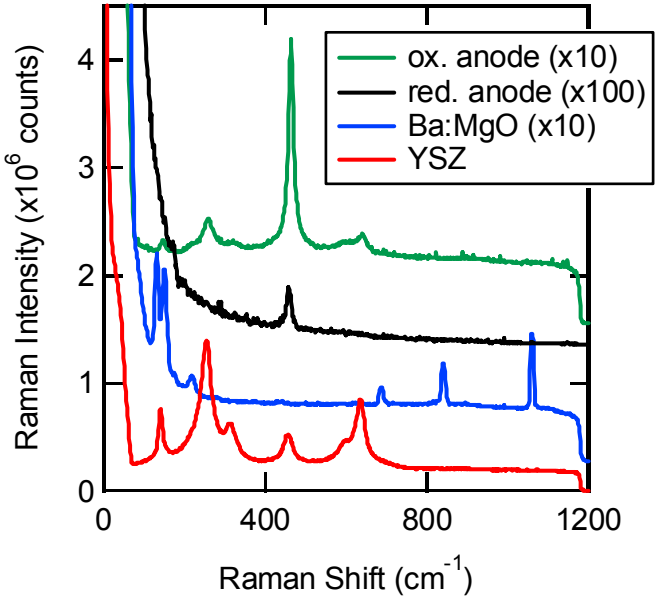
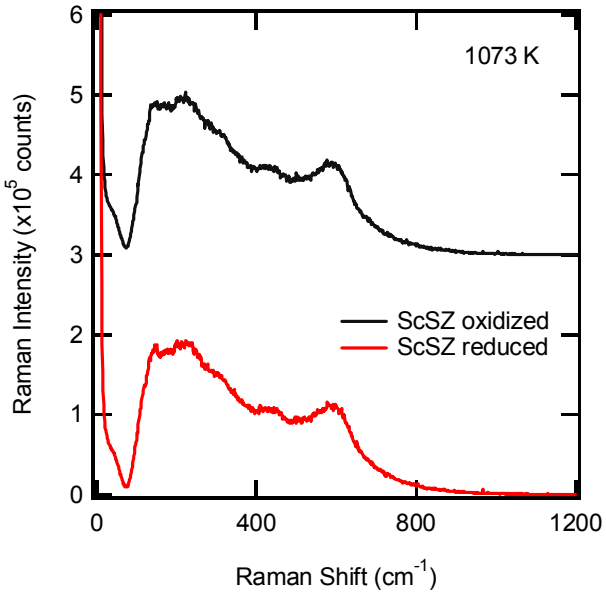
Raman scattering from relevant surfaces

- **Established high frequency surface Raman capability**
  - **Diode-pumped Q-switched Nd:YAG**
    - *5kHz /15 ns pulse width at 532 nm*
  - **Interface to tubular reactor**
    - *gated CCD to reduce effects of incandescence*



- **Ambient and elevated temperature Raman study**
  - **Oxidized anode (green material)**
    - *significant Ni-O feature at 463 cm^{-1}*
  - **Reduced anode (black material)**
    - *weak Ni-O band evident, otherwise featureless*



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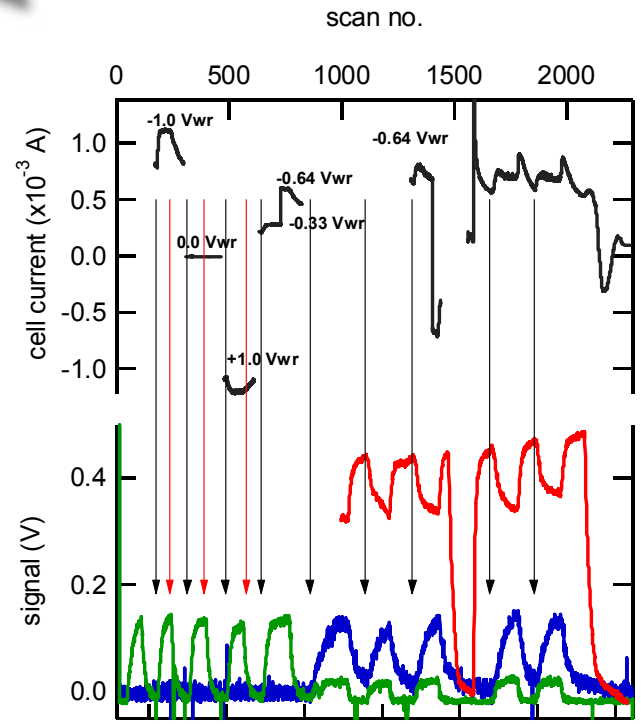
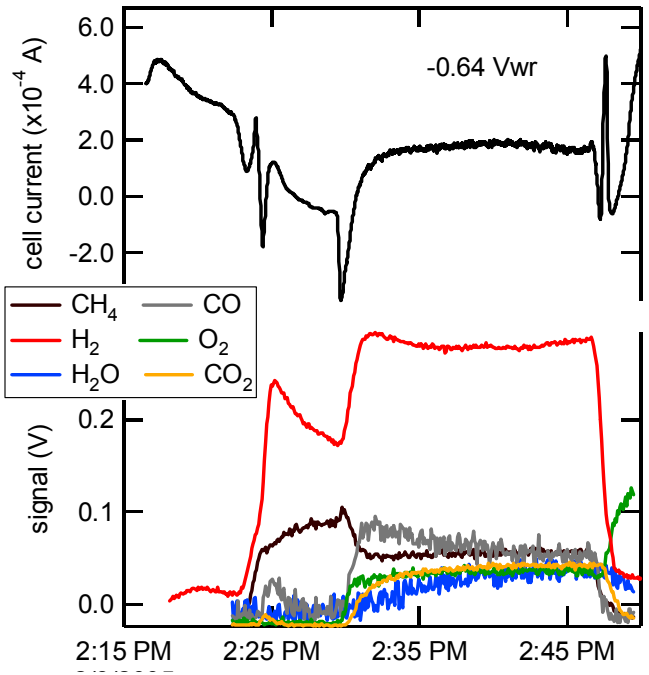
Summary of jet stirred reactor experiments

H_2 oxidation





CH_4 oxidation

- **Single chamber cell with Ni-YSZ anode at 900 K**
  - **Premixed inlet composition at dilute 4:1 H_2:O_2 or 5:1 CH_4:O_2**
- **Small, variable cell current dependent on potential and gas composition**
- **Catalyst surfaces support POM**
  - **No significant variation in selectivity or conversion with applied field**

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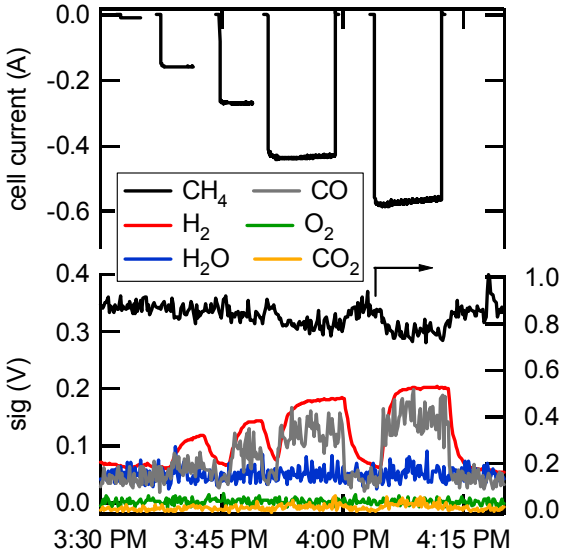
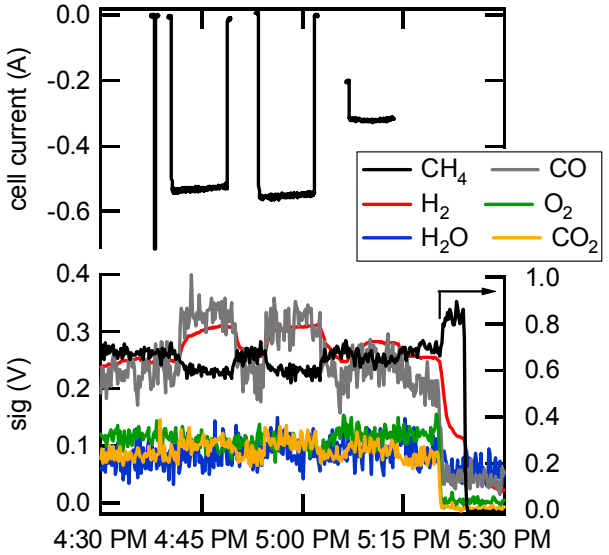
POM under anodic potential in air-breathing mode over Ni-YSZ



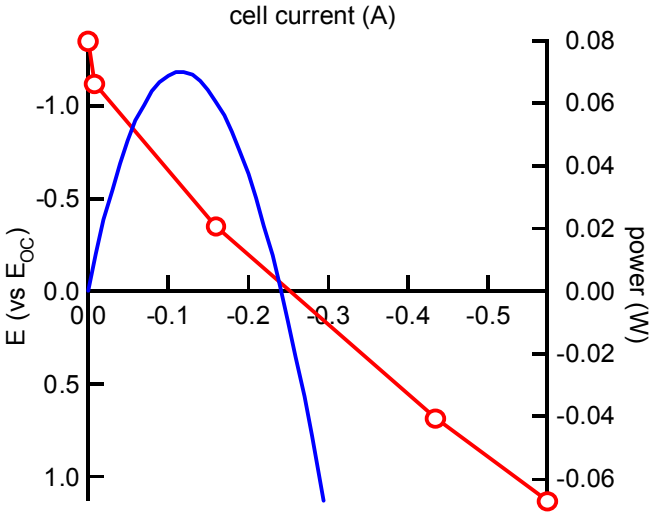
Depending on applied potential, H_2 and CO formed with positive cell power output



5% CH4 at 873 K

H_2 and CO produced at 2:1 under anodic potential

NO CO_2 or H_2O detected



5% CH4 1% O_2 at 873 K

Enhanced H_2 and CO production under anodic potential

No significant increase in CO_2 or H_2O

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Conclusions and path forward

- **Experimental evidence suggests membrane-transported O species prefer partial oxidation pathways even in the presence of chemisorbed O atoms**
  - **This observation has not been reported in the literature**
    - *significant debate over direct oxidation versus internal reforming*
  - **Supports the supposition that partial oxidation reactions can be exploited electrochemically**
- **Further explore simple hydrocarbon partial oxidation with Sandia anode formulations**
  - **POM, ethane and propane dehydrogenation**
- **Formulate MEA for epoxidation chemistry**
  - **Radically different anode formulations**
  - **Low temperature ion conductors**
    - *doped ceria or gadolinia electrolytes*
    - *monolithic stacks comprised of mixed conductors (ion, electron)*