HIGH PRESSURE PEM WATER ELECTROLYSIS
AND CORRESPONDING SAFETY ISSUES

Pierre Millet

International conference on Hydrogen Safety
(ICH3S-09)
Ajaccio, France, 16-18 September 2009
GenHyPEM project and Consortium (2005-2008)
GenHyPEM consortium

Institut de Chimie Moléculaire et des Matériaux, Orsay, France

GenHyPEM
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STREP n° 019802
Total cost = 2.2 M€
EC support: 1.1 M€
3 years from 10/2005

PEM water electrolysers

Delta Plus Engineering
(Liège, Belgium)

Université Paris-Sud – CNRS
(coordination, Orsay, France)

OVM ICCPET
(Bucharest, Romania)

KBSU

“Kurchatov Institute”

GKN Sinter Metals gmbh
(Radevormwald, Germany)

Compagnie Européenne des Technologies de l’Hydrogène (Marcoussis, France)

RRC “Kurchatov Institute”
(Moscow, Russian Federation)
High pressure PEM water electrolysis
High pressure operation

Polarization curves measured at $T = 90^\circ C$

1 : $P = 1$ bar
2 : $P = 50$ bar.

No significant impact of pressure on electrochemical performances
High pressure operation

PEM WE cell

O2 purity at anode

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High pressure PEM electrolyzer hydrogen safety problems
2nd International Conference on Hydrogen Safety, San Sebastian, Spain, 11-13 September 2007
Gas cross-permeation phenomena
High pressure operation

Nafion microstructure (Yeager 1981)

Gas permeability
Modelling

- Thermodynamics: Henry’s law
- Kinetics: Fick’s law of diffusion

<table>
<thead>
<tr>
<th>T / °C</th>
<th>10</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{\text{O}_2}^m$/cm².Pa⁻¹.s⁻¹</td>
<td>2.1x10⁻¹²</td>
<td>2.3x10⁻¹²</td>
<td>3.7x10⁻¹²</td>
<td>5.3x10⁻¹²</td>
<td>8.4x10⁻¹²</td>
</tr>
<tr>
<td>$D_{\text{O}_2}$/ cm².s⁻¹</td>
<td>2.1x10⁻⁷</td>
<td>2.5x10⁻⁷</td>
<td>4.2x10⁻⁷</td>
<td>6.5x10⁻⁷</td>
<td>1.1x10⁻⁶</td>
</tr>
<tr>
<td>$P_{\text{H}_2}^m$/cm².Pa⁻¹.s⁻¹</td>
<td>3.8x10⁻¹²</td>
<td>4.6x10⁻¹²</td>
<td>7.6x10⁻¹²</td>
<td>1.2x10⁻¹¹</td>
<td>2.0x10⁻¹¹</td>
</tr>
<tr>
<td>$D_{\text{H}_2}$/ cm².s⁻¹</td>
<td>3.9x10⁻⁷</td>
<td>4.9x10⁻⁷</td>
<td>8.7x10⁻⁷</td>
<td>1.5x10⁻⁶</td>
<td>2.6x10⁻⁶</td>
</tr>
<tr>
<td>$D_{\text{H}<em>2}/D</em>{\text{O}_2}$</td>
<td>1.9</td>
<td>2.0</td>
<td>2.1</td>
<td>2.3</td>
<td>2.4</td>
</tr>
</tbody>
</table>

$\text{H}_2$ and $\text{O}_2$ permeability and diffusion coefficient in fully hydrated Nafion 117 at different temperatures.

the $\text{H}_2$ content in $\text{O}_2$ (at constant temperature and pressure) is inversely proportional to current density.
Design of a high pressure stack
High pressure test bench
High pressure PEM water electrolyzer

GenHy1000 PEM stack

Pressurization vessel
High pressure test bench
Polarization curves measured on the stack

\[ \varepsilon_{\Delta H} = 70\% \]

(1-4)

(5-6)

\[ \varepsilon_{\Delta H} = 80\% \]

\[ \varepsilon_{\Delta H} = 90\% \]
Technological developments
GenHy® PEM water electrolysers

GenHy® 1000 Nl H₂/hour
max input = 5 kW
1-10 bars

GenHy® 3000 Nl H₂/hour
max input = 5 kW
1-50 bars

GenHy® 5000 Nl H₂/hour
max input = 30 kW
1-10 bars

automated, EC certified
Conclusions & perspectives

Achievements

• GenHy®100 to GenHy®5000 (5 m$^3$ H$_2$/hour)
• operating pressure: up to 100 bars
• different technologies for different applications

Short-term perspectives

• non-noble electro-catalysts
• catalyst deposition techniques to be improved
• reversible systems