Palladium composite membranes based on sinter metal supports for use in dehydrogenation of propane

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Motivation

Thin-film composite palladium membranes can be used for hydrogen separators and dehydrogenation reactors.

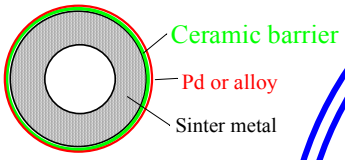
$R\text{-}CH_2\text{-}CH_2\text{-}R \rightleftharpoons R\text{-}CH{=}CH\text{-}R + H_2$

Separated by membranes in the reactor

Overcome equilibrium limitation — Burning H_2 supplies heat

Advantages of composite membrane on sinter metals:

- Low palladium amount (cost)
- High H_2 permeability
- Easy module construction



Ceramic barrier:

- To avoid inter-diffusion between Pd and sinter metal.

Membrane preparation

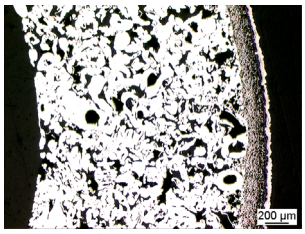
Support:
Asymmetric sinter metal tubes (coating on outer surface).

Ceramic barrier coating:

- PVD
- Wet powder spraying (WPS)
- Thermal spraying (APS: atmospheric plasma spraying)

Pd or Pd alloy membrane coating:

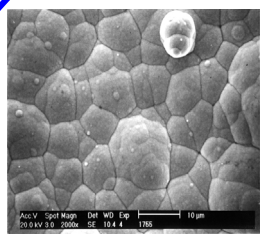
- PVD
- Thermal spraying (APS or HVOF: high velocity oxy-fuel flame spraying)
- Electroless plating (ELP)



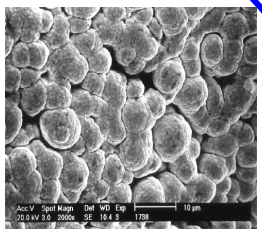
Membrane cross section

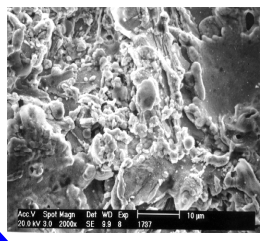
Pure Pd
Pd60%Cu40%
Pd77%Ag23%
} Membranes

Pd-ELP

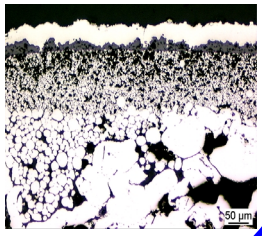


Pd-PVD





Surface view



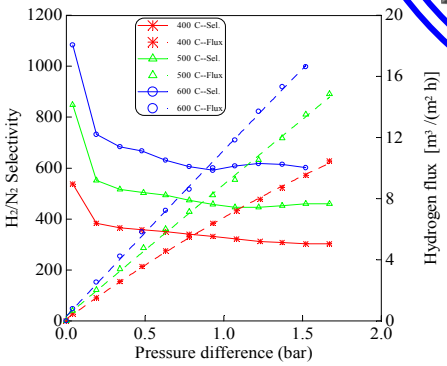
Cross section view

Pd-plasma spraying

Typical results

Pd membrane:

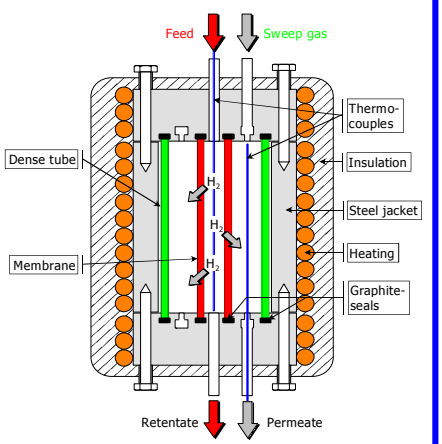
- Plated by ELP
- 11-cm-long
- 1-cm diameter
- Thickness of Pd layer: ~20 µm



Permeation results in single gas test

Temperature (°C)	H_2 Permeance F ($m^3/m^2 \cdot h \cdot bar^{0.5}$)
400	16.6
500	22.5
600	27.9

$$J_{H2} = F \cdot (P_{ret}^{0.5} - P_{perm}^{0.5})$$



Permeation and reaction apparatus

Achievements and Plans

- High H_2 permeability of ELP Pd-membranes
- Barrier properties presently limit successful plating of thinner Pd layers.
- Improvements of barrier surface roughness will allow thinner Pd membranes and thus higher H_2 fluxes.
- Membrane reactor tests under industrial process conditions are in progress, employing a new catalyst for propane dehydrogenation.
- PdCu and PdAg alloy membranes on sinter metal supports are being developed.
- Long-term tests on permeation and catalytic dehydrogenation are planned.
- Scale-up of membrane plating is in progress.
- Other applications of the developed membranes are being evaluated.

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