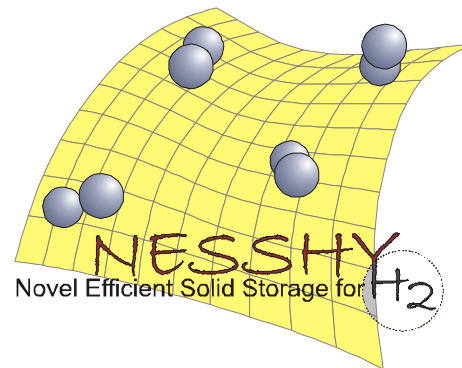




NESSHY

“Novel Efficient Solid Storage for Hydrogen”

Integrated Project SES6-CT-2006-518271



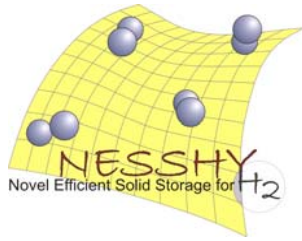
Theodore Steriotis

Institute of Physical Chemistry

National Center for Scientific Research «Demokritos»

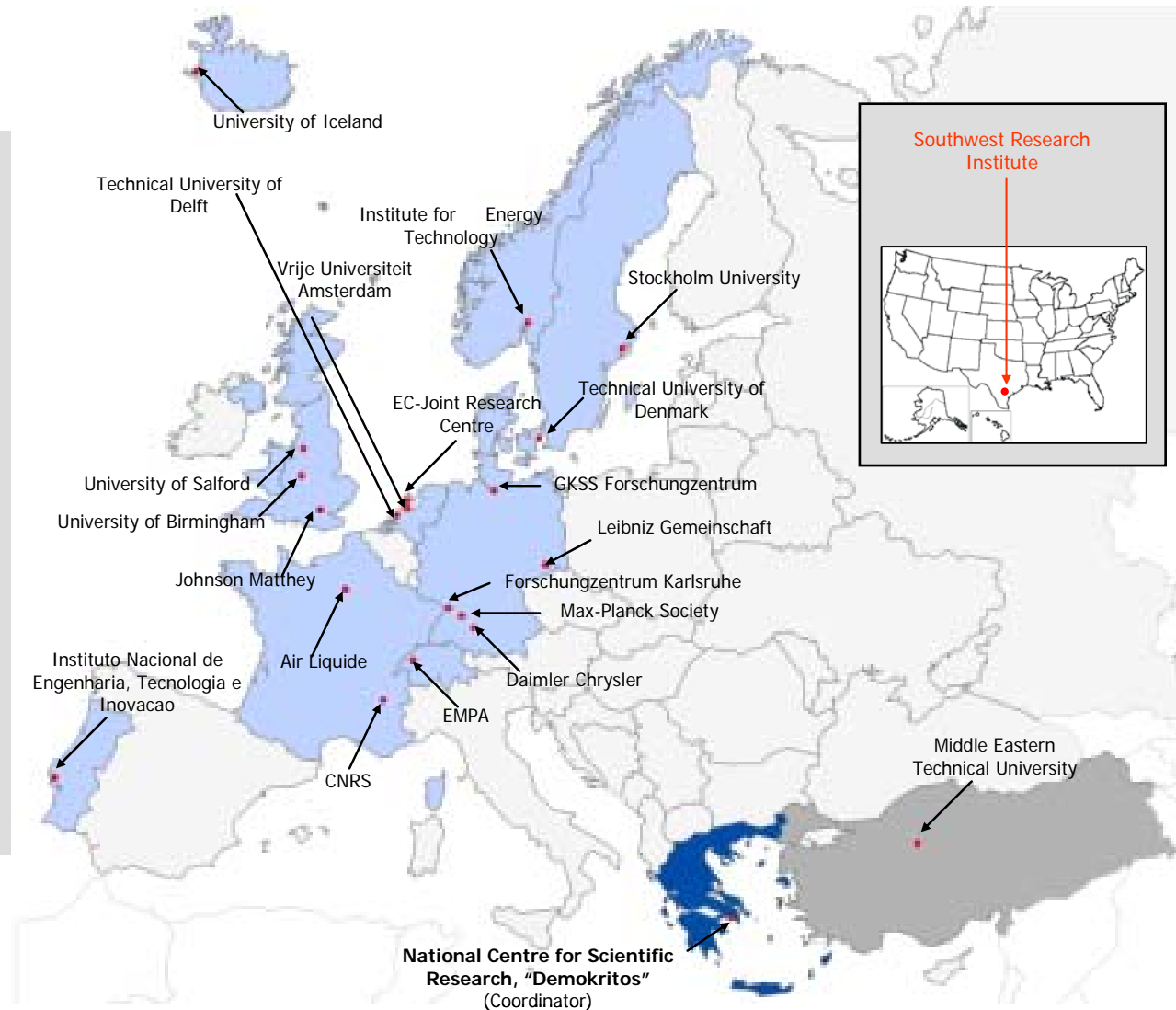
Athens - Greece

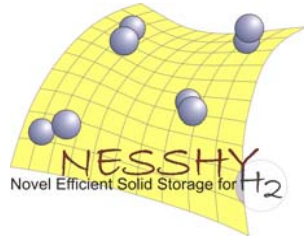




General facts

- **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)**

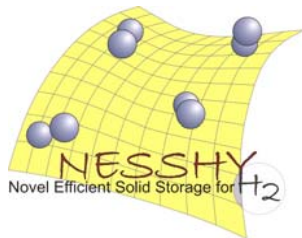




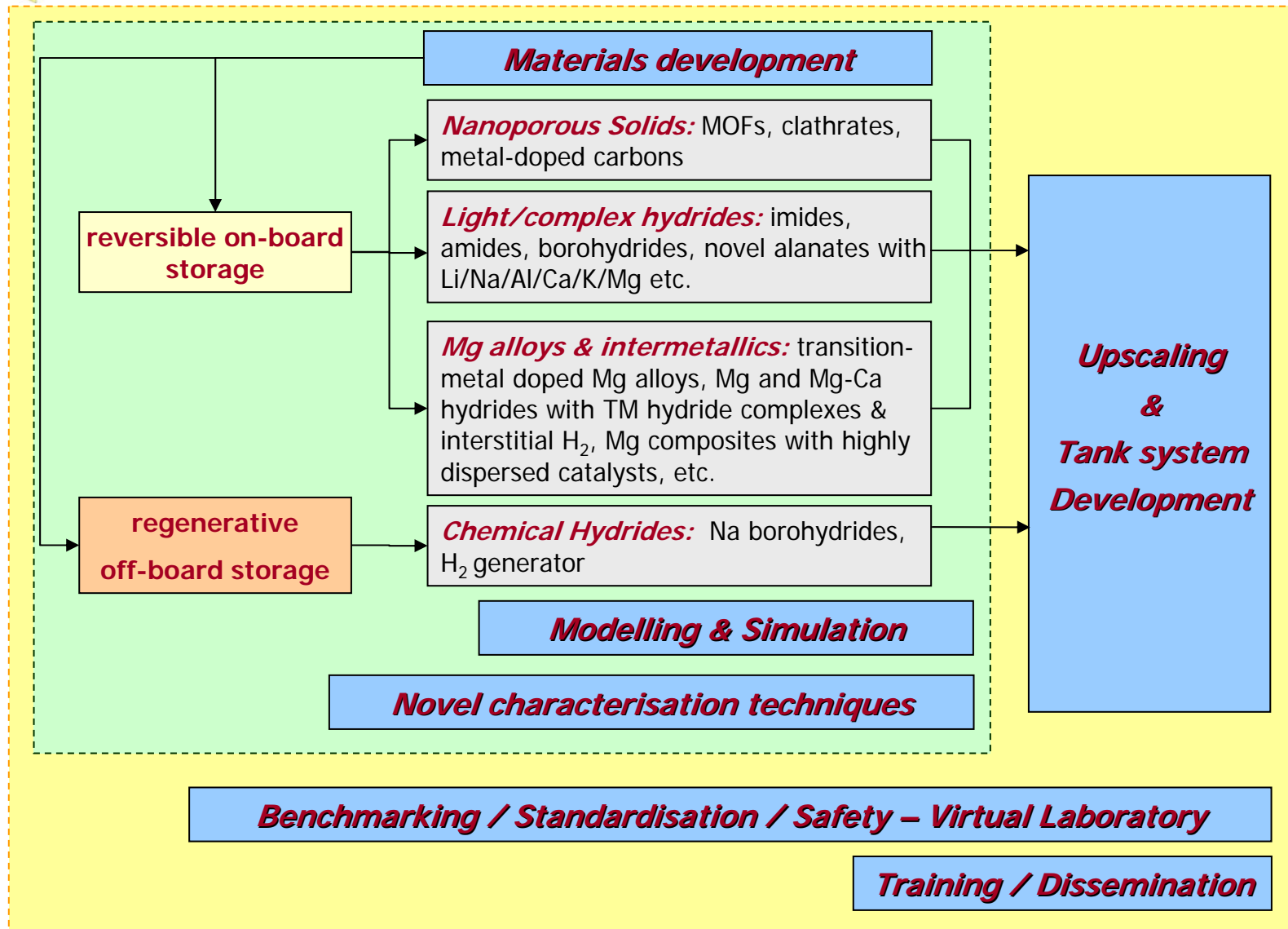
NESSHY vision

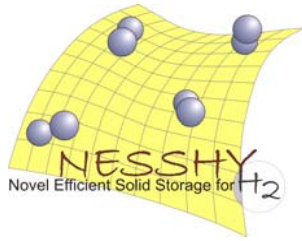
NESSHY aims at advancing the current state of hydrogen storage in solid materials, with respect to

- ✓ **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**

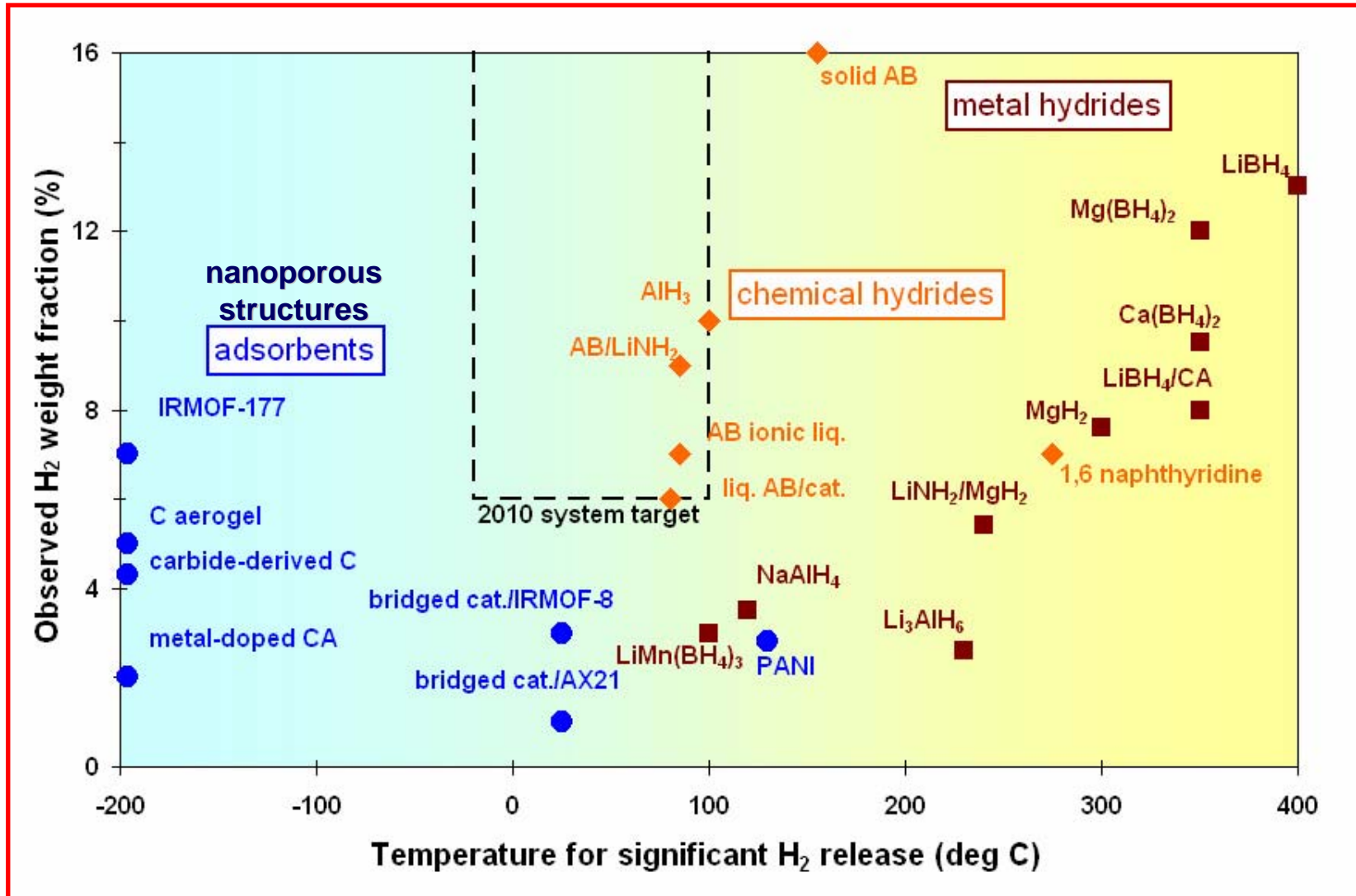


NESSHY workplan

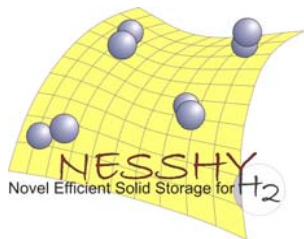




Materials State of the art

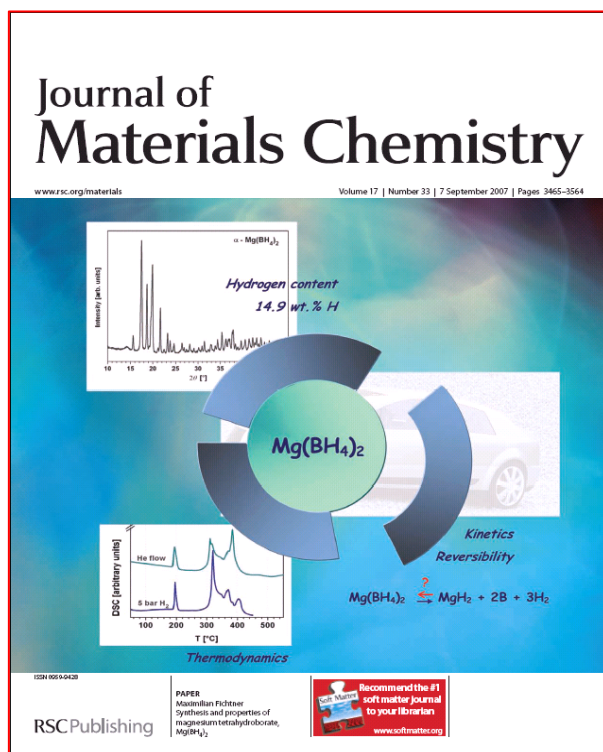


G. Thomas, et al., DOE (April 2007)



NESSHY 24 Month Highlights - Materials

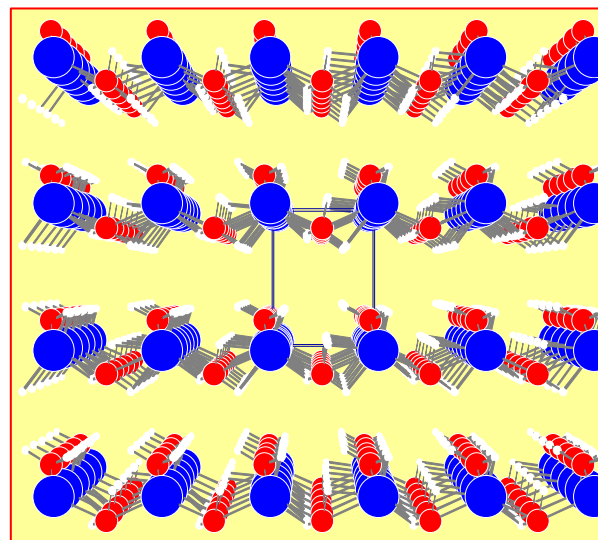
- ✓ Novel synthesis of magnesium tetrahydroborate, $\text{Mg}(\text{BH}_4)_2 \rightarrow$ potential for H_2 storage (14.9 mass % H & suitable thermodynamic properties)



J. Mater. Chem., **17** (2007) 3496–3503

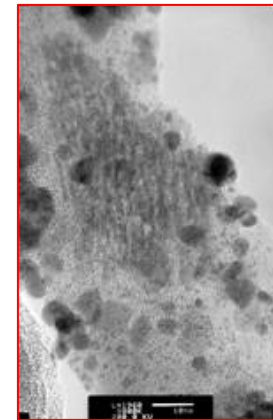
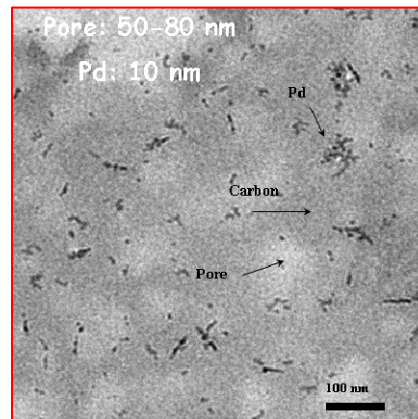
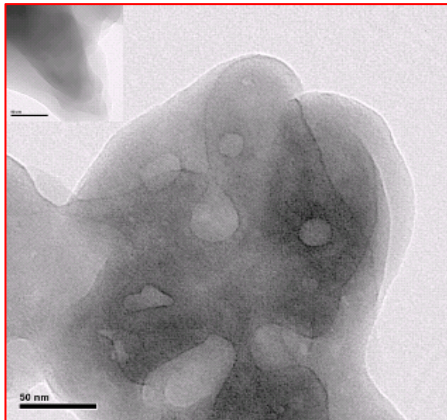


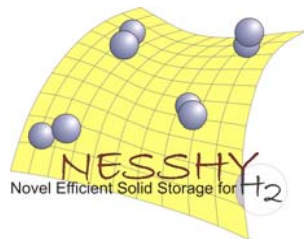
Danmarks Tekniske Universitet



✓ 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)

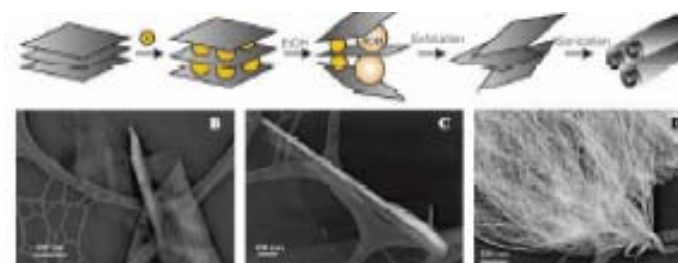




NESSHY 24 Month Highlights - Materials

✓ 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

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Special Reports

Technology

Roll up for better hydrogen fuel storage

13:45 25 June 2007
NewScientist.com news service
Duncan Graham-Rowe

The thorny problem of how to store hydrogen fuel safely for future vehicles and portable gadgets could be solved by simply storing it in nanoscopic scrolls of carbon.

Scientists in Greece say they have found a way to make so-called "carbon nanoscrolls" store more hydrogen than any other material.

By adding impurities to rolled sheets of carbon in detailed computer simulations, they found they could control how tightly the scrolls wind up and, hence, how much hydrogen they adsorb.

This result is very promising because it provides a potential solution to one of the major problems of hydrogen storage for mobile applications, says George Froudakis at the University of Crete, who led the work.

PRINT WIND

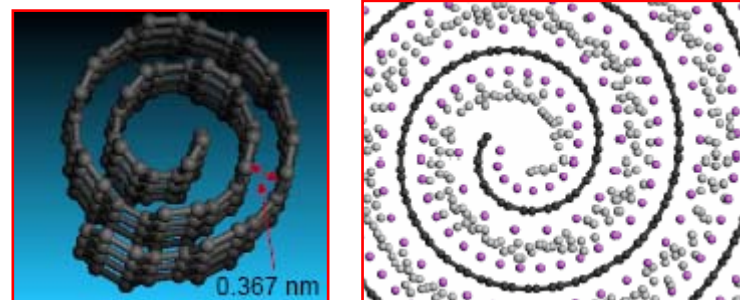
Tools

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Related Articles

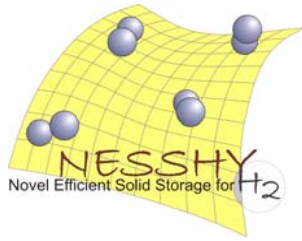
Nanoporous material gobbles up 07 November 2006
New type of hydrogen fuel cell p 13 September 2006
Fuel cell squeezes more from p 09 April 2005

Search New Scientist



Dept. of Chemistry, Uni. of Crete, Heraklion – Greece
NCSR "Demokritos", Athens - Greece

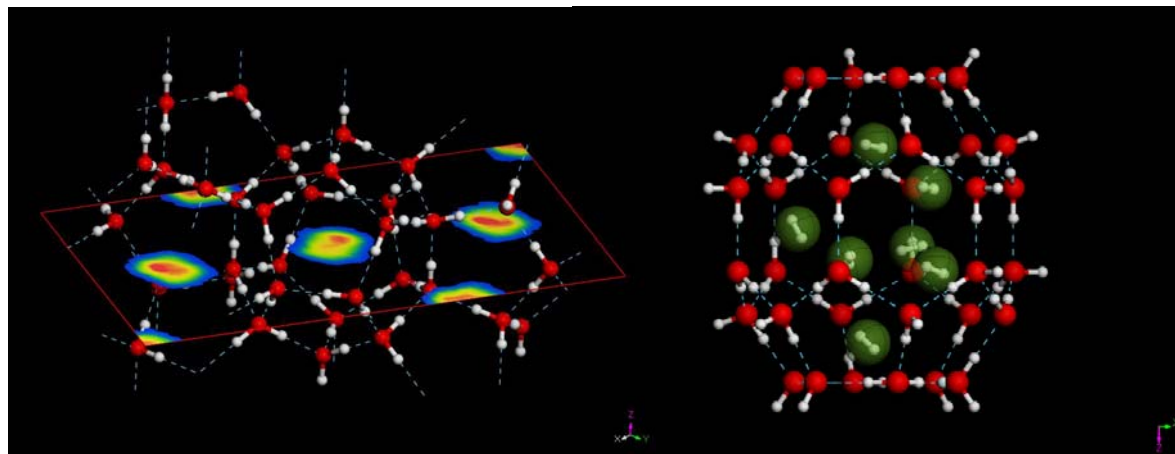
Nano Letters, 7 (2007) 1893-1897



NESSHY 24 Month Highlights - Materials

✓ Hydrogen clathrates:

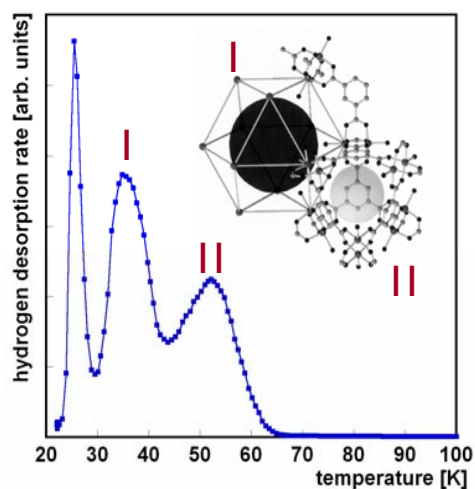
- Simulations suggest that H₂-THF sII clathrates cannot store more than 1.1 wt% H₂ at pressures up to 1200 bar and close-to-ambient temperatures
- For the first time, H₂ hydrates with the sH structure have been synthesized (TUD). Estimated H₂ storage capacity → 1.4%
- Simulations (NCSR D), suggest that if a promoter can stabilize the “medium” cavity, up to 7 H₂ molecules can be stored in the “large” cavity → H₂ content up to 4 wt%



✓ MOFs:

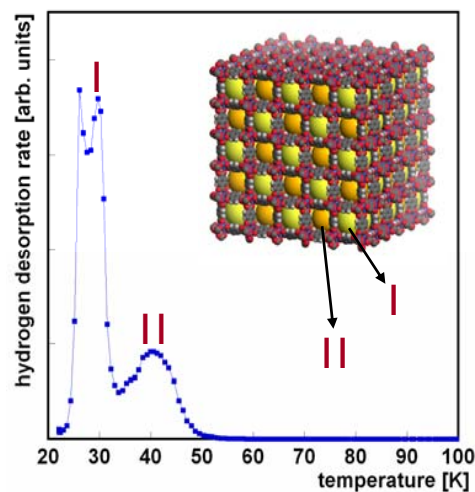
- Low temperature (from 20 K) thermal desorption spectroscopy measurements revealed adsorption sites → strongest adsorption in small pores

Cu-BTC



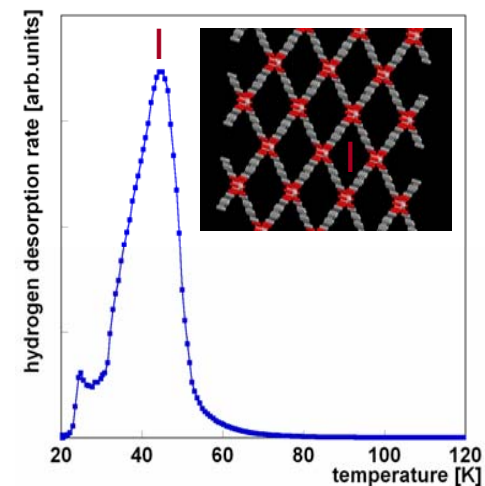
Picture from Krawiec et al. *Adv. Eng. Mater.* **8** (2006) 293

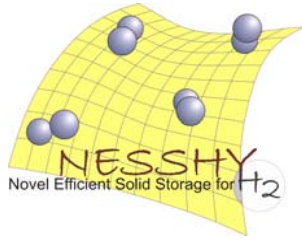
MOF-5



Picture kindly provided by J. Rowsell

MIL-53





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



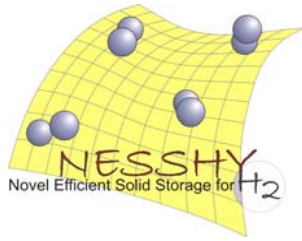
Equal-channel angular processing (ECAP)



Industrial scale Milling



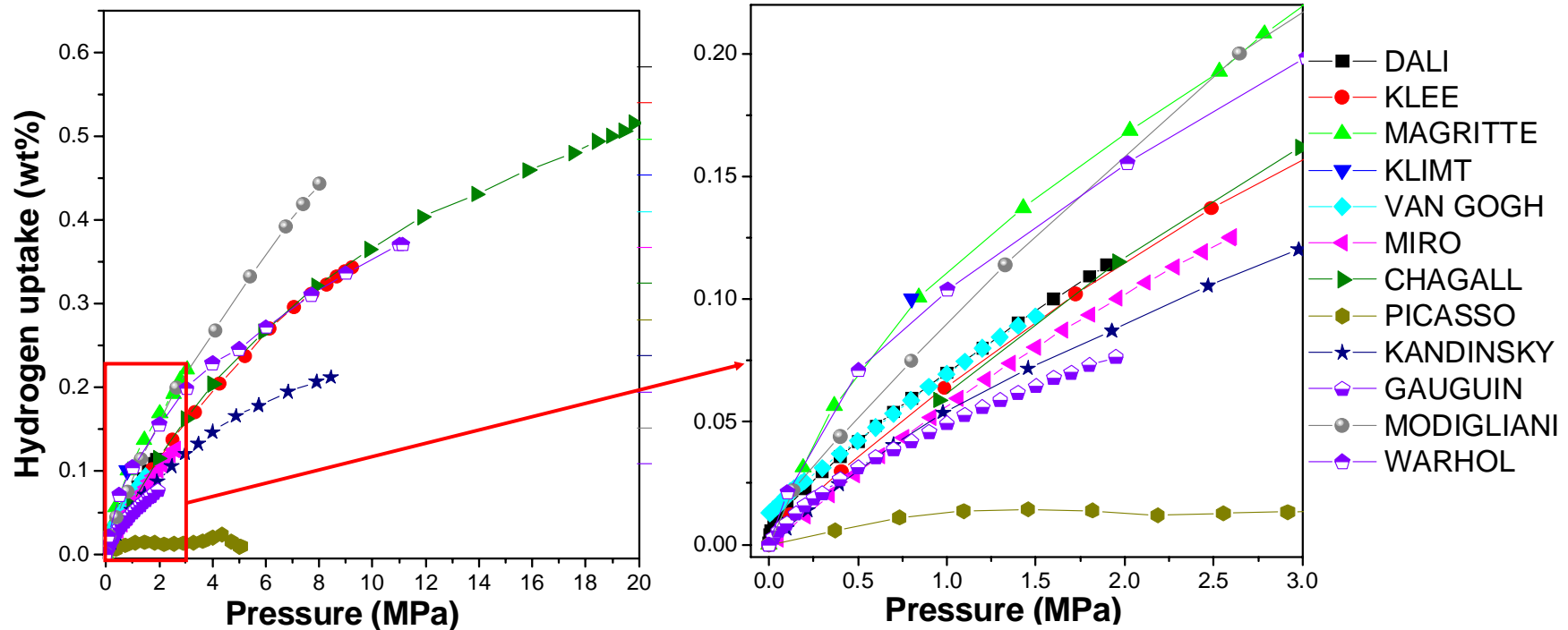
Helmet torch powered by Mg tank

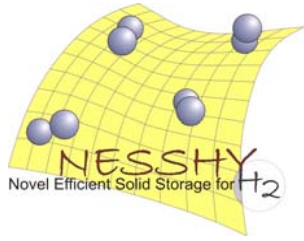


NESSHY 24 Month Highlights - RRTs

✓ Organisation of the first Round Robin Test in Europe:

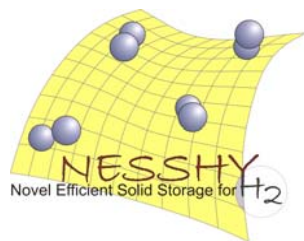
- Physisorption @ 77K (commercial Carbon Molecular Sieve) - Completed
- Complex hydride (already started) & Mg-based materials (starting soon)
- In collaboration with SwRI/DoE and external (EU & non EU) organisations
 - Analysis in progress





NESSHY Training & Dissemination activities

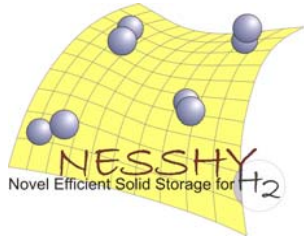
- www.nesshy.net
- IPHE recognition (September 2006)
- Interaction with other hydrogen related projects (HYTRAIN, COSY, HYDROGEN RTNs, SURMOF, MOFCAT, HYCONES)
- Two training and dissemination events with wide multi-national participation have been supported up to now by NESSHY
 - Hydrogen Summer School, 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

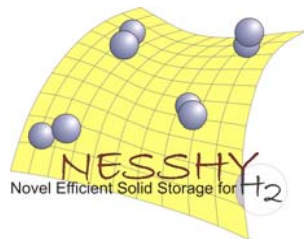
Collaboration with other FP6 projects

	Project Acronym	Coordinator	Topic
Energy Priority	STORHY www.storhy.net 2004 – 2008	Magna Steyr <i>Austria</i>	Next generation H ₂ storage technologies (compressed gas, cryogenic liquid and solid materials*) with a focus on automotive applications *Na-alanate, mixed alanates, alane
NMP Priority	HYCONES www.hycones.eu 2006 – 2009	NCSR Demokritos <i>Greece</i>	Hydrogen storage in Carbon cones
	SURMOF www.ruhr-uni-bochum.de/pc1/SURMOF 2006 – 2009	Rhur University <i>Germany</i>	Anchoring of MOFs to surfaces
	MOFCAT www.sintef.no 2006 - 2011	SINTEF <i>Norway</i>	Functional MOFs as heterogeneous catalysts and adsorbents
Marie Curie Research Training Networks (RTN)	HYTRAIN www.hytrain.net 2005 - 2008	University of Salford <i>UK</i>	Mg-based hydrides, complex hydrides (e.g. alanates, borohydrides), novel light hydrides (e.g. Li nitrides, amides)
	COSY www.cosy-net.eu 2006 - 2009	GKSS <i>Germany</i>	Fundamental understanding of the sorption kinetics in reactive hydride composites
	HYDROGEN www.theorchem.leidenuniv.nl 2006 - 2009	Leiden University <i>The Netherlands</i>	Hydrogen storage in alanates, borohydrides, and new class of materials to store it in form of ammonia



Enhancing Cooperation *International Collaborations*

- **IPHE** label (September 2006)
- Participation of **SwRI**, the American institute officially appointed by DoE for standardisation in H₂ solid storage measurements
- **HySIC**: “Enhancing International Cooperation in running FP6 Hydrogen Solid Storage Activities” Special Scientific Action linked to NESSH_y (2007-2008)
 - 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 screenshot shows the NESSHY website in a Microsoft Internet Explorer browser window. The browser's address bar displays <http://www.nesshy.net/>. The website header features the NESSHY logo and the text "Novel Efficient Solid Storage for H2". A navigation menu includes links for Home, Partners, Publications, Events, Job Opportunities, Links, and Contact. The main content area is titled "Home Page" and contains the following text:

Integrated Project NESSHY, partly funded by the European Commission in the context of the 6th Framework Programme for Research (6FP), is coordinated by the Environmental Research Laboratory of the National Research Center "Demokritos" (EL) and aspires to comprise the major European initiative in the field of Hydrogen Storage in Solids. The project started officially on January 1, 2006, with a contractual duration of five years.

Objectives

NESSHY aims at developing novel materials, storage methods and fabrication processes that provide the energy density and the charge/discharge, storage/restitution rates necessary for mobile applications with spin-offs in stationary systems. The final aim of the project is to identify the most promising solid storage solutions for such applications. The envisaged objectives cover **porous storage systems**, **regenerative hydrogen stores** (such as the borohydrides) and solid hydrides having reversible hydrogen storage and improved gravimetric storage performance. Initially, two categories of reversible stores will be investigated – **light/complex hydrides**, such as **alanates** and **imides**, and **intermetallic** systems involving magnesium, although further categories may be included later. In all cases, the performance of different systems will be compared by a standards laboratory (working in collaboration with the US DoE standardisation activity). Further, efforts will be made to understand the mechanisms involved by innovative modelling activities. When promising new materials are identified, industrial and R&D collaborators will be brought in to upscale the material production, develop appropriate demonstration storage tanks and test out the prototype stores in practical conditions.

Approach and innovation

NESSHY addresses key issues related to hydrogen storage in solid materials such as new...

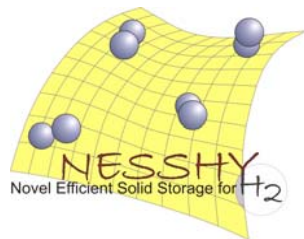
Private Area Login

Username:
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Latest Announcements

- 2nd Annual NESSHY Governing Board Meeting: December 12-14, 2007 – Istanbul (hosted by METU)
- 1st NESSHY electronic Newsletter (February 2007)
- Job Opportunities

FP6 Integrated Project NESSHY
Contract no.: SES6-510271 (2006-2011)
Coordinator: Dr. A. Stubos – NESR Demokritos, Athens-Greece
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The NESSHY Team