Fuel Processor Development for Miniature Power Supplies to Power Microdevices

Jamie Holladay, Evan Jones, Max Phelps,
Ya-Huei Chin
Battelle, Richland WA, USA

Robert Savinell, Jesse Wainright, Morton Litt
Case Western Reserve University, Cleveland OH, USA

IMRET 6
New Orleans, USA
March 10-15, 2002

Acknowledgement: Dr. William Tang, DARPA MTO

Battelle

Need

- Broaden the possibilities for using self-sustaining devices in remote or difficult-to-access locations such as sensors or mobile devices.
- Battery replacement
- Self-sustaining portable power supply for wireless electronic devices
  - Wireless equipment & sensors
  - Remote operation
  - Sensors
  - MEMS
  - Hand-held devices

MTO DARPA

Battelle . . . Putting Technology To Work

Required Fuel Efficiency to exceed battery performance

Fuel	LHV (kJ/mol)	Energy Density (kWh/kg)	Efficiency Required
Methanol 1:1 water:C	639	5.6 3.3	5.5%
n-Ocatane 2:1 water:C	5100	12.3 3.0	2.4%
n-Dodecane 2:1 water:C	7552	12.3 3.1	2.4%
H_2 storage	242	0.5-1.0	30-60%
$NaBH_4$ solution 1kg $NaBH_4$ + 950g H_2O	495	3.6	12.1%
Lithium polymer battery		0.3 (projected)	

MTO DARPA

Battelle . . . Putting Technology To Work

Goals and Objectives

- Develop an integrated fuel cell and fuel processor for microscale (10- to 500-mW_e) power generation.
- Demonstrate 10-500 mW_e fuel processor.
- Demonstrate 10-500 mW_e fuel cell.
- Demonstrate integrated mW_e fuel processor and fuel cell system.

MTO DARPA

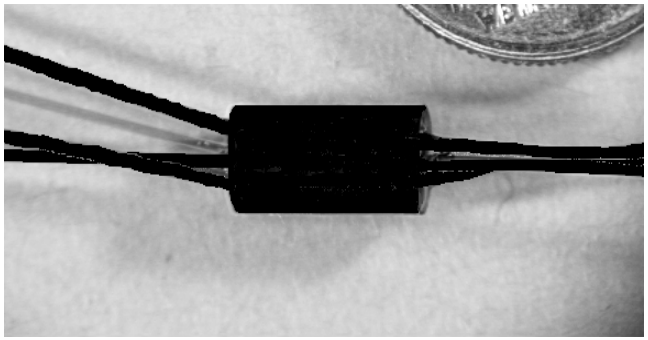
Battelle . . . Putting Technology To Work

Overall System and System efficiency

Fuel Steam Reformer:

Converts fuel and water into H_2 and CO_2 gas.

$$\text{Efficiency} = \frac{\text{Hydrogen lhv}}{\text{Reformer Fuel lhv} + \text{CR Fuel lhv}}$$

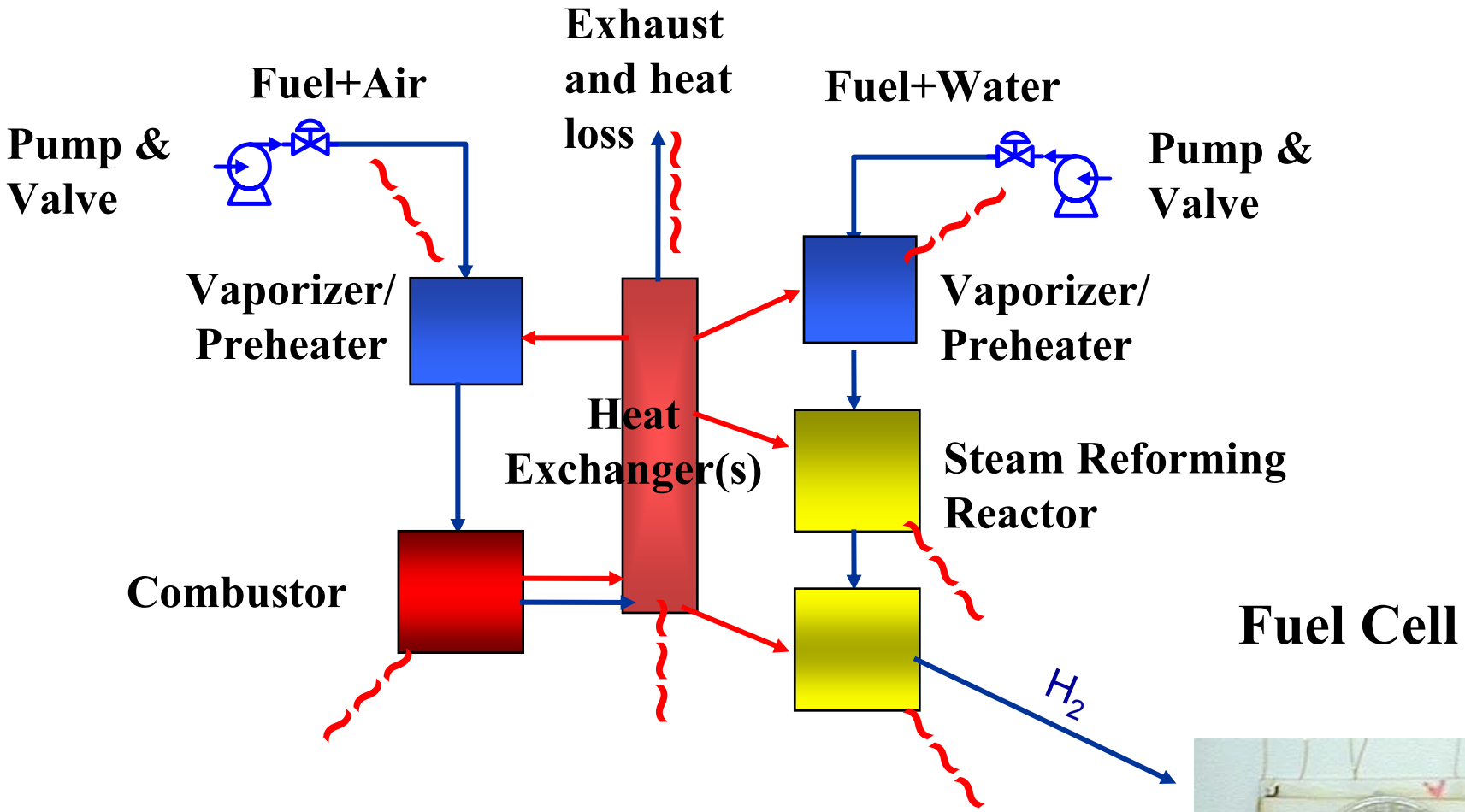


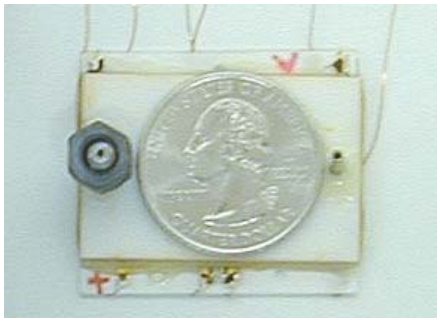
Fuel Cell:

Converts H_2 gas into H_2O and electricity.

$$\text{Efficiency} = \frac{\text{Electric power out}}{\text{Reformer Fuel lhv} + \text{CR Fuel lhv}}$$

Fuel Processor System





Energy →

Fluid →

Heat loss ~~~

Heat lost by conduction, convection, and radiation

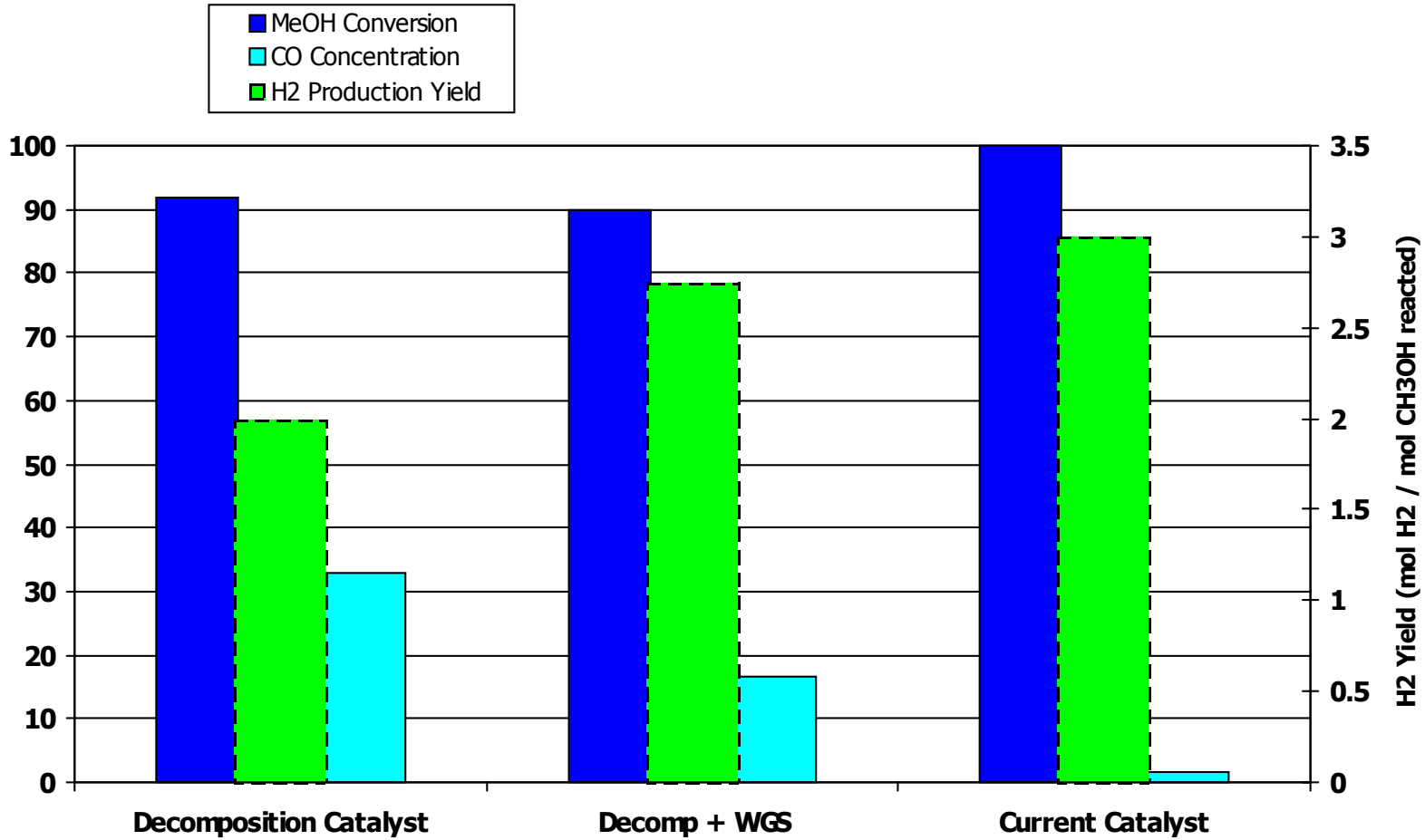
MTO DARPA

Battelle . . . Putting Technology To Work

Methanol SR Catalyst:

Different Approaches on Steam Reforming of Methanol

(100 ms contact time, H2O/C=1.8, 300°C and 1 atm)



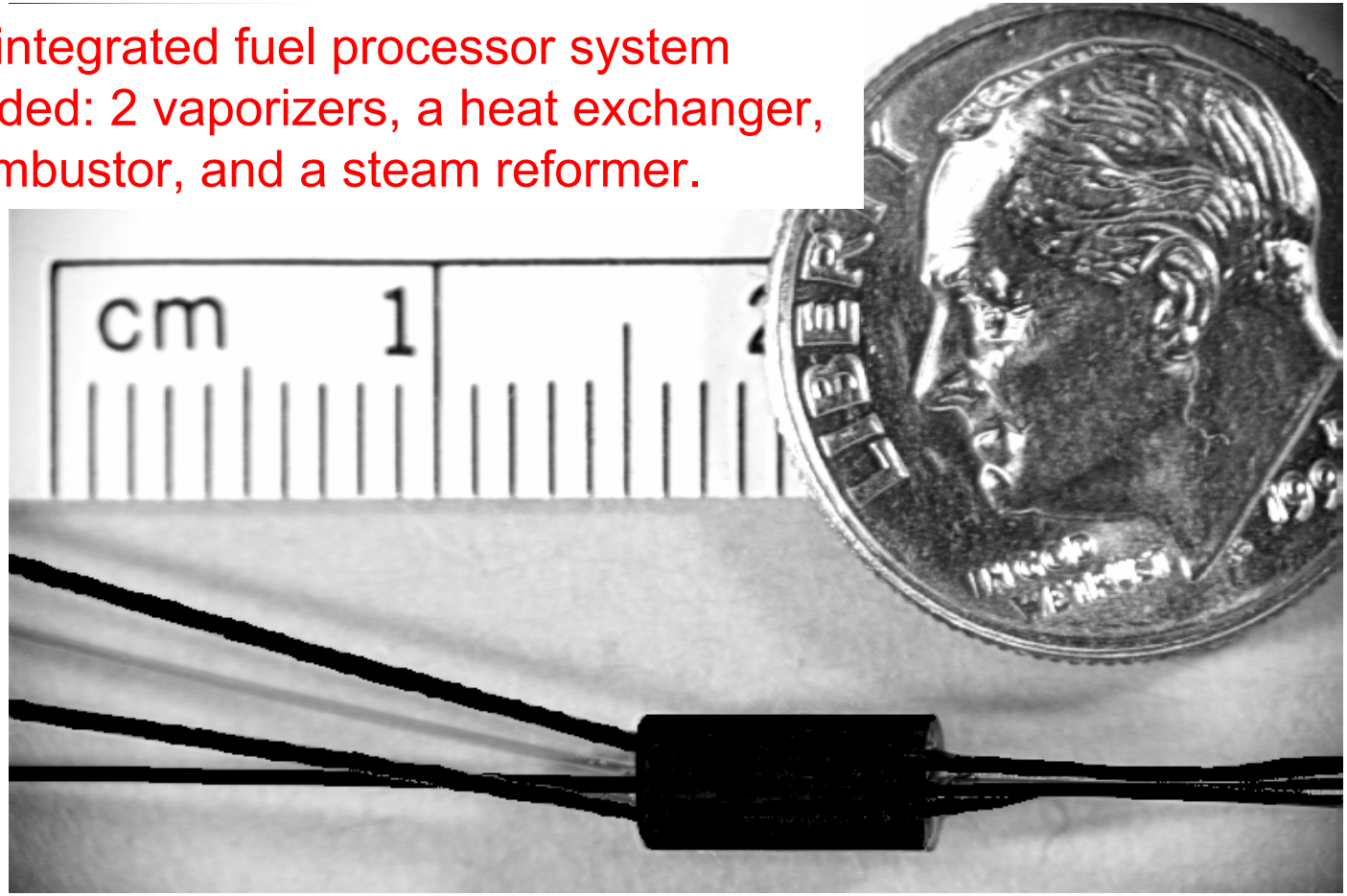
- For methanol reforming the H_2 yield is close to theoretical maximum
- CO Concentration (~1 vol.%) low enough to eliminate the need for additional reactors

MTO DARPA

Battelle . . . Putting Technology To Work

Experimental Reactor

The integrated fuel processor system included: 2 vaporizers, a heat exchanger, a combustor, and a steam reformer.



reformer volume: <5 mm^3

reformer capacity: 200 mW

combustor volume: < 5 mm^3

combustor capacity: 3 W

MTO DARPA

Battelle . . . Putting Technology To Work

Reforming Reactor Test Results

- Reactor Output:
  - H_2 flow = 0.1 –1.1 sccm
  - Power = 18-200 mW_t
  - Efficiency 3%-9%
- Estimated electric power output
  - Assumptions
    - 60% efficient fuel cell
    - 80% H_2 utilization
  - Power 9-100 mW_e
  - Efficiency 1.5-4.8%
- Reactor Conditions:
  - Contact time: 50-300 mS
  - Temperature: 300-475°C
  - Pressure ~ atmospheric

MTO DARPA

Battelle . . . Putting Technology To Work

High Temperature Mesoscale Fuel Cells

- Joint Effort with Battelle – PNNL
- Electrode areas ≈ 1 cm^2
- Electrodes, current collectors printed on PBI electrolyte membrane
- Cell interconnects, heaters, RTD printed on alumina
- Adhesive assembly of components
- Cathodes exposed to ambient air

Greek "*Mesos*"; middle

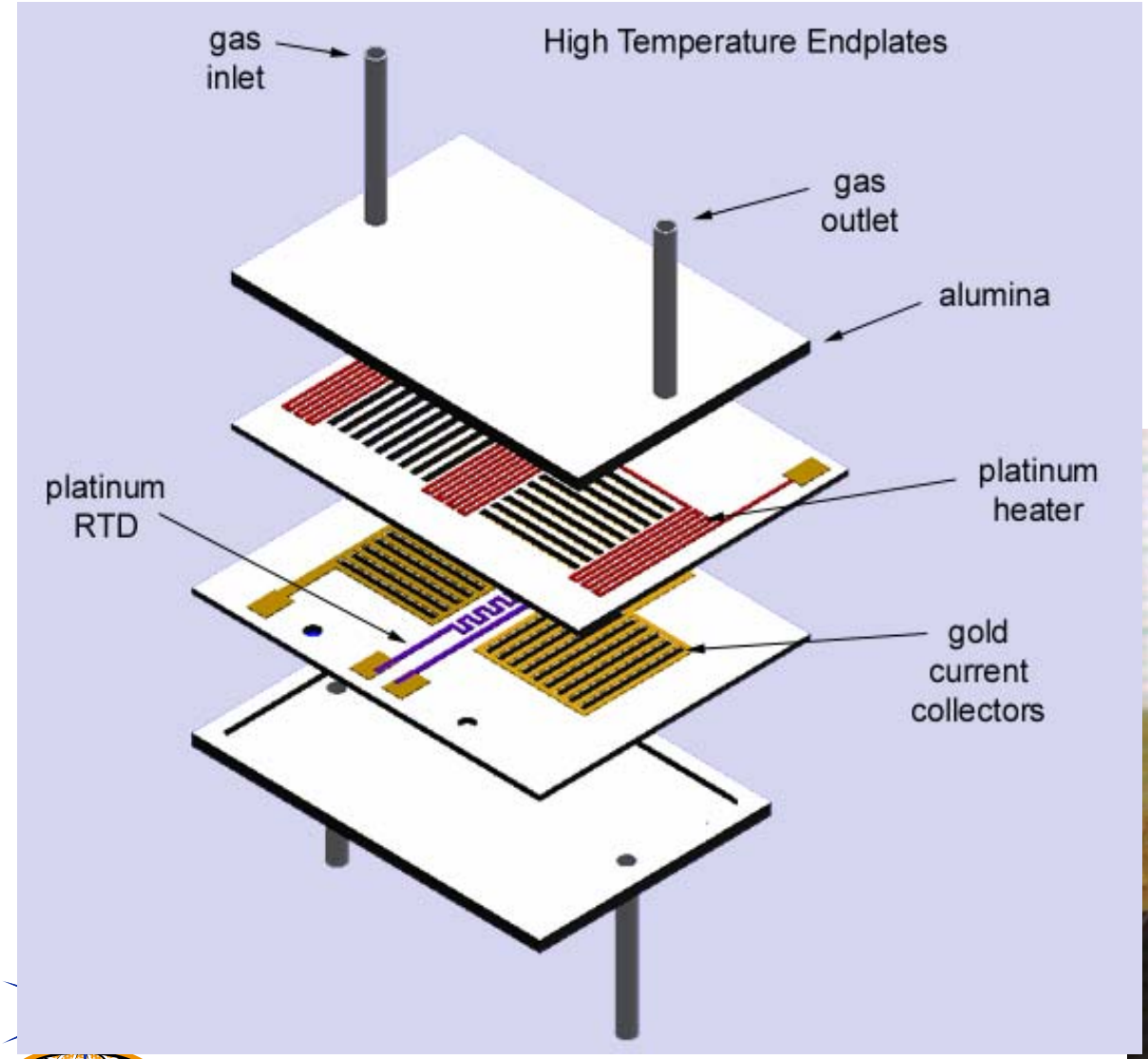
• this is an intermediate sized device, and the construction uses both microfabricated and conventionally fabricated components

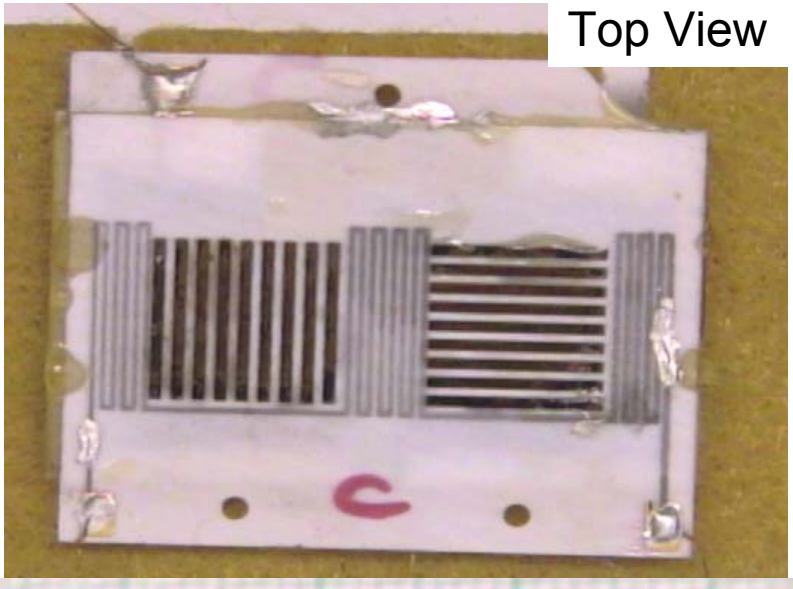
MTO DARPA

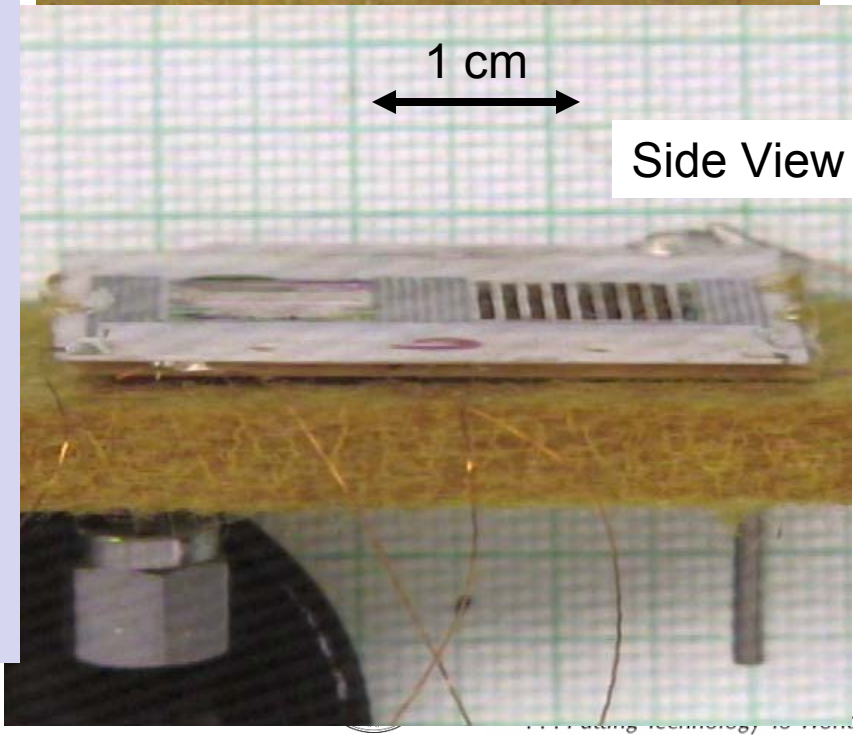
Battelle . . . Putting Technology To Work

High Temperature Mesoscale Fuel Cells

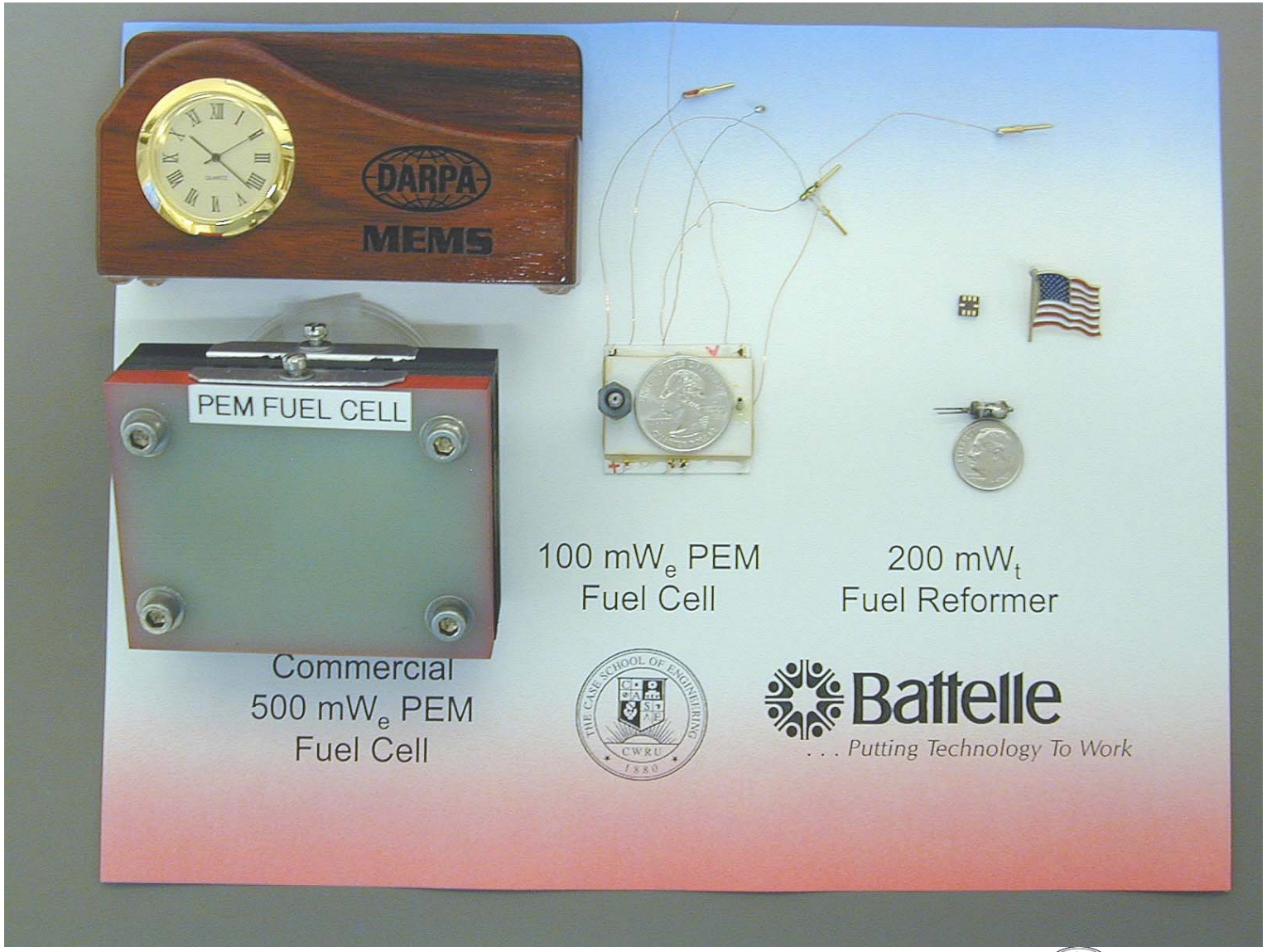
Fuel Cell Fabrication







Size Comparison



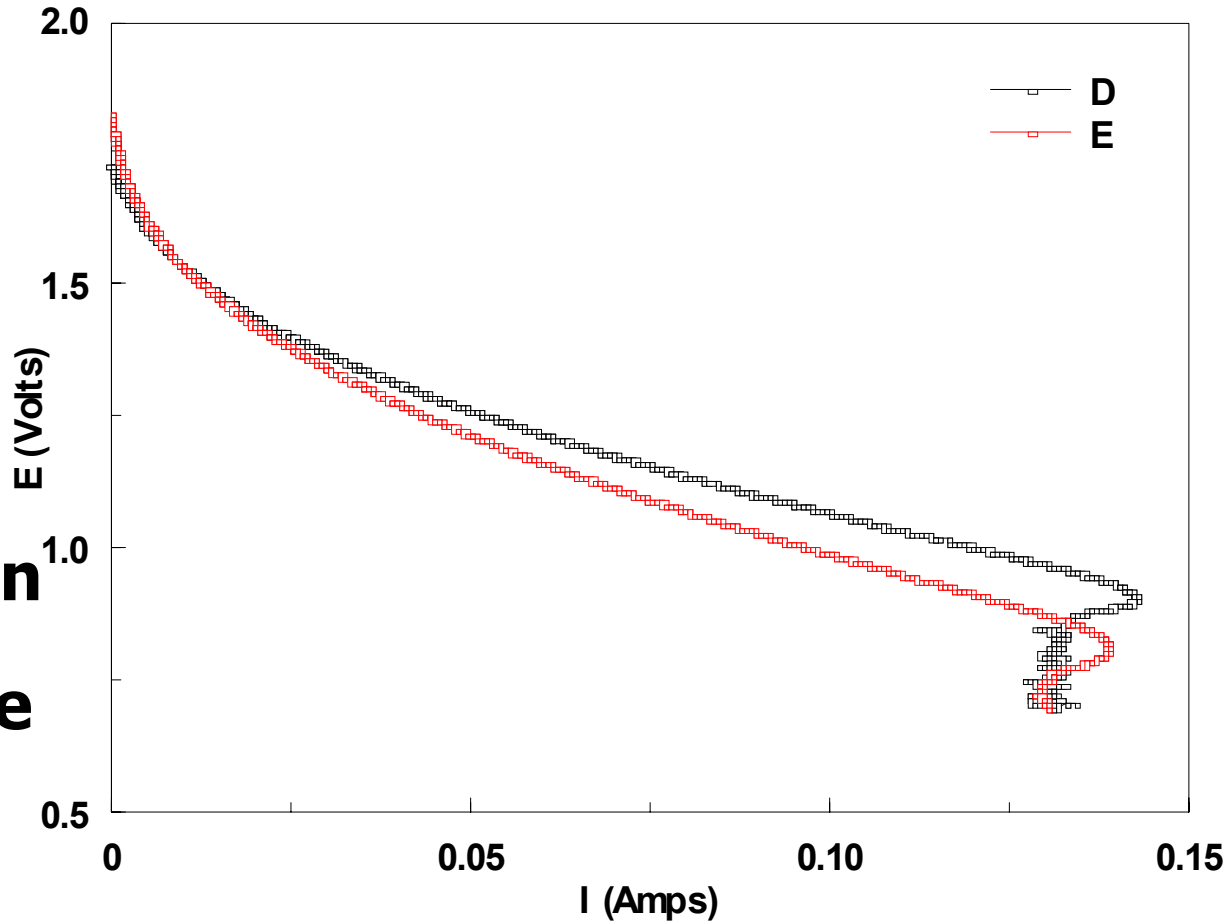
MTO DARPA

Battelle . . . Putting Technology To Work

High Temperature Mesoscale Fuel Cells

- Data shown for two different devices
- 2 Cells in Series per device
- H_2 feed at 1.7 sccm

  ≈90% fuel utilization
- Air Breathing Cathode
- 150 C
- ≈100 mW @ 1V

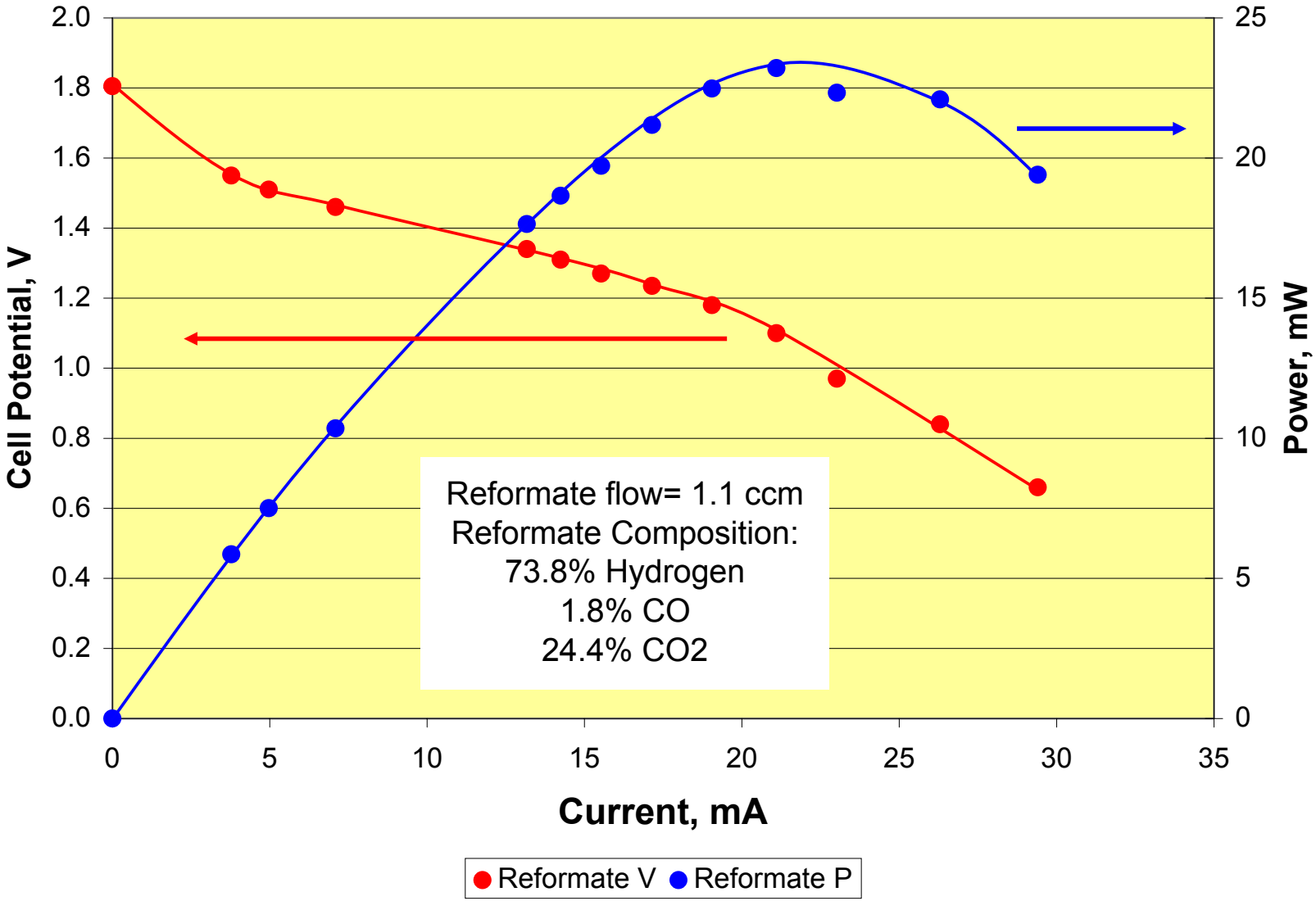


Device performance should be a good match with Battelle microreformer

MTO DARPA

Battelle . . . Putting Technology To Work

Fuel Processor and Fuel Cell System Testing



MTO DARPA

Battelle . . . Putting Technology To Work

Future Work

- Improved System
  - Fuel processor development
  - Fuel Cell improvement
- Systemization
  - Thermal integration
  - BOP
- See us at www.pnl.gov/microcats/

MICRO-CATS™

MTO DARPA

Battelle . . . Putting Technology To Work