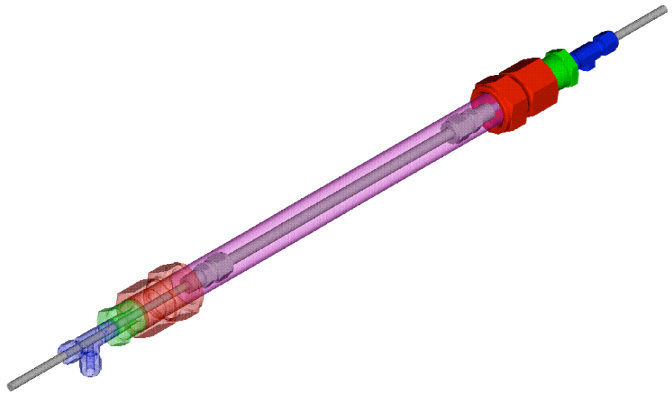
High Temperature, Inorganic Membranes for Hydrogen Production with CO_2 Capture



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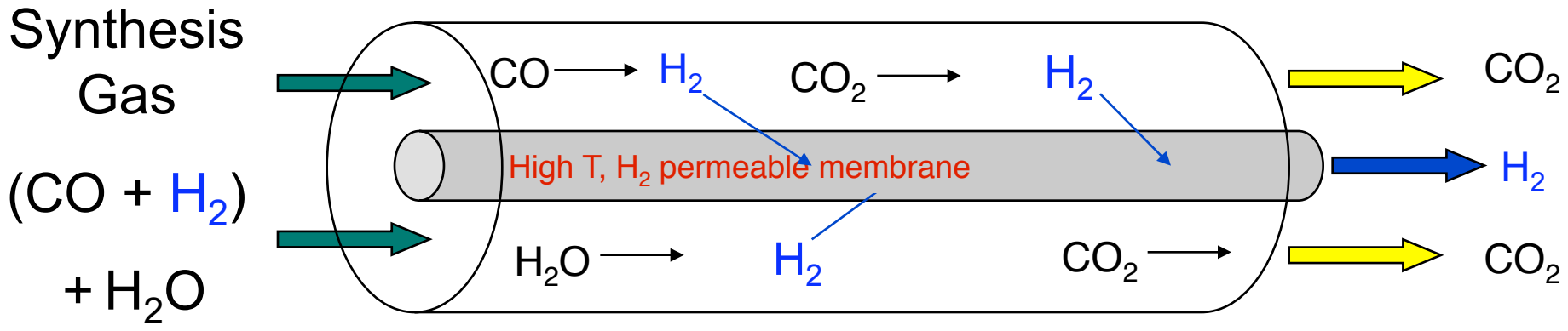
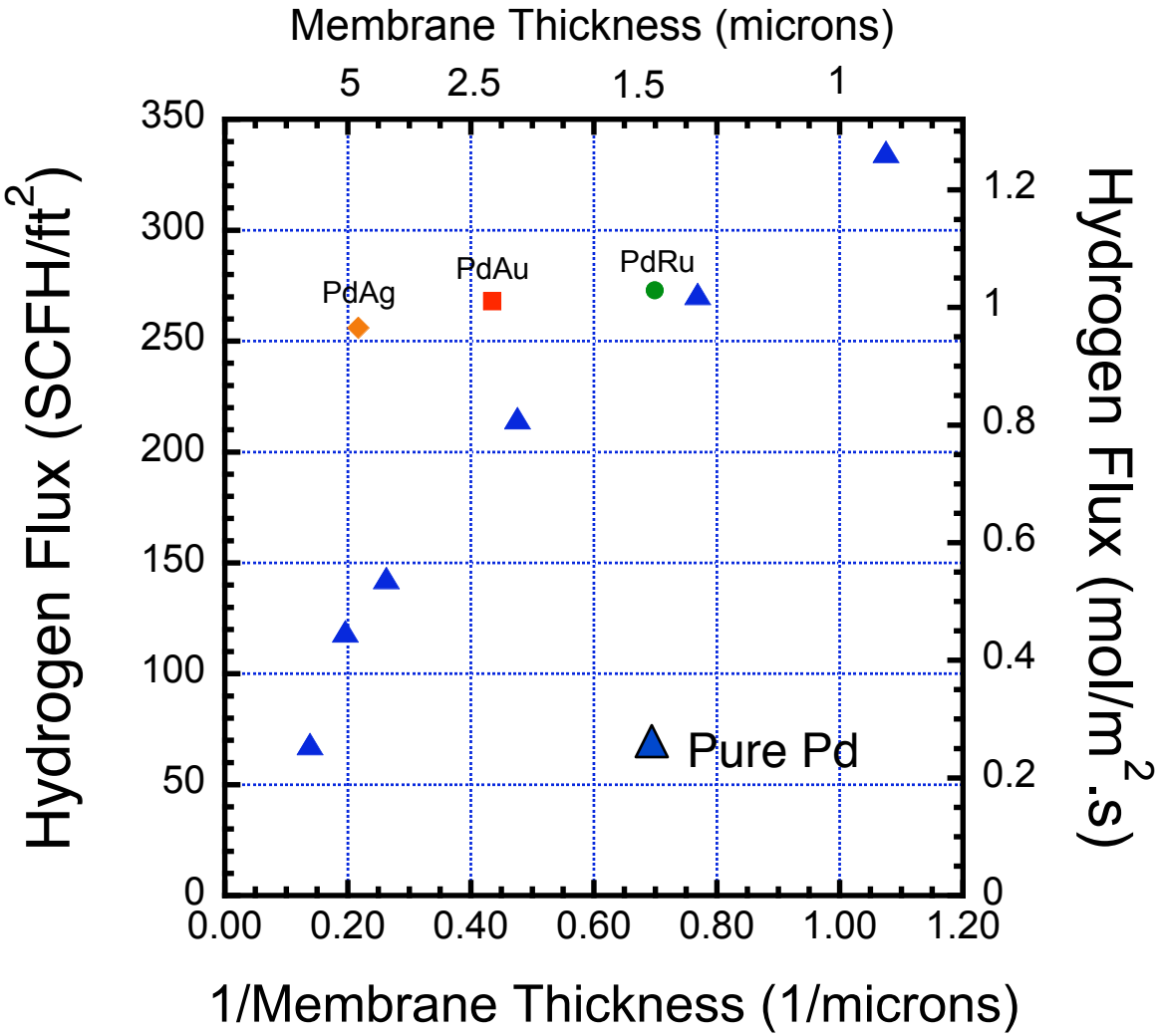
Pre-combustion Carbon Capture using Water Gas Shift Reactor/H_2 Sepn

$$CO + H_2O = H_2 + CO_2$$



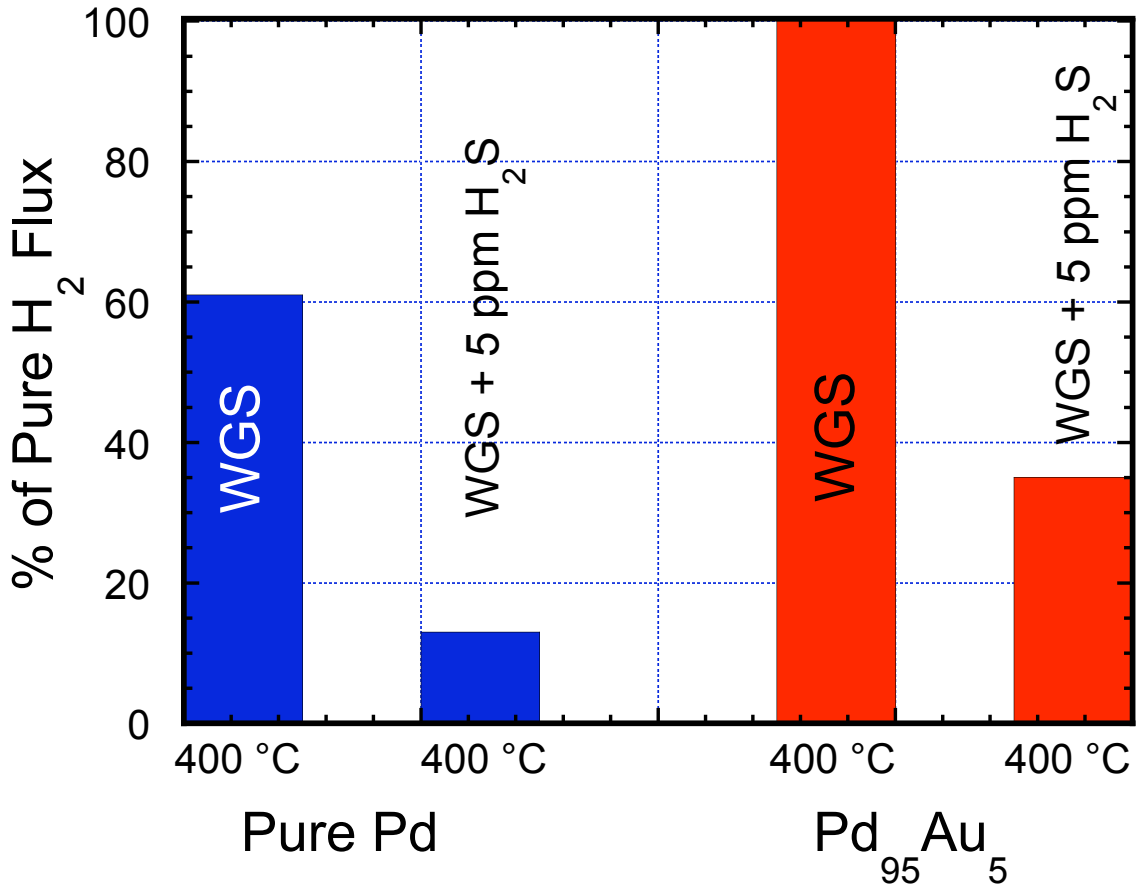
- A WGS membrane reactor could produce **both** a pure hydrogen product and a retentate stream containing CO_2, still at high pressure
  - Removal of product H_2 will shift the equil. towards products, maximizing conversion of CO
  - S. Uemiya et al., *Ind. Eng. Chem. Res*. **30** (1991) 585-589.
- Can also have WGS reactor and membrane separator as separate process units
  - BP (CO_2 Capture Project) design has 3 WGS reactors/membranes in series

Pd and Pd alloy AccuSep® Membranes @ 400 °C, ΔP = 20 psig, Pure H_2



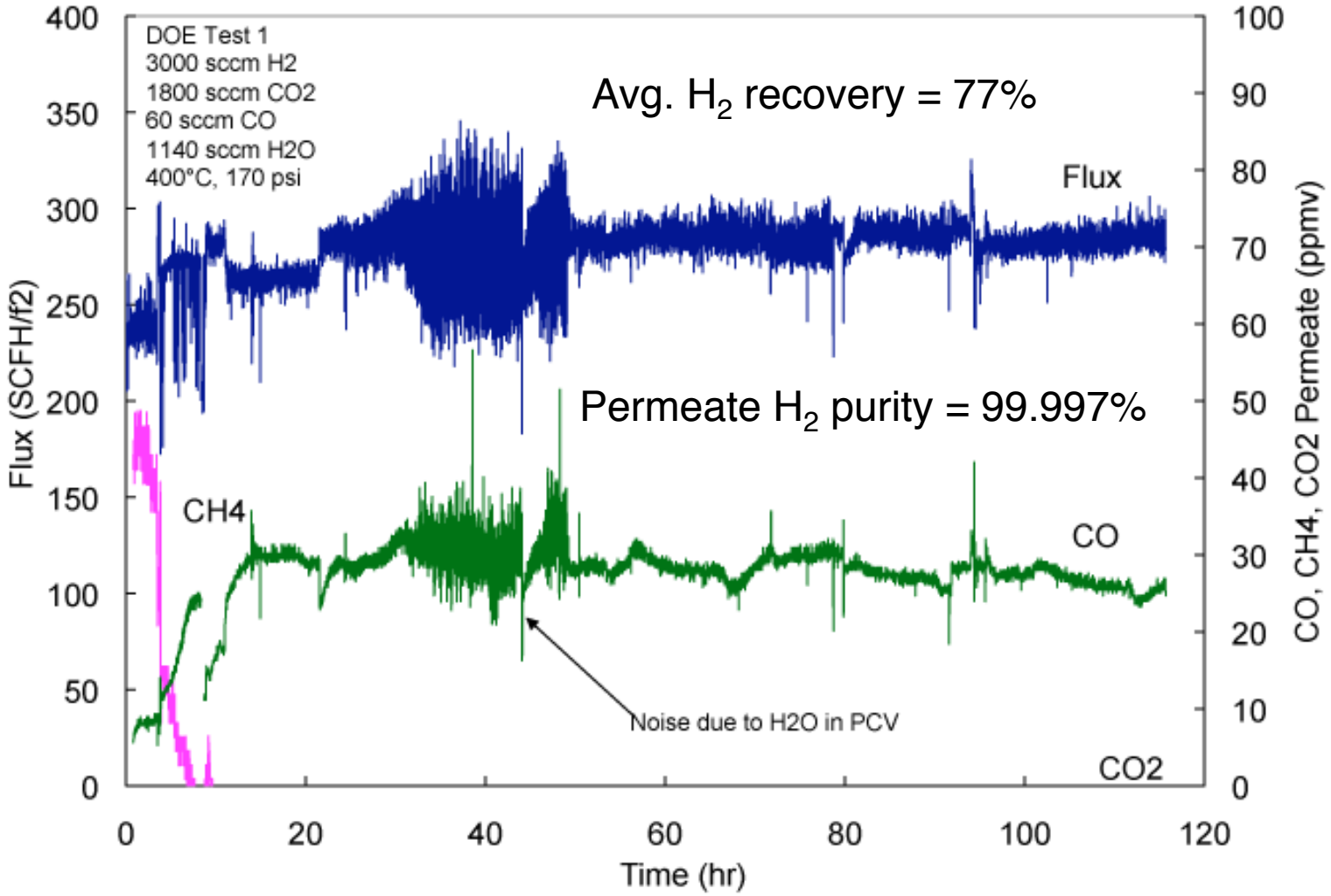
- How big is a flux of 200 SCFH/ft^2?
- 2 inch long tubular membrane element will produce ~100 L/hr of hydrogen or 0.2 kg/day at a H_2 pressure difference of 20 psi
- Pure H_2 permeance = 91 ft^3(STP)/ft^2.h.psia$^{0.5}$

Pd and $Pd_{95}Au_5$ (#105) with WGS Feed and WGS + H_2S, 400 °C, 50 psig Feed Pressure



- WGS composition: 51% H_2, 26% CO_2, 21% H_2O, 2% CO

CSM 214 ($Pd_{81}Au_{29}$), 4.7 micron 170 psig, 400 °C, WGS Test



Cost of Pd in a Composite Membrane

- Common misconception: “The cost of Pd is too large for a system to be practical”
- A 25 cm long, 2 μm thick $Pd_{85}Au_{15}$ film on a 1 cm diameter tubular support: 80 cm^2 active area, ~ 9 slm H_2 @ 20 psig feed pressure
  - Requires ~0.2 g of Pd and 0.052 g of Au
  - Retail cost for Pd from $PdCl_2$ = $23.80/g
  - Pd cost ~ $4.77
  - Retail cost of Au from $AuCl_3$ = $66.20/g
  - Au cost ~ $3.44
  - Total retail metals cost ~ $8 ($400/m^2 for Pd & Au based on spot market)
- Membrane support, module and labor costs will dominate

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C2B2 Colorado Center for Biorefining and Biofuels

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