NESSHY

“Novel Efficient Solid Storage for Hydrogen”
Integrated Project SES6-CT-2006-518271

Theodore Steriotis
Institute of Physical Chemistry
National Center for Scientific Research «Demokritos»
Athens - Greece
- **Co-ordinator:** NCSR Demokritos (EL)
- **Duration:** 1.1.2006 – 31.12.2010 (5 years)
- **Budget:** M€ 11.3
- **EC contr.:** M€ 7.5
- **22 partners from 12 European countries and USA (1 OEM, 19 research institutes, 2 industrial companies)**
NESSHY aims at advancing the current state of hydrogen storage in solid materials, with respect to

✓ novel materials
✓ enhanced understanding of the physical mechanisms involved
✓ novel analytical and characterisation tools and measurement techniques
  ✓ standardisation, testing protocols (virtual laboratory)
✓ advanced numerical methods for optimal material & storage design
✓ upscaling the production processes of promising materials
✓ design and testing of storage tank systems
NESSHY workplan

Materials development

Nanoporous Solids: MOFs, clathrates, metal-doped carbons

Light/complex hydrides: imides, amides, borohydrides, novel alanates with Li/Na/Al/Ca/K/Mg etc.

Mg alloys & intermetallics: transition-metal doped Mg alloys, Mg and Mg-Ca hydrides with TM hydride complexes & interstitial H₂, Mg composites with highly dispersed catalysts, etc.

Chemical Hydrides: Na borohydrides, H₂ generator

Up scaling & Tank system Development

Modelling & Simulation

Novel characterisation techniques

Benchmarking / Standardisation / Safety - Virtual Laboratory

Training / Dissemination

reversible on-board storage

regenerative off-board storage
Materials State of the art

G. Thomas, et al., DOE (April 2007)
New synthesis of magnesium tetrahydroborate, $\text{Mg(BH}_4\text{)}_2 \rightarrow$ potential for $\text{H}_2$ storage (14.9 mass % H & suitable thermodynamic properties)

NESSHY 24 Month Highlights - Materials

✓ Metal-doped carbons:

- Synthesis of novel carbogenic foam with high surface spin concentration
- Synthesis of Pd/C foam nanocomposites to exploit the “spillover effect” → H₂ uptake: >2 wt % at 298 K
- Synthesis of Pd-alloy/C foam nanocomposites → Enhanced H₂ uptake at 298 K (verified also by JRC and SwRI)
Metal-doped carbons (simulation):

- theoretical studies of Li-intercalated nanoscrolls → GCMC calculations predict H₂ uptake ~ 4 wt % at 293 K

Viculis et al., Science, 299 (2003), 1361

Nano Letters, 7 (2007) 1893-1897
Hydrogen clathrates:

- Simulations suggest that H$_2$-THF sII clathrates cannot store more than 1.1 wt% H$_2$ at pressures up to 1200 bar and close-to-ambient temperatures.

- For the first time, H$_2$ hydrates with the sH structure have been synthesized (TUD). Estimated H$_2$ storage capacity $\rightarrow$ 1.4%.

- Simulations (NCSRD), suggest that if a promoter can stabilize the “medium” cavity, up to 7 H$_2$ molecules can be stored in the “large” cavity $\rightarrow$ H$_2$ content up to 4 wt%.
MOFs:

- Low temperature (from 20 K) thermal desorption spectroscopy measurements revealed adsorption sites → strongest adsorption in small pores

Cu-BTC

MOF-5

MIL-53

Picture kindly provided by J. Rowsell
NESSHY 24 Month Highlights - Upscaling & Storage systems

✓ Tanks:

- Large scale production of Mg based hydrides and development of storage tanks (2 kg of material available)
- 10 kg tank under development

Equal-channel angular processing (ECAP)  Industrial scale Milling  Helmet torch powered by Mg tank
NESSHY 24 Month Highlights - RRTs

✓ Organisation of the first Round Robin Test in Europe:

- Physisorption @ 77K (commercial Carbon Molecular Sieve) - Completed
- Complex hydride (already started) & Mg-based materials (starting soon)
- In collaboration with SwRI/DoE and external (EU & non EU) organisations
  - Analysis in progress
NESSHY Training & Dissemination activities

- www.nesshy.net
- IPHE recognition (September 2006)
- Interaction with other hydrogen related projects (HYTRAIN, COSY, HYDROGEN RTNs, SURMOF, MOFCAT, HYCONES)
- Two training and dissemination events with wide multi-national participation have been supported up to now by NESSHY
  - Hydrogen Summer School, University of Iceland - Reykjavik (June 2006)
  - One day Magnesium Titanium Hydride workshop, Vrije Universiteit - Amsterdam (August 2006)
- NESSHY Newsletter
- Establishment of collaboration with Chinese and Russian organisations → Specific Support Action HYSIC
- More than 50 papers in journals/conferences in the 1st year of the project
# Enhancing Cooperation

**Collaboration with other FP6 projects**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Project Acronym</th>
<th>Coordinator</th>
<th>Topic</th>
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</thead>
<tbody>
<tr>
<td>Energy</td>
<td>STORHY <a href="http://www.storhy.net">www.storhy.net</a> 2004 – 2008</td>
<td>Magna Steyr Austria</td>
<td>Next generation H₂ storage technologies (compressed gas, cryogenic liquid and solid materials*) with a focus on automotive applications</td>
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<td>NMP</td>
<td>SURMOF <a href="http://www.ruhr-uni-bochum.de/pc1/SURMOF">www.ruhr-uni-bochum.de/pc1/SURMOF</a> 2006 – 2009</td>
<td>Ruhr University Germany</td>
<td>Anchoring of MOFs to surfaces</td>
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<td>MOFCAT <a href="http://www.sintef.no">www.sintef.no</a> 2006 - 2011</td>
<td>SINTEF Norway</td>
<td>Functional MOFs as heterogeneous catalysts and adsorbents</td>
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<td></td>
<td>HYTRAIN <a href="http://www.hytrain.net">www.hytrain.net</a> 2005 - 2008</td>
<td>University of Salford UK</td>
<td>Mg-based hydrides, complex hydrides (e.g. alanates, borohydrides), novel light hydrides (e.g. Li nitrides, amides)</td>
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<td></td>
<td>COSY <a href="http://www.cosy-net.eu">www.cosy-net.eu</a> 2006 - 2009</td>
<td>GKSS Germany</td>
<td>Fundamental understanding of the sorption kinetics in reactive hydride composites</td>
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<td>HYDROGEN <a href="http://www.theorchem.leidenuniv.nl">www.theorchem.leidenuniv.nl</a> 2006 - 2009</td>
<td>Leiden University The Netherlands</td>
<td>Hydrogen storage in alanates, borohydrides, and new class of materials to store it in form of ammonia</td>
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IPHE label (September 2006)

Participation of SwRI, the American institute officially appointed by DoE for standardisation in H₂ solid storage measurements


- 8 partners from EU, Russian Federation, P. R. China and Lithuania
- Objectives:
  - Performance of studies enhancing international cooperation (benchmarking, round-robin testing, testing protocol standardization)
  - Joint dissemination actions (workshops and integration activities)
more information at

www.nesshy.net
The NESSHY Team