

Hydrogen and Fuel Cells: Research at UD

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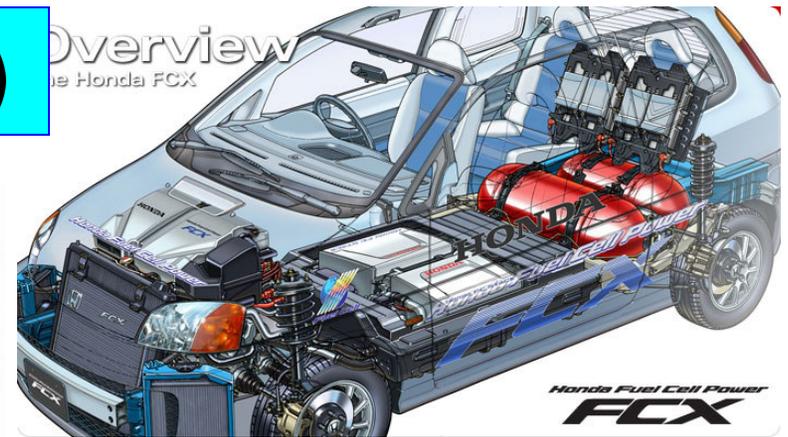
Director, Center for Fuel Cell Research

University of Delaware

DE Energy Plan Working Group

August 25, 2008

Automotive fuel cells (PEM)



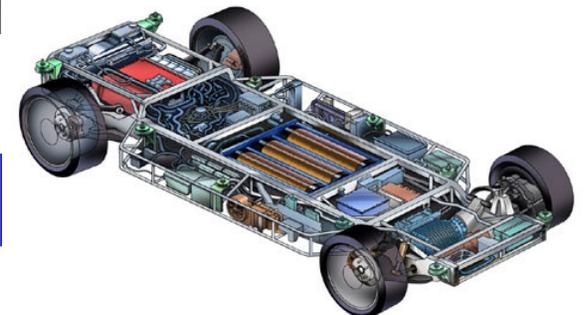
Honda FCX Clarity



Clean Urban Transport in Europe (CUTE):
30 fuel cell buses operated in European
capitals over the past two years.



GM's skateboard
chassis idea.



Fuel cells for stationary power (SOFC)



UTC Fuel Cells: (PureCell™ 200) 200kW of electricity and 900,000 BTUs of usable heat. This system provides clean, reliable power at locations including a New York City police station, a major postal facility in Alaska, a credit-card processing system facility in Nebraska, and a science center in Japan.

UTC Fuel Cells: 5kW fuel cell power plants for backup power for telecommunications towers, power for small businesses, and residential use.



Fuel cells for portable power (DMFC)



Casio: World's smallest fuel cell for use in laptop PC, and aims to market it in 2007. The polymer electrolyte fuel can power a typical laptop computer for eight to 16 hours.

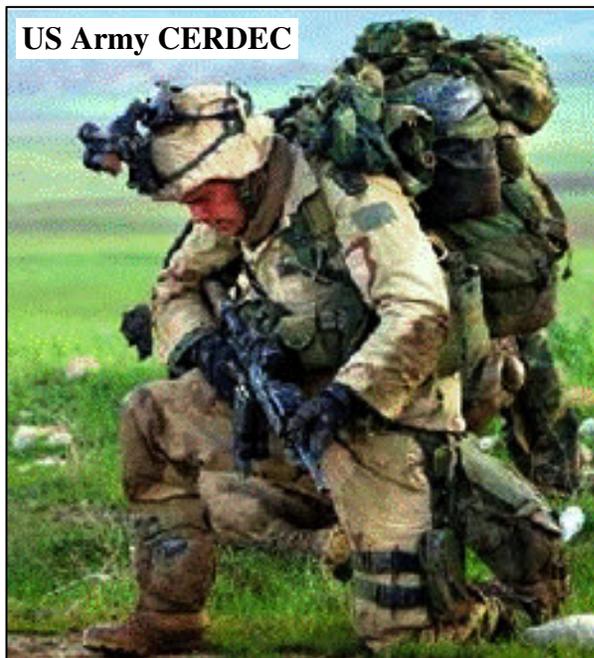


Samsung Electronics: 100Wh laptop PC fuel cell using 100cc of methanol solution, enabling continuous usage for more than 10 hours without recharging.

Fuel cells for soldier power, automotive and stationary power

DARPA, Defense Science Office- Robust Portable Power:

“Today’s warfighter must often carry an extremely cumbersome number of heavy primary batteries in order to provide power to various radios, laptops, laser designators, and other mission critical electronic equipment. DARPA’s investments in portable power have demonstrated that **fuel cell** and Stirling engine generators can achieve energy densities up to **seven times** that of today’s military logistic batteries.”



(Nicholas Sifer, Army Power Division)

Objective: Reduce the logistics burden of batteries by demonstrating novel, high density, energy conversion devices for soldier-portable or robotic applications



55 BA-5590 +2 BA-5800 = 125 lbs

... A typical requirement for ONE operational day for a radio reconnaissance team!!!



Portable, lightweight, devices that convert logistic fuels to electrical power

(Valerie Browning, DARPA)

UD Engineering Faculty involved in Fuel Cell/Hydrogen research

Civil

Chu
Cha
Faghri
Huang

Chemical

Barteau
Buttrey
Chen
Epps
Lauterbach
Vlachos
Wagner
Willis

Electrical

Honsberg
Prather

Matl. Sci.

Birkmire
Shah

Mechanical

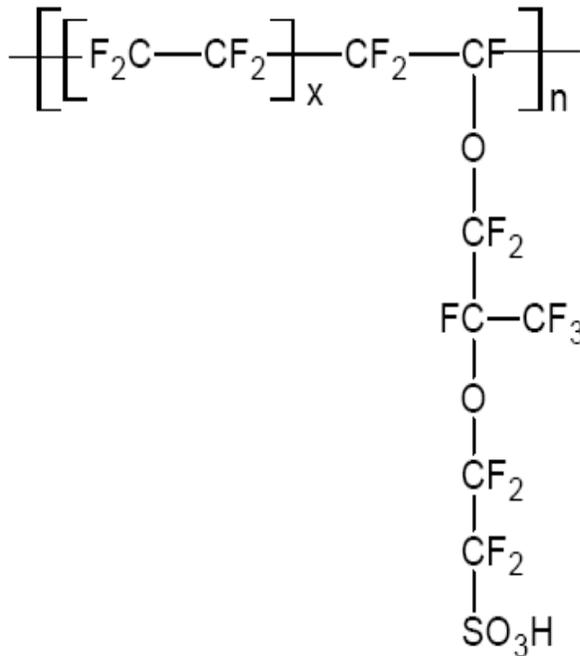
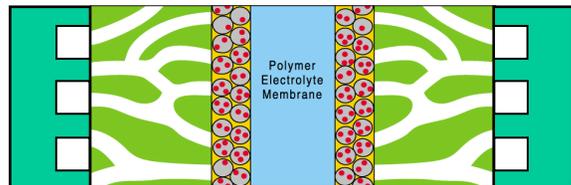
Advani
Karlsson
Prasad
Roy
Santare
Sarkar
Wang, LP
Wei

Center for Fuel Cell Research

- Thriving research in COE in fuel cells with funding from FTA, NSF, DOE, ARO, ONR, AFOSR, ARL, DNREC, DEDO, WL Gore, Air Liquide, Fuceltech, Amsen, DuPont, BP, ACS-PRF, ConocoPhillips, Rohm-Haas, Engelhard/BASF, and Praxair.
- Proximity to Dupont, WL Gore, Ion Power, Air Liquide, Air Products, Arkema, Johnson-Matthey, BASF.
- Strong buy-in and support for fuel cell research from Delaware congressional delegations and government.

Polymer Electrolyte Membrane (PEM)

(Collaboration between UD and WL Gore)



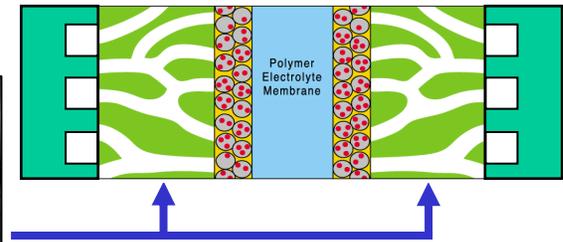
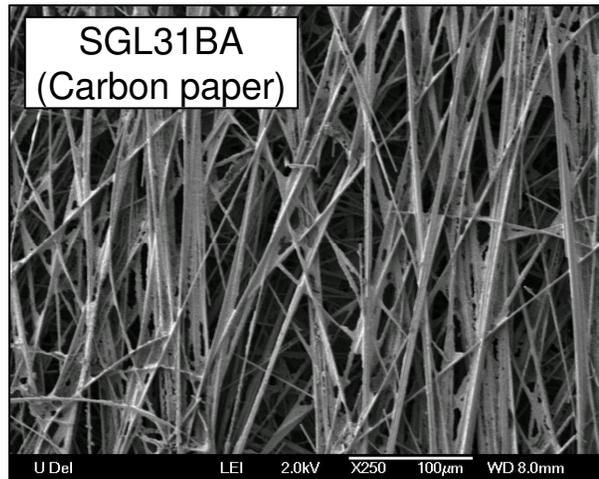
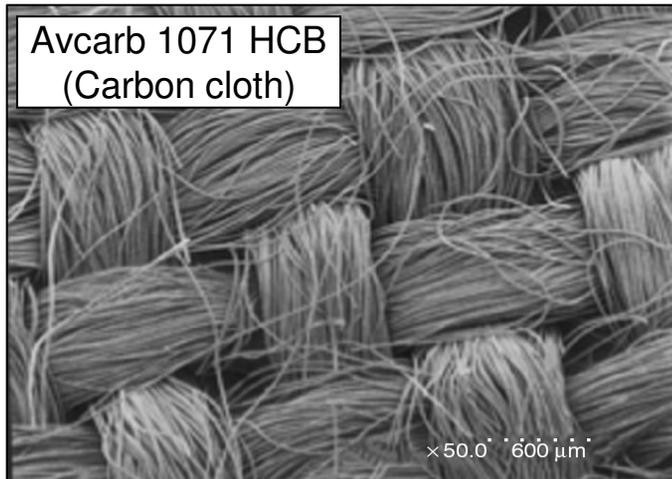
PFSA (Nafion®)

- Nafion cost is ~ \$2000/kg.
Need ~ 1kg for 100 kW vehicle.
- GM projects that cost will drop to \$50/kg at high production volume (million cars/year).

Issues:

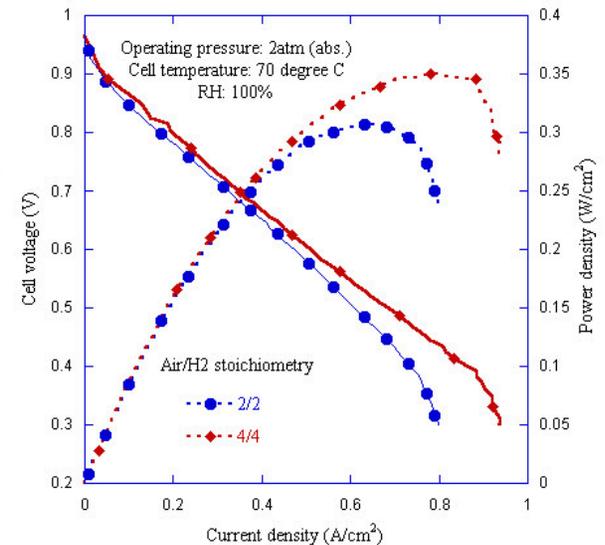
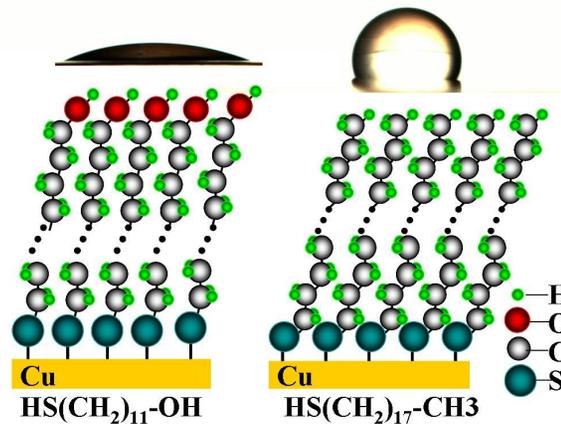
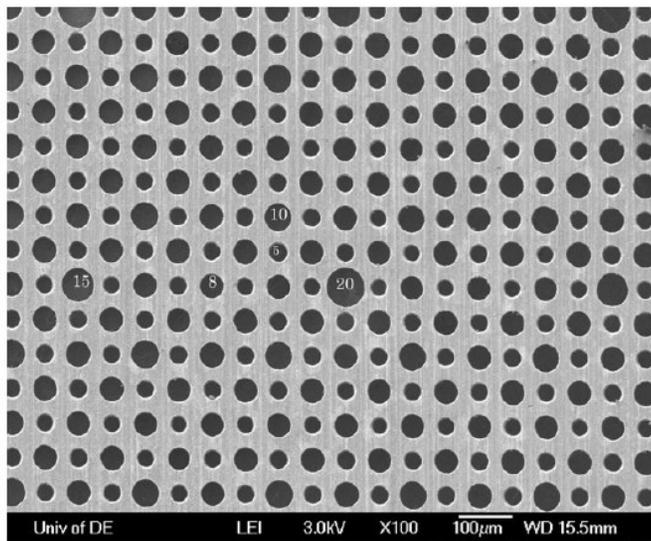
- Low temperature membrane, high Pt loading, CO poisoning
- Requires careful control of hydration
- Suffers from fuel crossover
- Undergoes hygrothermal loading
- Freeze-tolerance?

Gas Diffusion Layers (GDL)

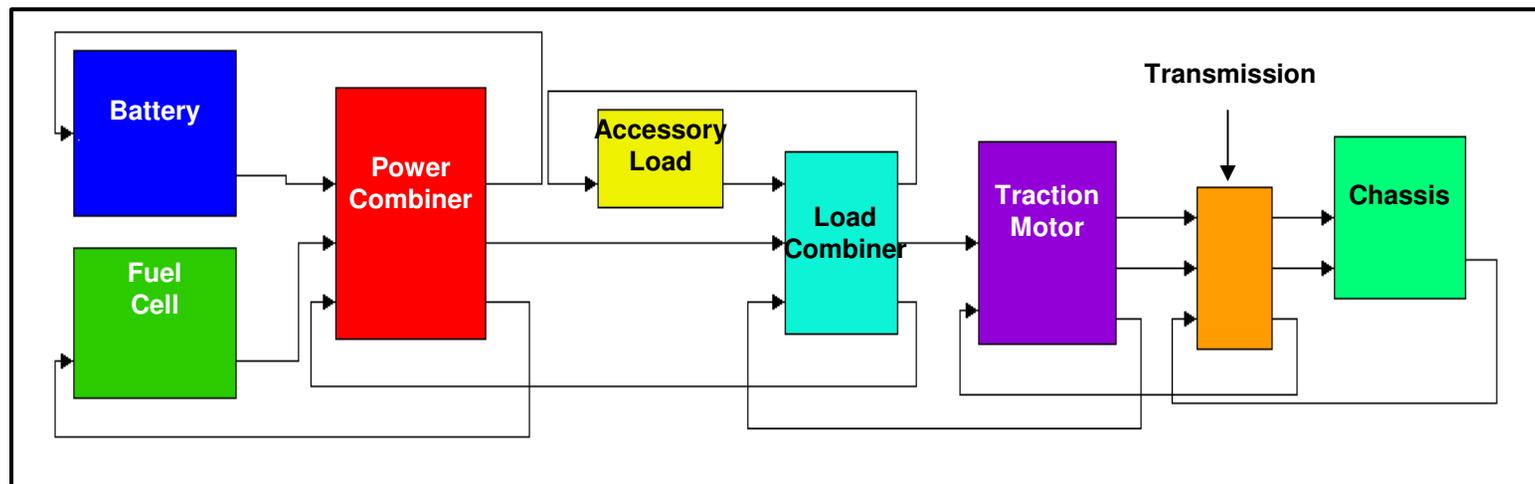


Highly porous, good electrical and thermal conductivity, water management

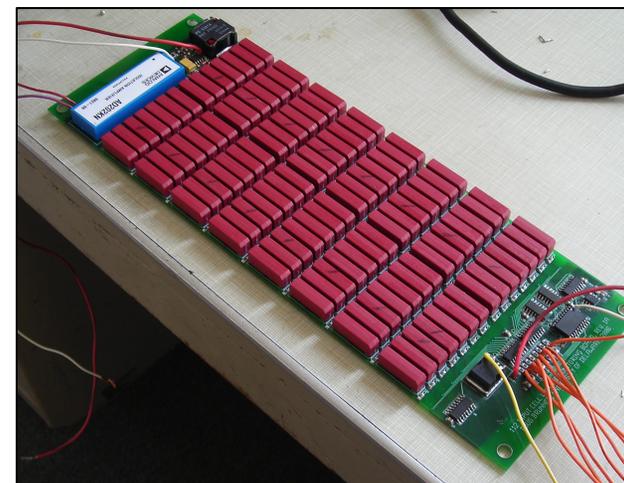
Novel metallic gas diffusion layer (Zhang, Prasad and Advani)



Matlab/Simulink drive-train simulator for fuel cell hybrid transit vehicles (Brown, Advani and Prasad)

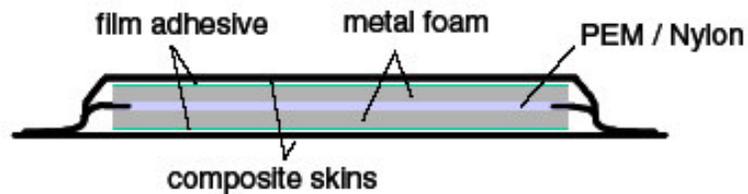
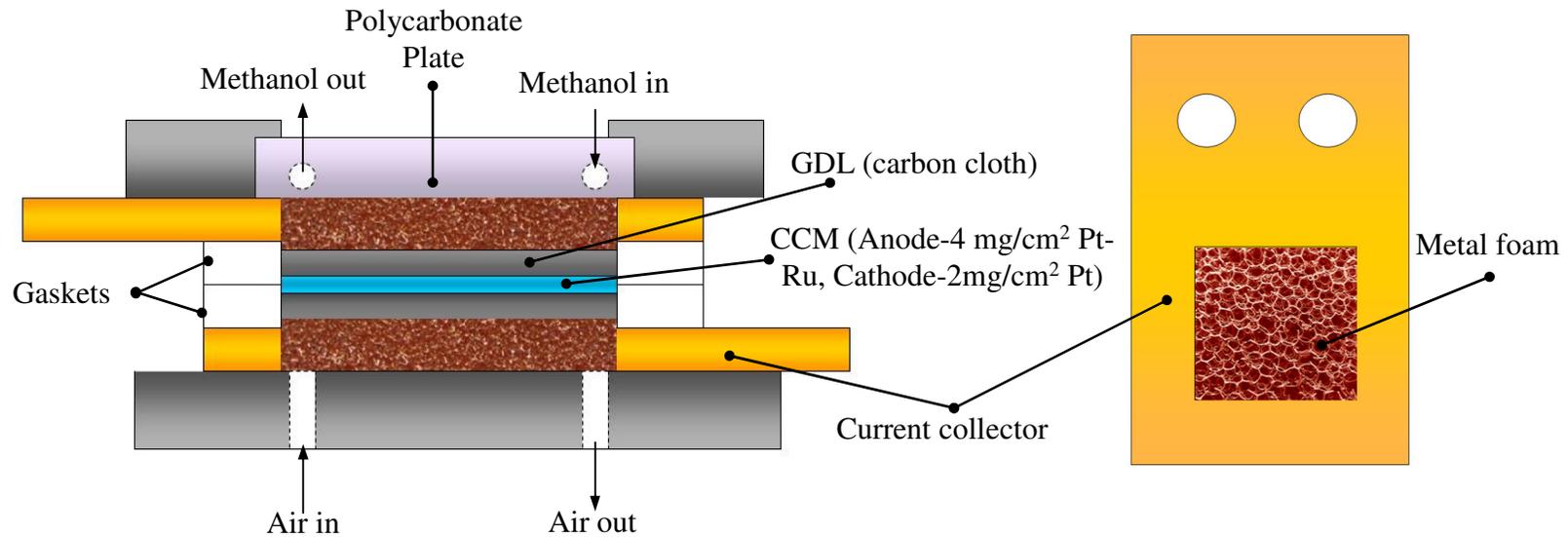


Cell voltage monitoring system for real time fuel cell stack diagnostics (Brunner, Advani, and Prasad)

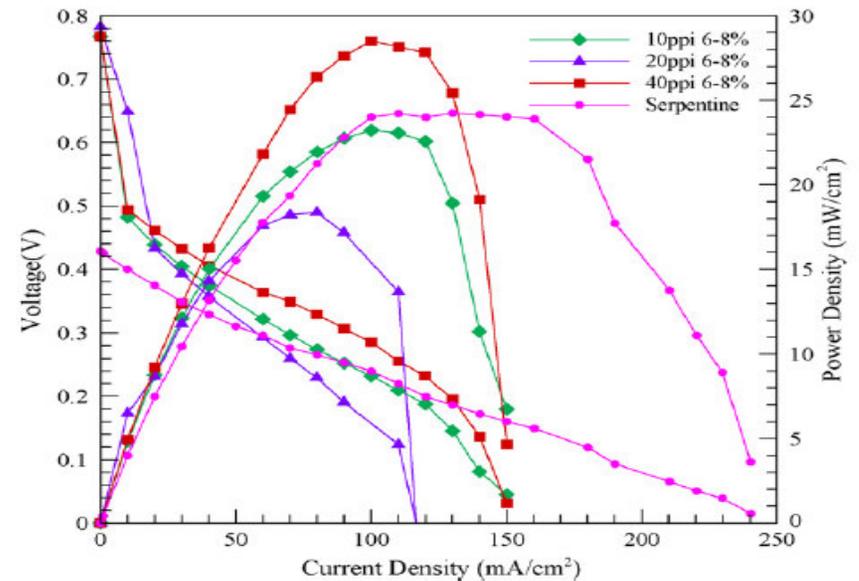


Multifunctional composites: Use of metal foams in DMFC

(Arisetty, Advani and Prasad)



ARL



Where will the Hydrogen come from?

Currently:

- Steam reforming of natural gas
- Produces GHG's! Hence, not sustainable

Are there viable alternatives? Hydro, nuclear, ...

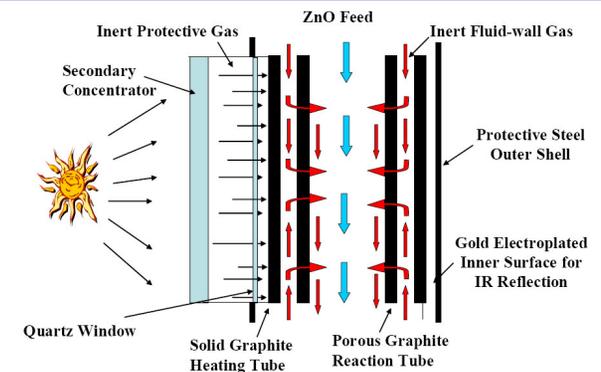
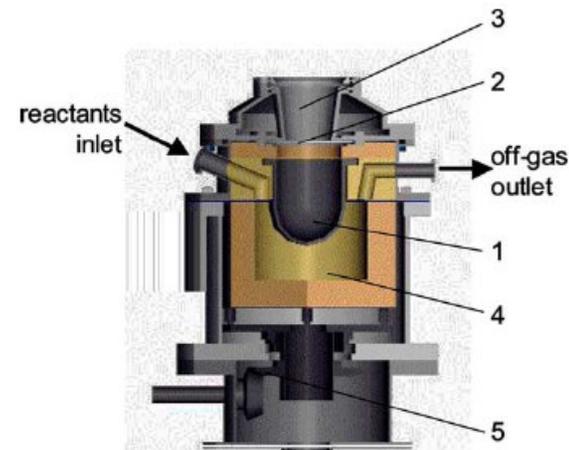
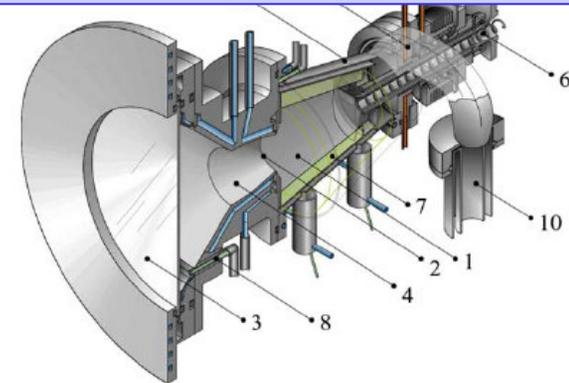
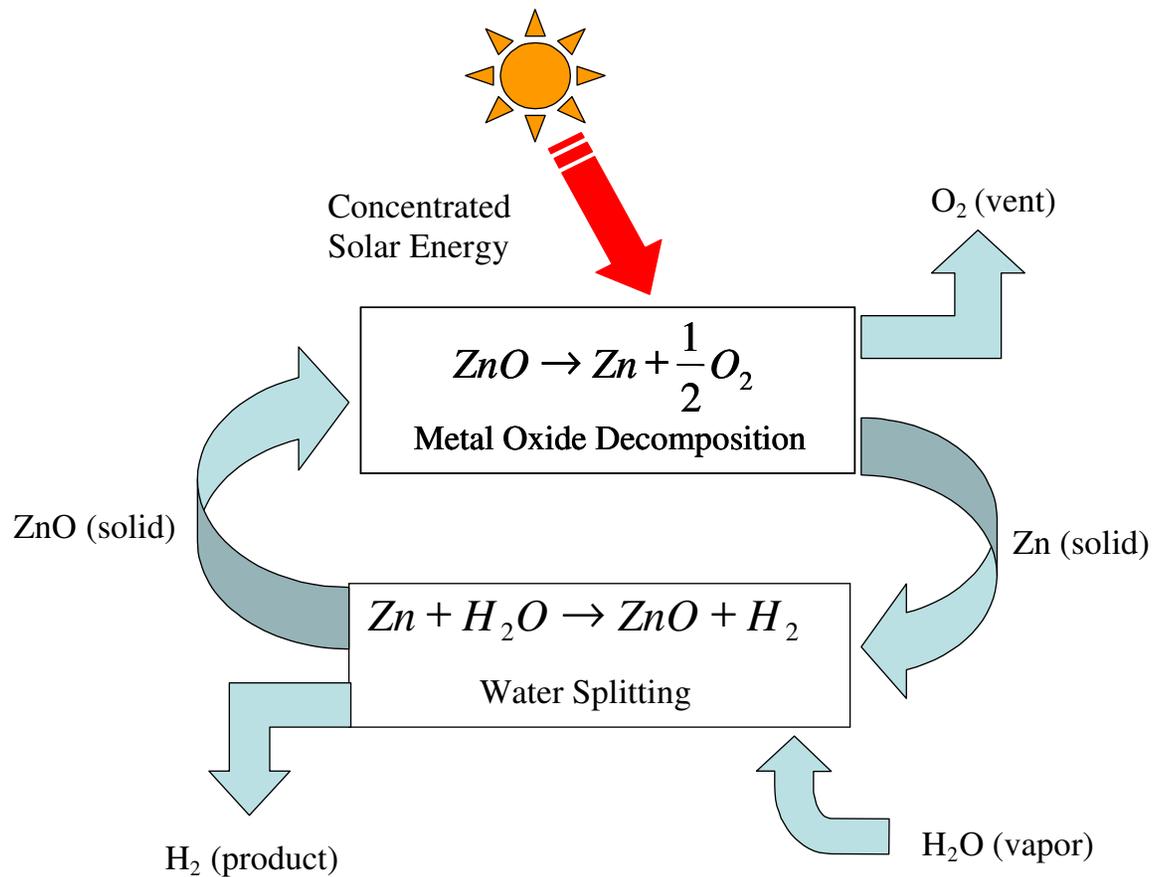
Renewable options:

- Thermochemical
- photo-electro-chemical
- photo-biological

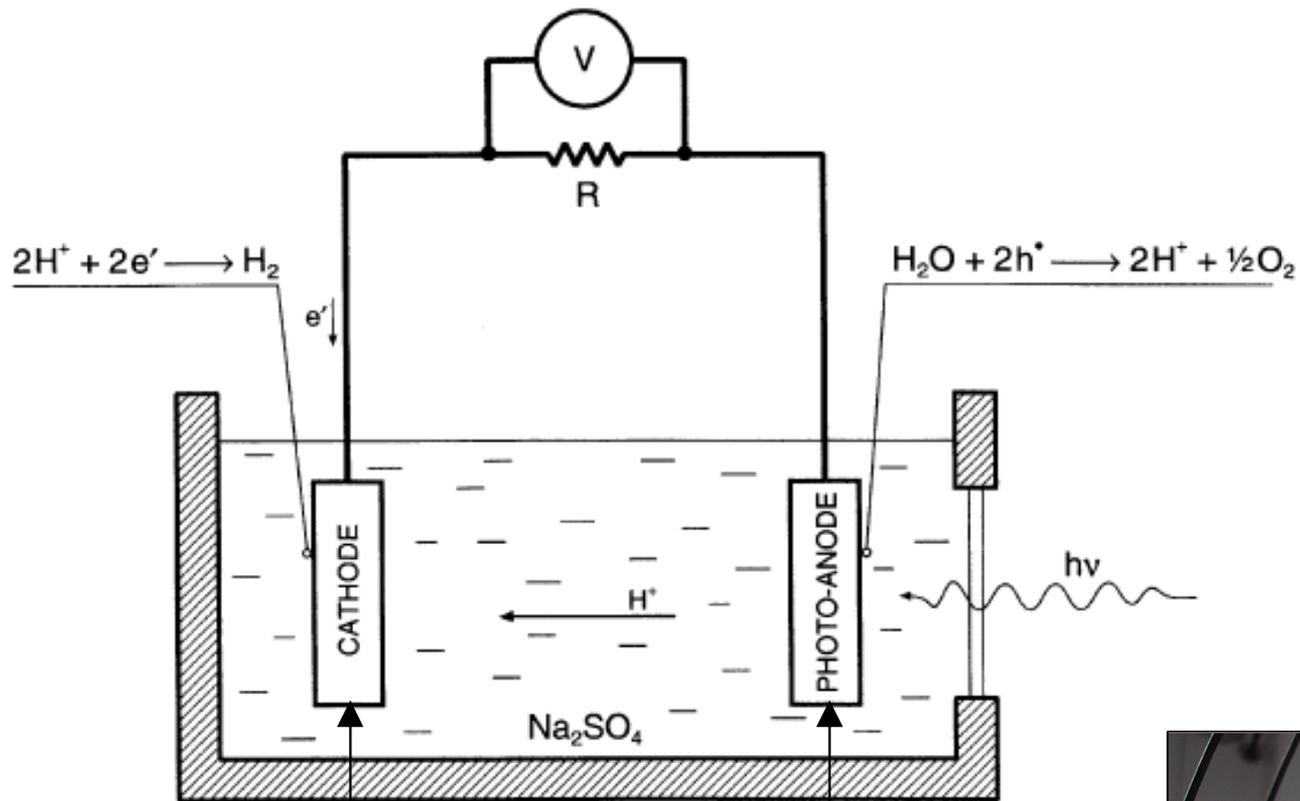
H₂ production from solar energy: Thermochemical cycles

(Koepf, Advani and Prasad; Collaboration Air Liquide)

Zinc Oxide cycle for the thermochemical splitting of water

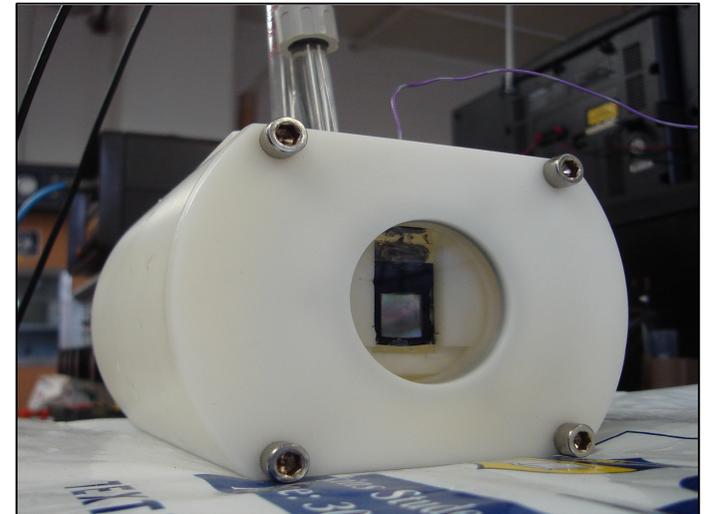


H₂ production from solar energy: Photo-electro-chemical (PEC)

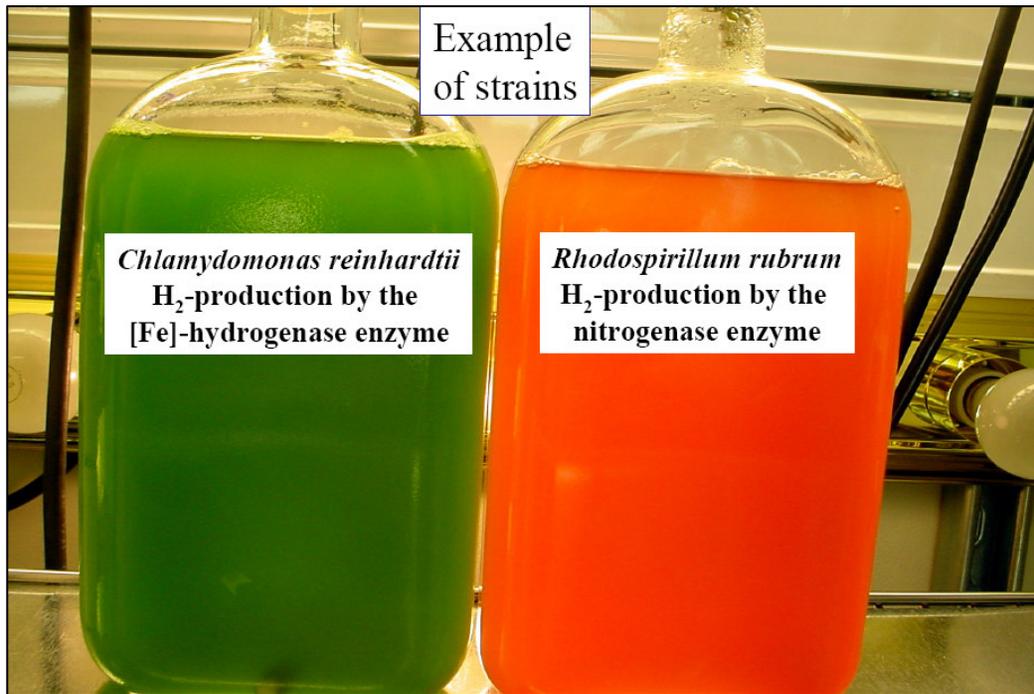
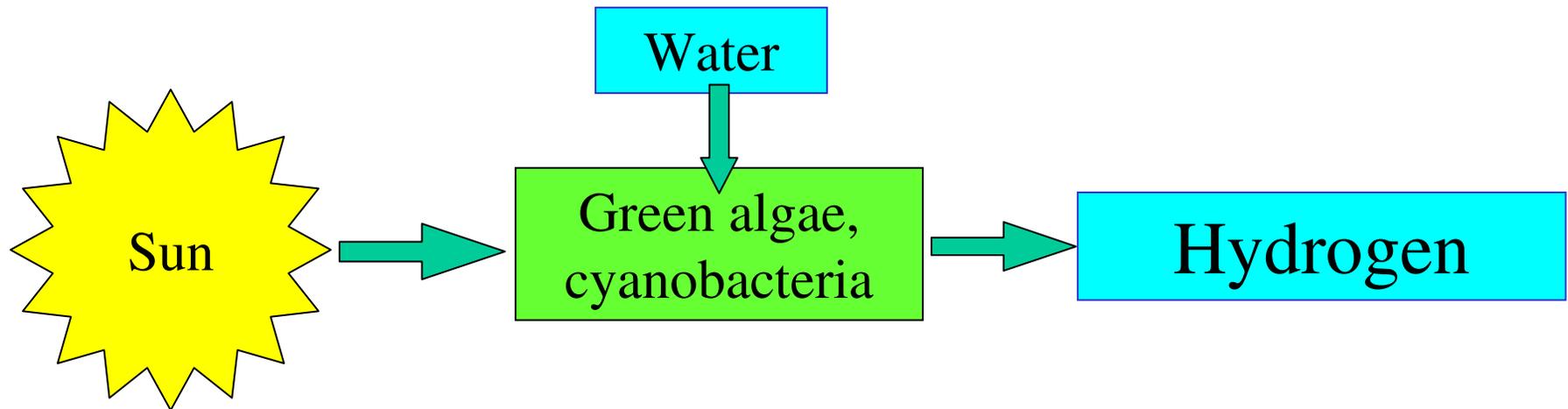


Tungsten Monocarbide
as a novel low-cost
counter electrode for
PEC (Esposito, Chen
and Birkmire)

N-doped TiO₂
Photoelectrodes for
Solar Hydrogen
Generation
(Schulz and Shah)



H₂ production from solar energy: Photobiological water splitting (Dan Cha, Civil Eng)

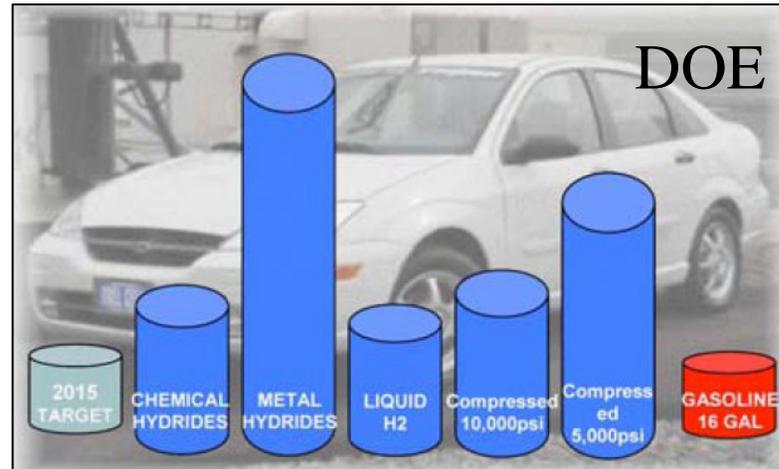


DOE



DOE

H2 storage: H2 is light! Difficult to store



Options:

- Compressed Hydrogen at 10,000 psi
- Liquefied Hydrogen at 22 K (- 420 F)
- Solid state materials, complex hydrides: highest potential (Collaboration between UD, Del State Univ, Air Liquide)

UD Fuel Cell Hybrid Bus Program

UD Fuel Cell Bus Program: 05-09

- Phase 1: 22-ft bus, 20 kW stack, Ni-Cad batteries (in operation, 100 students/day)
- Phase 2: 22-ft bus, 40 kW stack, Li-Ti batteries (Spring '08)
- Phase 3: 30-ft bus (Spring '09)
- Phase 4: 30-ft bus, plus refueling stations in Wilmington and Dover



H2 Refueling station at Air Liquide



FC Bus Roll-out on April 9, 2007



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Delaware's First Fuel Cell Powered Bus



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