Statome kosmoso elektrines

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2020

Pranešimo turinys

- Energijos saugojimo technologijos kosmose: baterijos ir vandenilio energetikos technologijos;
- Tyrimai vykdomi Lietuvoje baterijų ir vandenilio energetikos technologijų srityje;
- Metalų hidridai kosmoso technologijom: persijungiantys veidrodžiai; šilumos saugojimas.

Energija kosmose

Each power technology contributes to an integrated Regenerative Fuel Cells (RFCs) for Lunar Exploration

- Batteries meet energy storage needs for low energy applications
- RFCs address high energy storage requirements where nuclear power may not be an option (in locations near humans)
- Nuclear and radio isotope power systems provide constant power independent of sunlight

NASA Fuel Cell and Hydrogen Activities; Presented by: Ian Jakupca Department of Energy Annual Merit Review 30 April 2019

Space Batteries Applications

- GEO telecommunication satellites
- MEO global positioning satellites
- LEO Defense satellites
- Launchers
- Space vehicles
- Space experiments
- Rovers
- Planetary landers
- Astronaut tools
- Space object study
- Planetary/deep space probes

Shmuel De-Leon; Shmuel De-Leon Energy, Ltd. NASA Battery Workshop November 2017

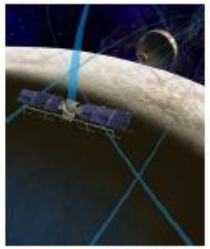
Energy Storage System Needs for Future Planetary Missions

- **Primary Batteries/Fuel Cells for Surface Probes:**
  - High Temperature Operation (> 465C)
  - High Specific Energy (>400 Wh/kg)
  - Operation in Corrosive Environments
- **Rechargeable Batteries for Aerial Platforms:**
  - High Temperature Operation (300-465C)
  - Operation in Corrosive Environments
  - Low-Medium Cycle Life
  - High Specific Energy (>200 Wh/kg)
  - Operation in High Pressures

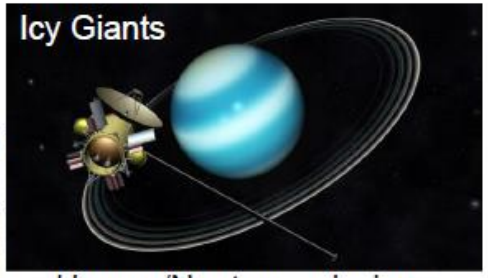
Inner Planets

Outer Planets

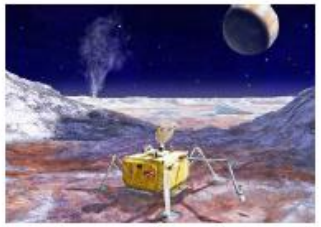
- **Primary Batteries/Fuel cells for planetary landers/probes:**
  - High Specific Energy (> 500 Wh/kg),
  - Long Life (> 15 years),
  - Radiation Tolerance & Sterilizable by heat or radiation
- **Rechargeable Batteries for flyby/orbital missions:**
  - High Specific Energy (> 250 Wh/kg)
  - Long Life (> 15 years)
  - Radiation Tolerance & Sterilizable by heat or radiation.
- **Low temperature Batteries for Probes and Landers:**
  - Low Temperature Primary batteries (< -80C)
  - Low Temperature Rechargeable Batteries (< -60 C)



Europa Orbiter



Uranus/Neptune missions



Europa Lander

All images are Artist's Concepts

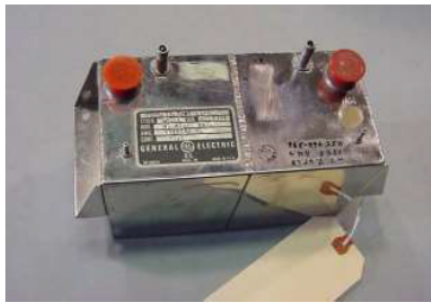
NASA Fuel Cell and Hydrogen Activities; Presented by: Ian Jakupca Department of Energy Annual Merit Review 30 April 2019

Is there any Electrochemistry System that can meet all requirements?

No!!!

Systems in use:

- Silver-zinc rechargeable (Launchers)
- Nickel-cadmium rechargeable (past)
- Nickel hydrogen rechargeable (???)
- Lithium Primary
- Lithium Ion rechargeable



Silver-zinc battery, made by General Electric, was the only power source for the Corona satellite's film return capsule

The Next Generation: Lithium-ion

EaglePicher now designs and assembles batteries using large Li-ion cells, which provide higher energy levels and longer cycle life at a lower weight and in smaller volumes than Ni-Cd or Ni-H_2 batteries.

- State-of-the-art Li-ion research and manufacturing facilities
- First to launch prismatic Li-ion battery into orbit
- Multiple research grants and contracts for advanced Li-ion development

CR123A Li-Mno2 cells used by the Astronaut Jetpack (Safer)

Shmuel De-Leon; Shmuel De-Leon Energy, Ltd. NASA Battery Workshop November 2017

EPT Market Segments

EaglePicher Technologies, LLC
An OEC Company

Missiles:
- Batteries
  - Thermal
  - Silver Zinc
  - Lithium Oxyhalide
  - Custom Packaging
- Energetic Devices

Launchers:
- Batteries
  - Silver Zinc
  - Lithium Ion

Portable Power:
- Batteries
  - Lithium Sulfur Dioxide
  - Lithium Carbon Monofluoride
  - Lithium Manganese Dioxide
  - Lithium Thionyl Chloride

Special Applications:
- Chargers & Charger/Analyzers
- Battery Systems
- Custom Cells & Batteries

Unmanned Vehicles:
- Batteries
  - Lithium Ion
  - Lead Acid
  - Nickel Cadmium
- Battery Assemblies
- BMS

Aircraft:
- Batteries
  - Lithium Ion
  - Nickel Cadmium
  - Nickel Metal Hydride
  - Primary Lithium
- Electronics
- BMS

Satellites:
- Batteries
  - Nickel Hydrogen
  - Lithium Ion
- Electronics & BMS

Distributed/ Commercial Power:
- Batteries
  - Sealed Lead Acid
  - Lithium Thionyl Chloride

Medical Power:
- Batteries
  - Lithium Ion
  - Lithium Manganese Dioxide
  - Lithium Carbon Monofluoride
  - Lithium Thionyl Chloride
  - Microcell
  - Nickel Cadmium

Alternative Energy:
- Hybrid Power Storage Systems
- HEV Systems

Baterijų tyrimai Lietuvoje

Lino Vilčiausko grupė FTMC Li jonų; Na jonų baterijos (NASICON-tipo fosfatinių karkasų medžiagų paieška, sintezė, struktūrinis irelektrocheminis charakterizavimas, bei taikymas baterijų celių konstravime).

Tomo Šalkaus grupė VU, Li jonų technologijos (joninio laidumo matavimo technologijos).

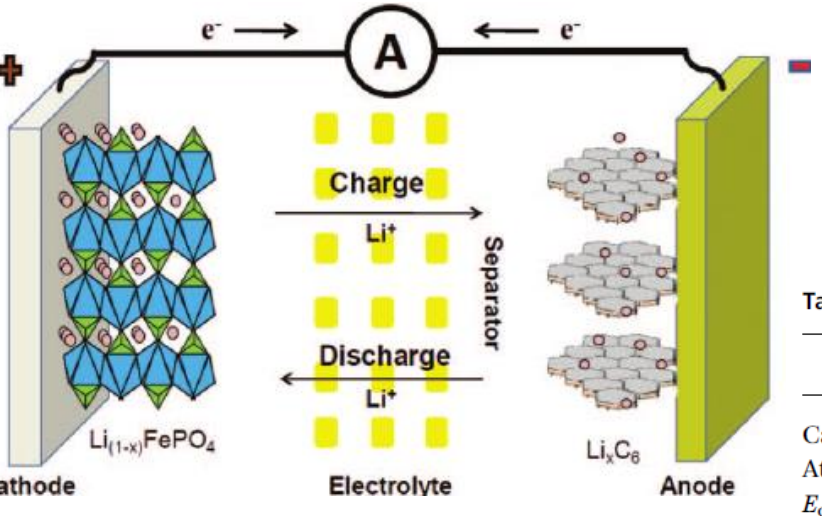
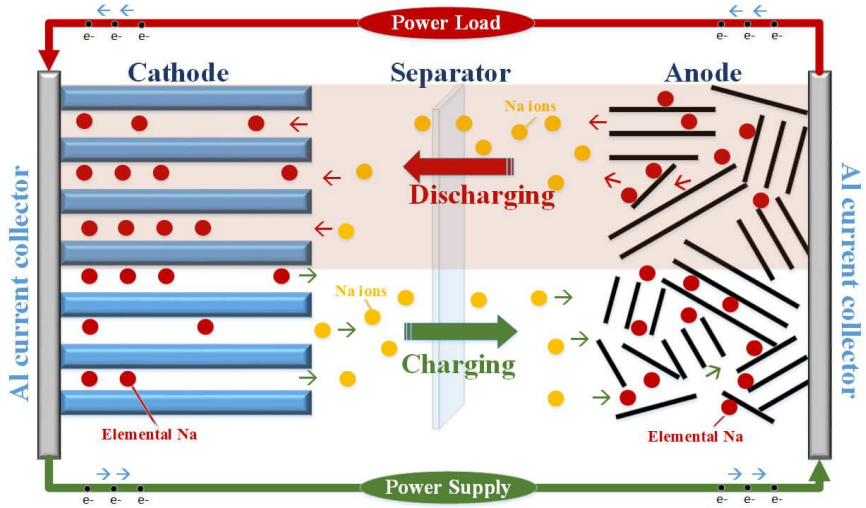


Table 1 The comparison between Na and Li elements[9–12]

	Na	Li
Cation radius	97 pm	68 pm
Atomic weight	23 g mol^{-1}	6.9 g mol^{-1}
E_o *vs.* SHE	−2.7 V	−3.04 V
A–O coordination	Octahedral or prismatic	Octahedral or tetrahedral
Melting point	97.7 °C	180.5 °C
Abundance	23.6 × 10^3 mg kg^{-1}	20 mg kg^{-1}
Distribution	Everywhere	70% in South America
Price, carbonates	~2 RMB per kg	~40 RMB per kg



Energy Environ. Sci., 2013, 6, 2338

Example: A 1 Wh NiMH battery

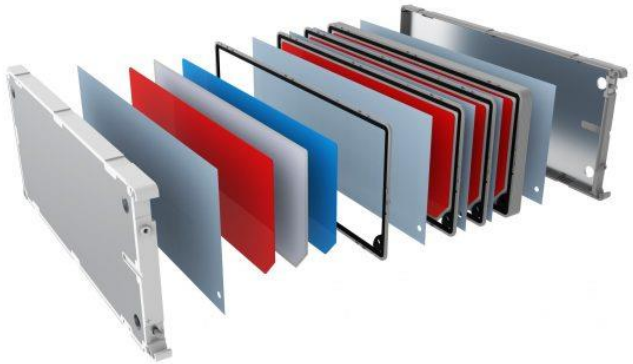
Cycling	100 % SOC	→	2262	cycles	→	2262 Wh
Cycling	50 % SOC	→	6570	cycles	→	3285 Wh
Cycling	25 % SOC	→	19070	cycles	→	4770 Wh
Cycling	10 % SOC	→	78150	cycles	→	7815 Wh
Cycling	5 % SOC	→	227000	cycles	→	11350 Wh
Cycling	2 % SOC	→	$9.3*10^5$	cycles	→	18590 Wh
Cycling	1 % SOC	→	$2.7*10^7$	cycles	→	27000 Wh

An HEV application will give ~ 50 times better value for the money

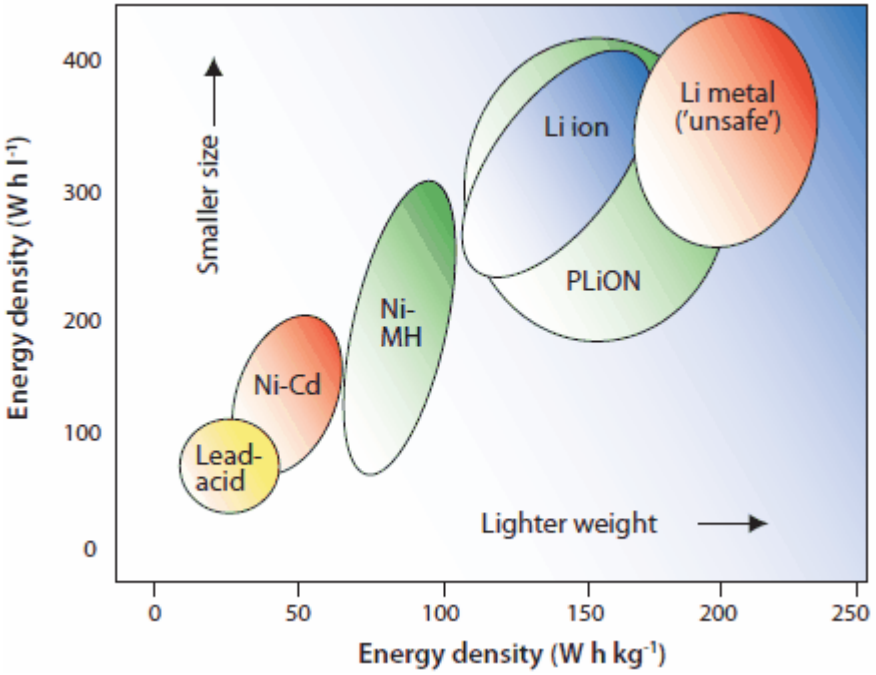
Prof. Dag Noreus pristatymas INTERACTION 2012 konferencijoje

Baterijų tyrimai Lietuvoje

LEI darbai su Nilar AB, Hoganas AB NiMH medžiagų aktyvavimo ir senėjimo procesų tyrimai

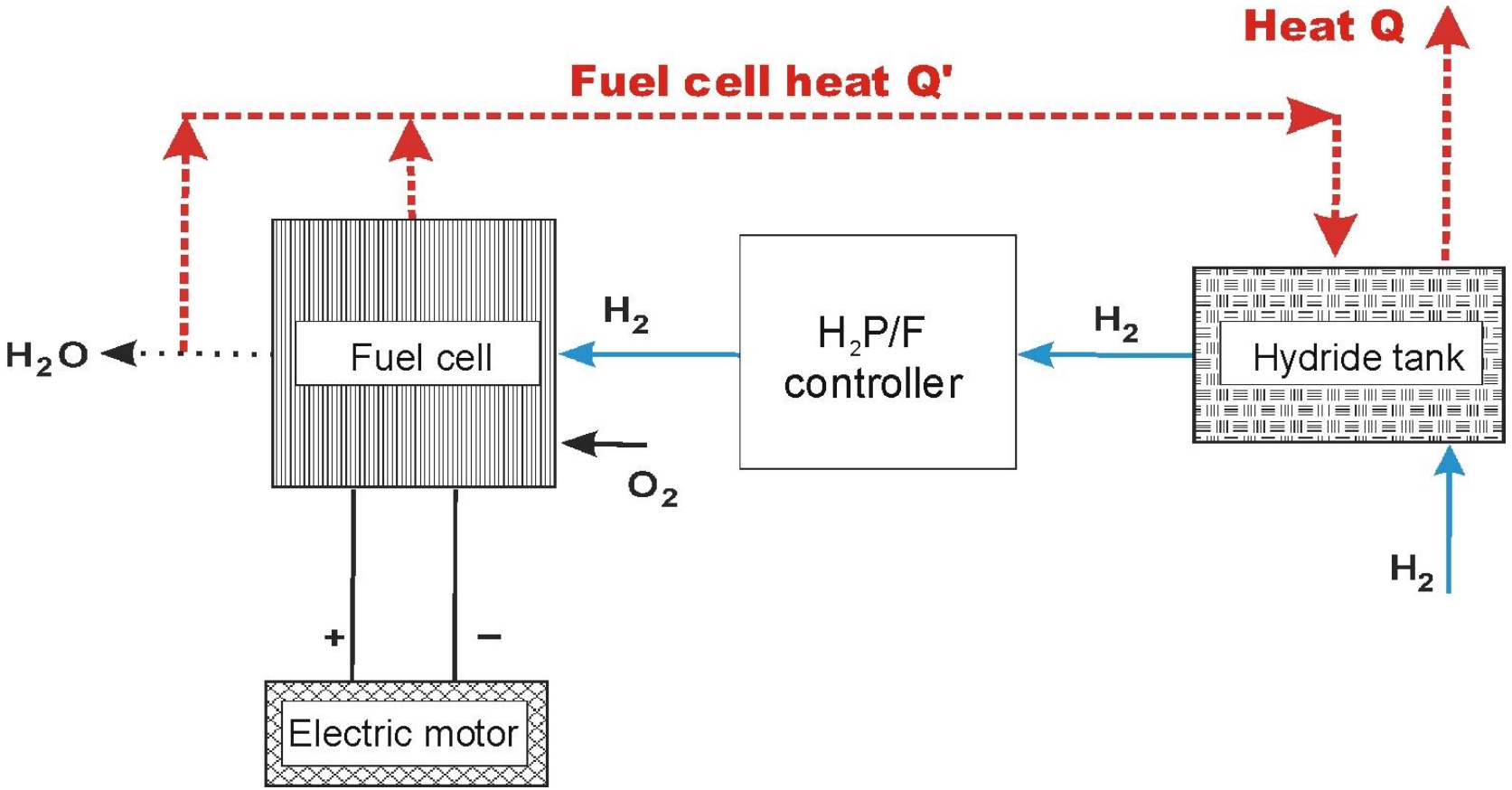


www.nilar.com



https://www.sigmaaldrich.com/technical-documents/articles/material-matters/metal-hydrides-nimh-batteries.html

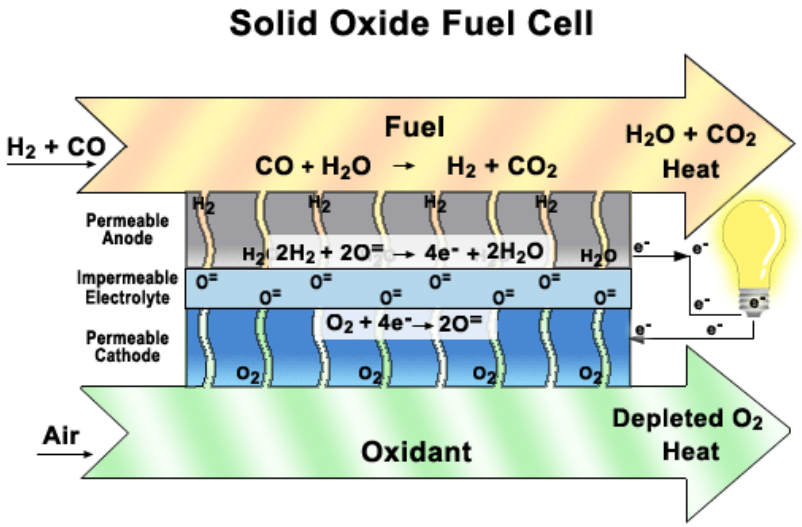
Hydrogen energy system

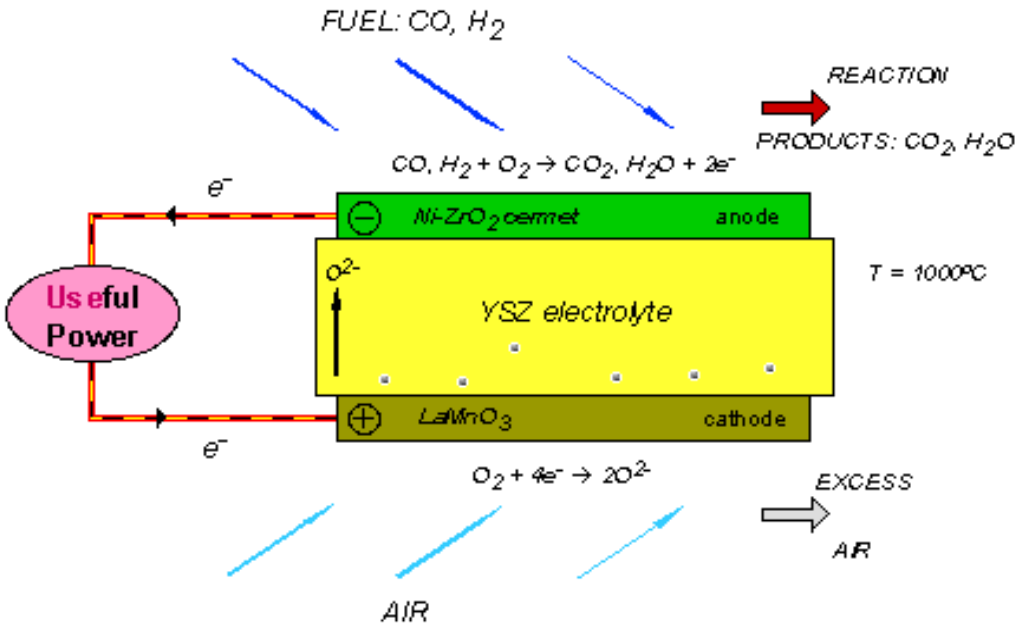


G. Sandrock, in HANDBOOK OF FUEL CELLS, 2003, Vol. 3, Part 2, pp. 101-112

- „...Why fuel cells? For one thing, they're lighter. For another, they last longer. A compact, 12-pound device with stacks of those fuel cells can produce about 250 watts of electricity continuously for one or two years, while a comparably sized battery might work for about a month...“ Jakupca said.
- „....With a price tag of about $1.5 million per kilogram of material shipped into space, he and others are also looking at possible sources for hydrogen and oxygen on the moon. Water has been found in the lunar regolith...”.

https://energynews.us/2019/07/15/midwest/nasas-new-moon-mission-reignites-fuel-cell-research-at-ohio-lab





Anion conduction O^{2-}

http://science.nasa.gov/headlines/y2003/18mar_fuelcell.htm

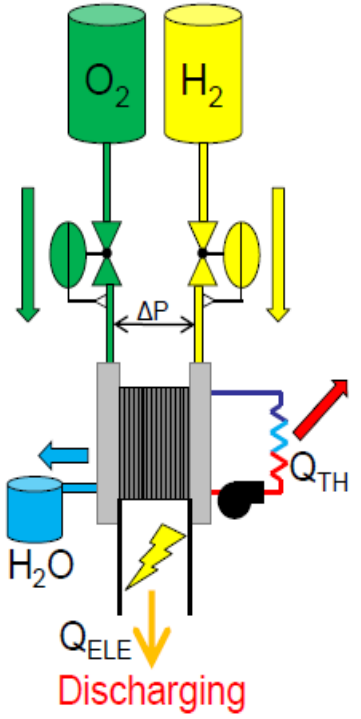
http://www.doitpoms.ac.uk/tlplib/fuel-cells/high_temp_sofc.php

Electrochemical System Definitions

Primary Fuel Cell

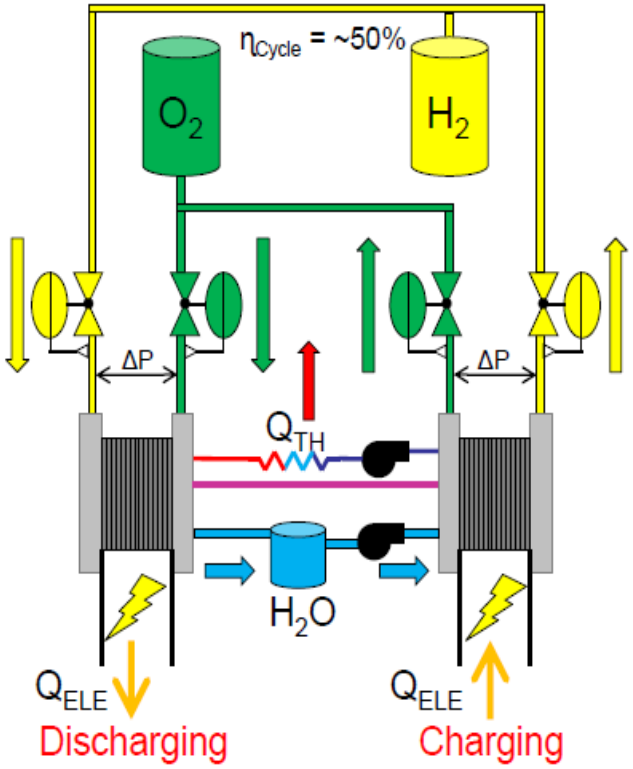
Discharge Power Only

$2H_2 + O_2 \rightarrow 2H_2O + 4e^- + \text{Heat}$



Regenerative Fuel Cell

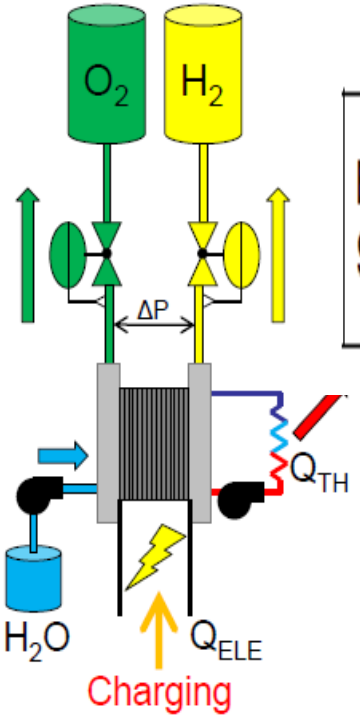
Charge + Store + Discharge



Electrolysis

Chemical Conversion

$2H_2O + 4e^- \rightarrow 2H_2 + O_2 + \text{Heat}$



Energy Options for Space Applications	
	Battery = TRL 9
	Primary Fuel Cell = TRL 5
	Regenerative Fuel Cell = TRL 3

Regenerative Fuel Cell = Fuel Cell + Interconnecting Fluidic System + Electrolysis

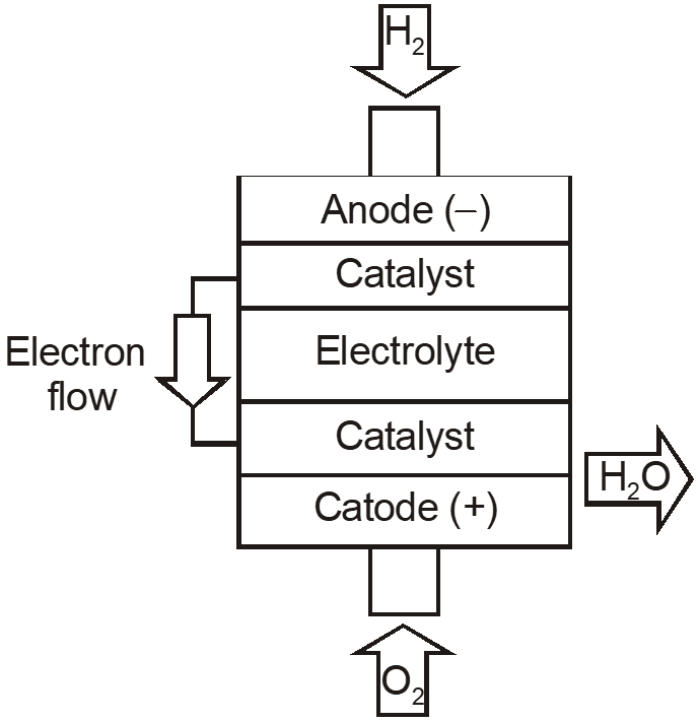
NASA Fuel Cell and Hydrogen Activities; Presented by: Ian Jakupca Department of Energy Annual Merit Review 30 April 2019

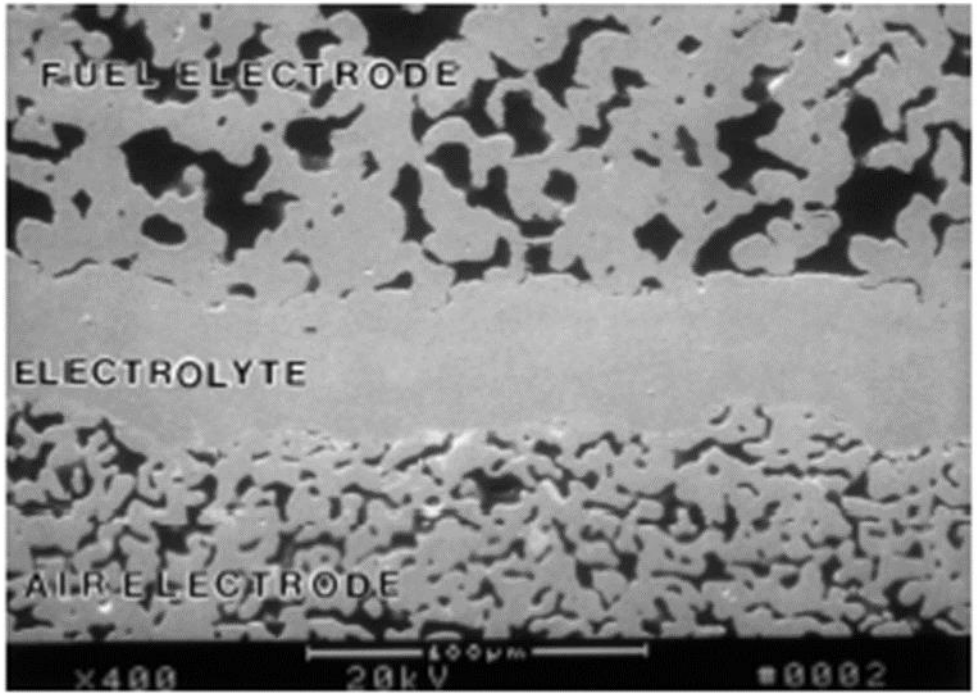
Vandenilio kuro elementai Lietuvoje

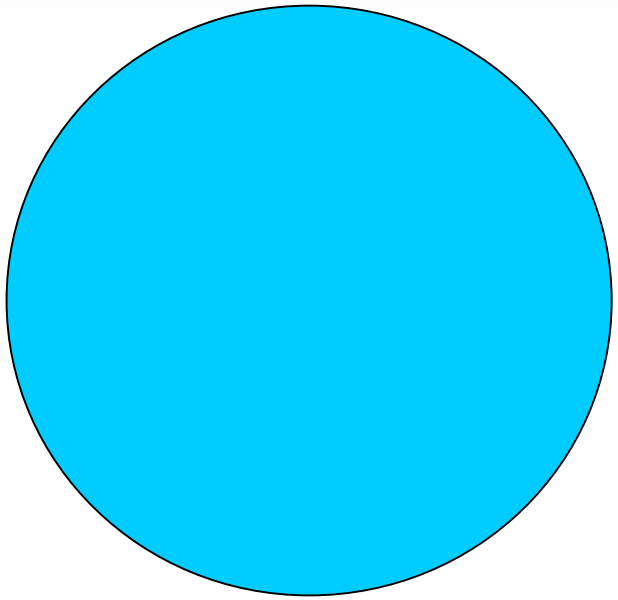
Giedriaus Laukaičio grupė, KTU – kieto oksido kuro elementų aktyvių sluoksnių sintezė

Tomo Šalkaus grupė, VU – joninio laidumo matavimai

LEI - kieto oksido kuro elementų aktyvių sluoksnių sintezė



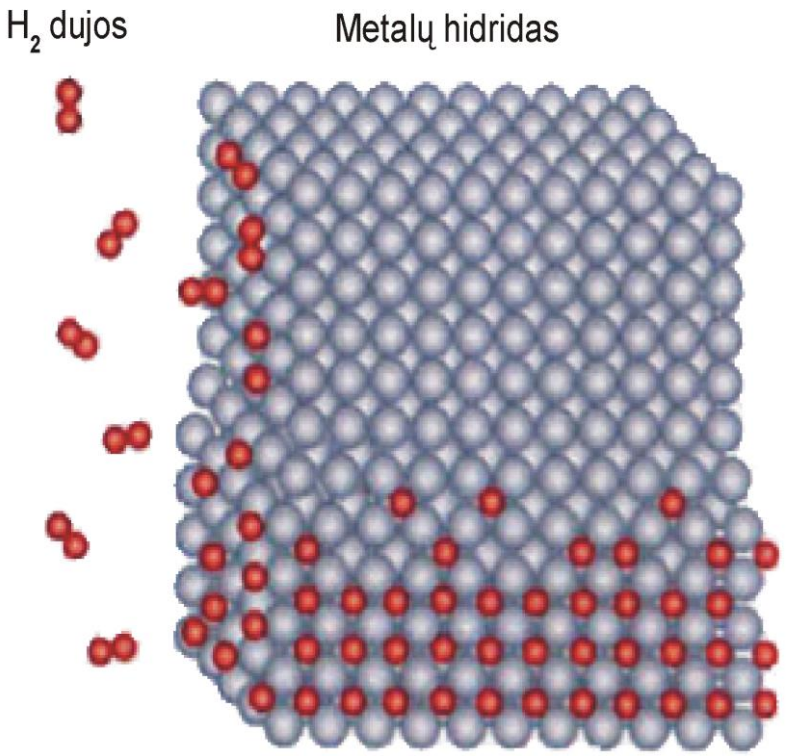




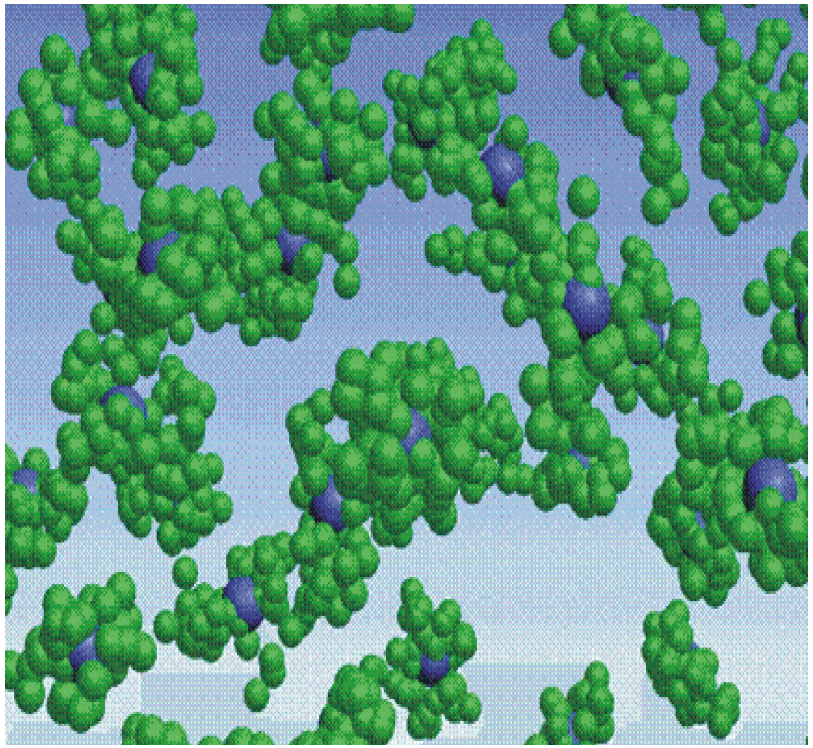
Petrol

L. Schlapbach and A. Züttel, Nature 414 (2001) 353-358

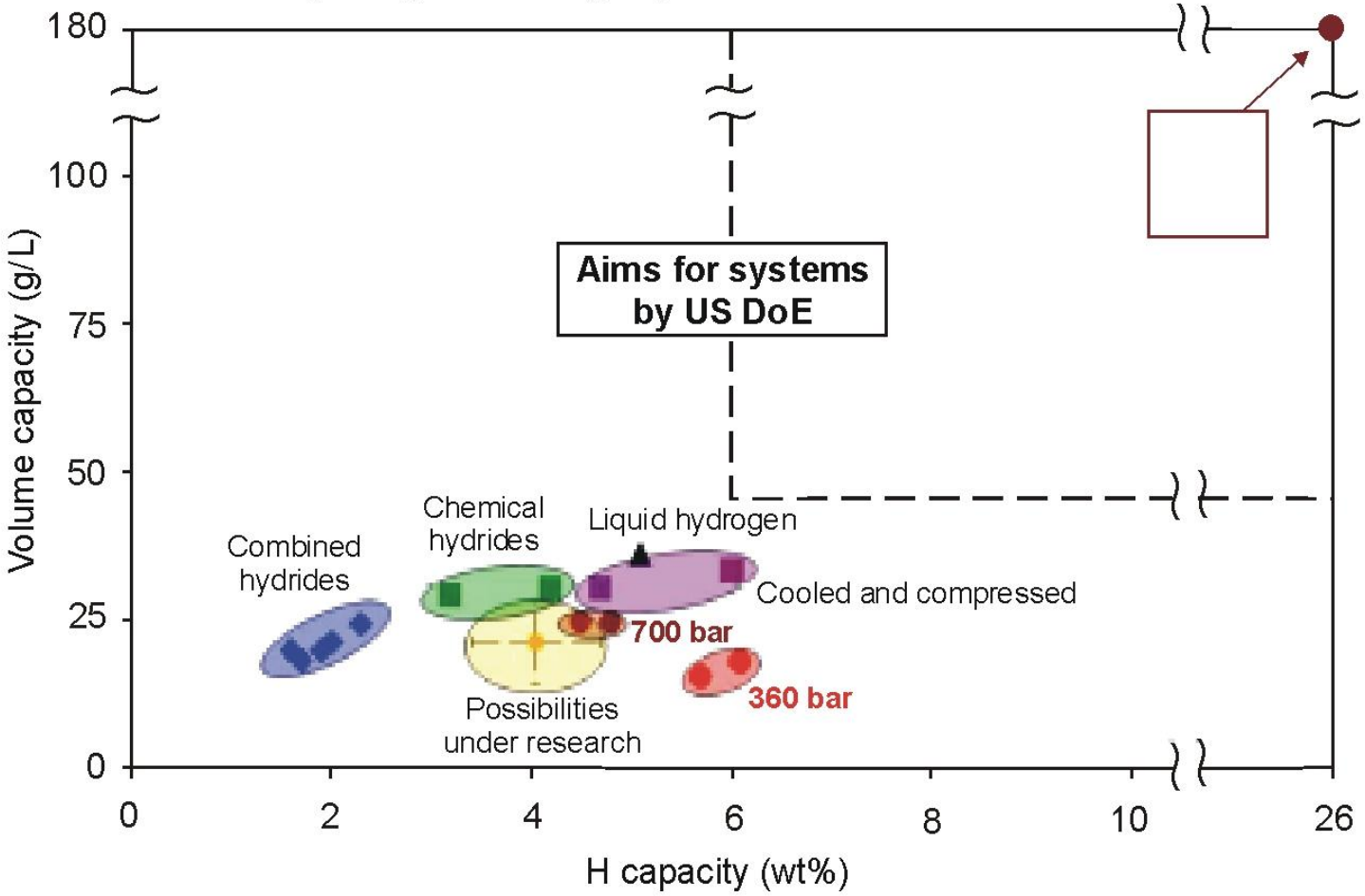
Vandenilio saugojimas



suskystintas vandenilis

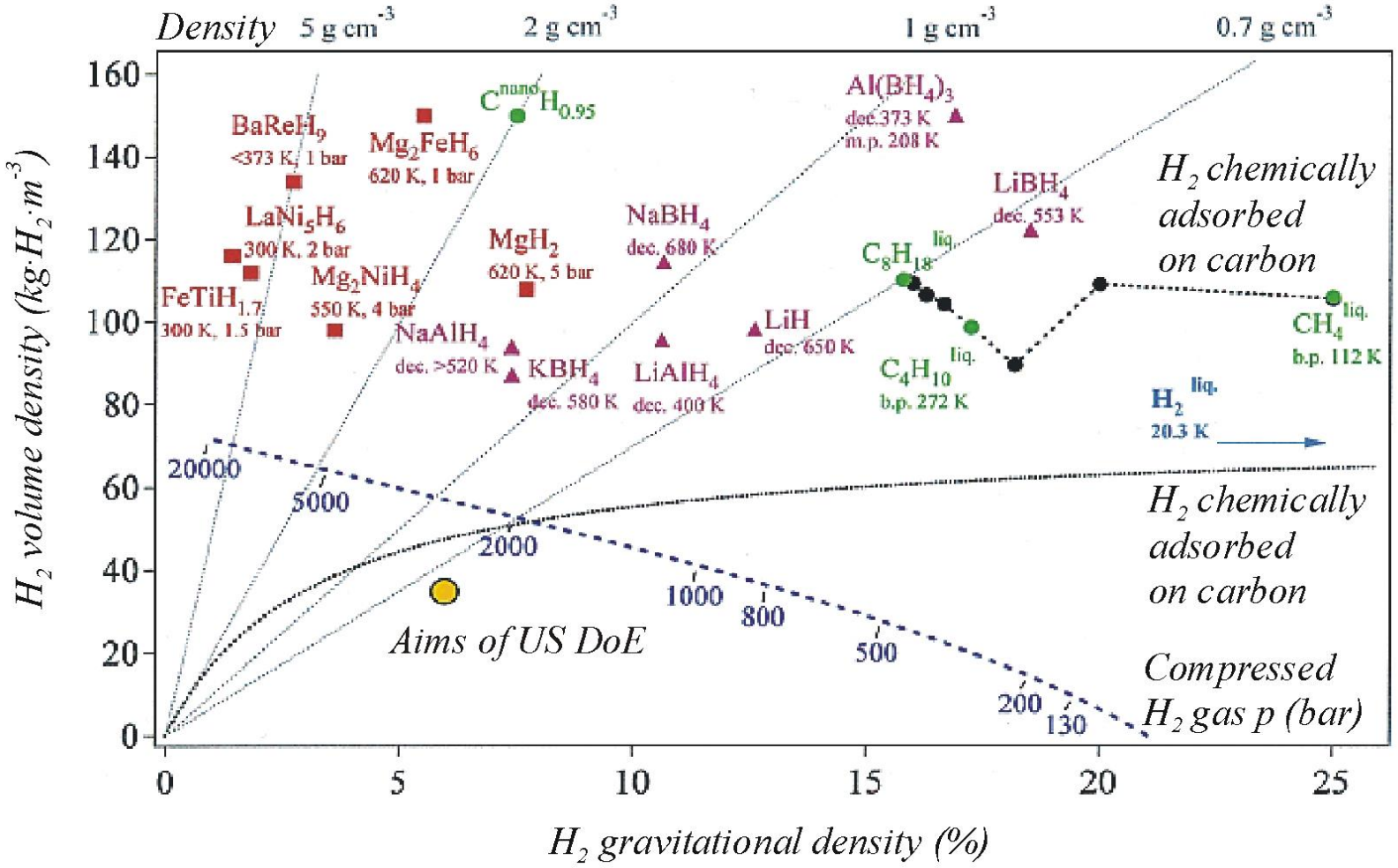


Hydrogen storage: present situations and aims



2009 FUEL CELL TECHNOLOGIESMARKET REPORT, June 2010

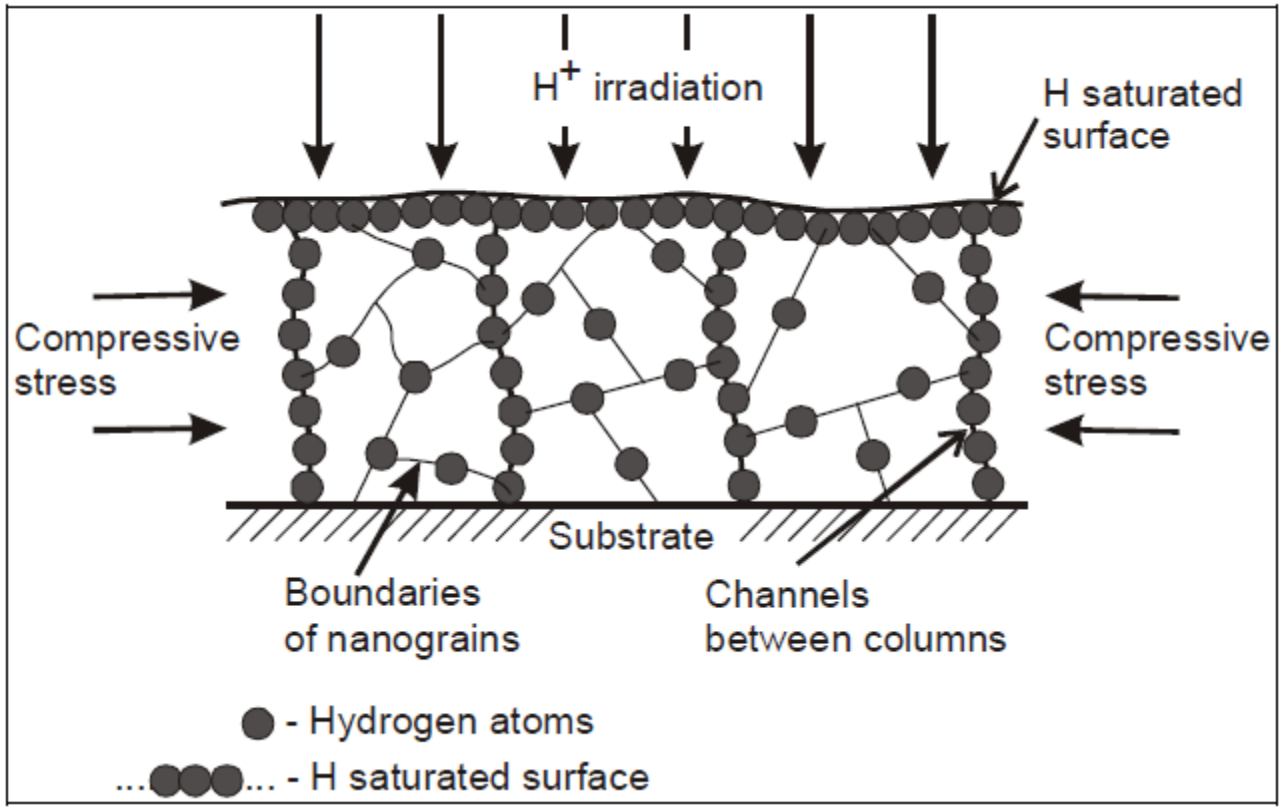
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



2009 FUEL CELL TECHNOLOGIESMARKET REPORT, June 2010

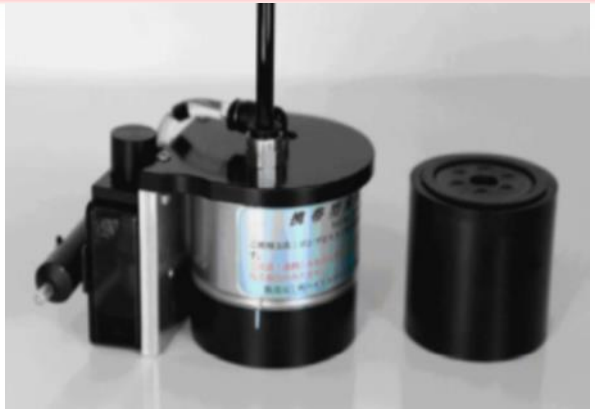
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Plasma enchanced hydrogenation of metals and alloys:



LEI CHET patent https://data.epo.org/publication-server/rest/v1.0/publication-dates/20110629/patents/EP2338834NWA1/document.pdf

Vandenilio gavyba naudojant aktyvuoto Al + H2O reakcijas



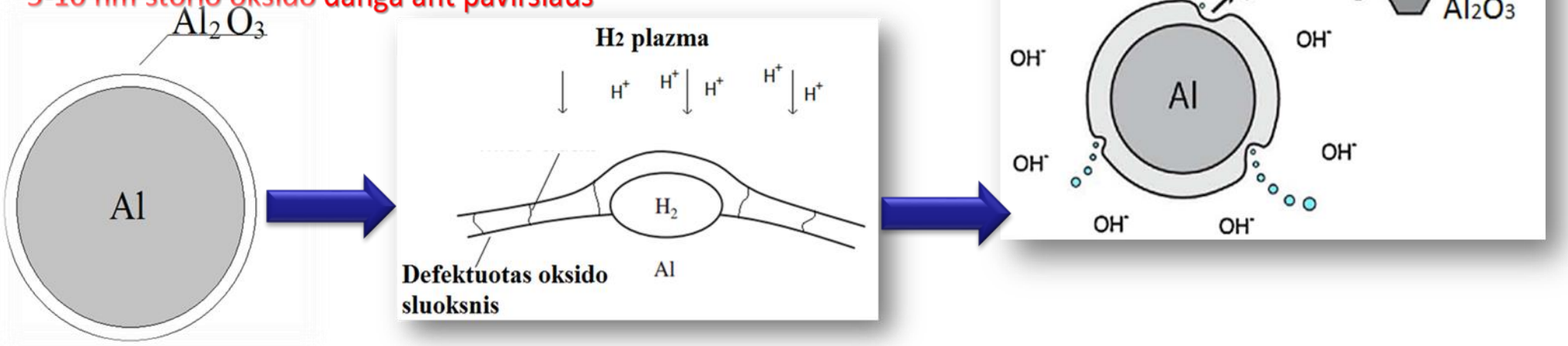
$$2Al + 3H_2O \rightarrow 3H_2 + Al_2O_3$$

$$2Al + 6H_2O \rightarrow 3H_2 + 2Al(OH)_3$$

1g Al → 1.245 l H2

Problema:

5-10 nm storio oksido danga ant paviršiaus



Method of hydrogenation of metals and their alloys. European Patent Office. Patent number: 10478001.0-2111.

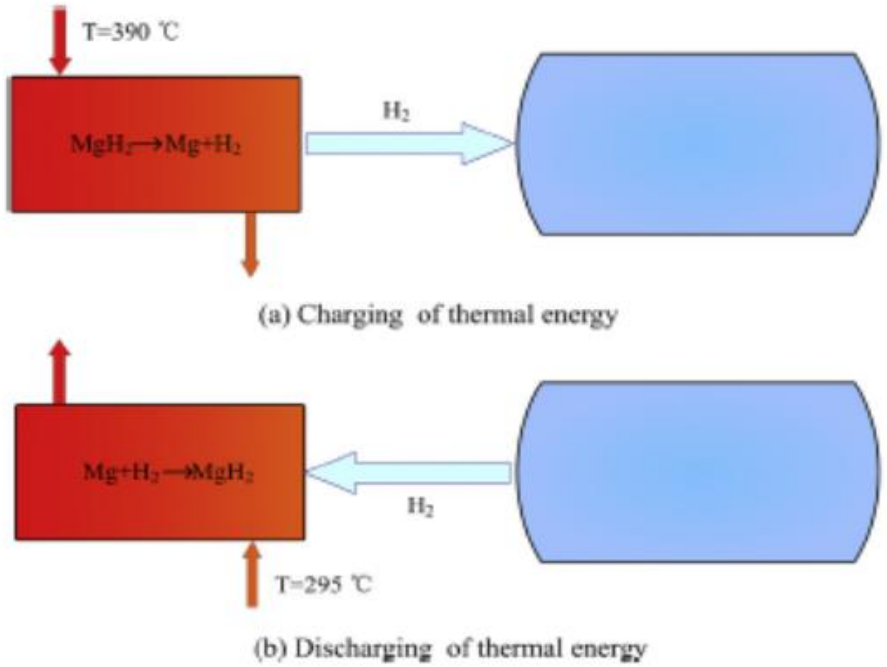
"Switchable" mirrors: LEI, Stockholm University, IFE.

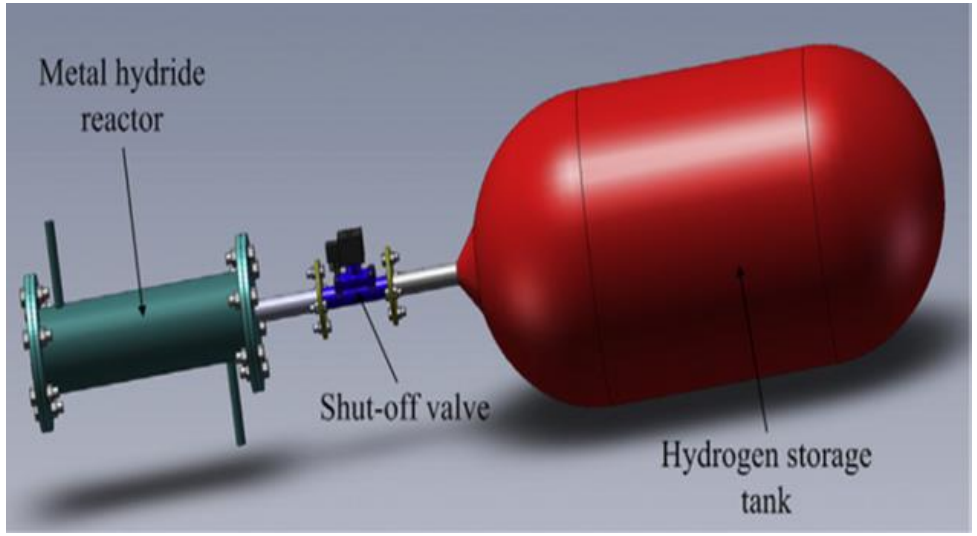
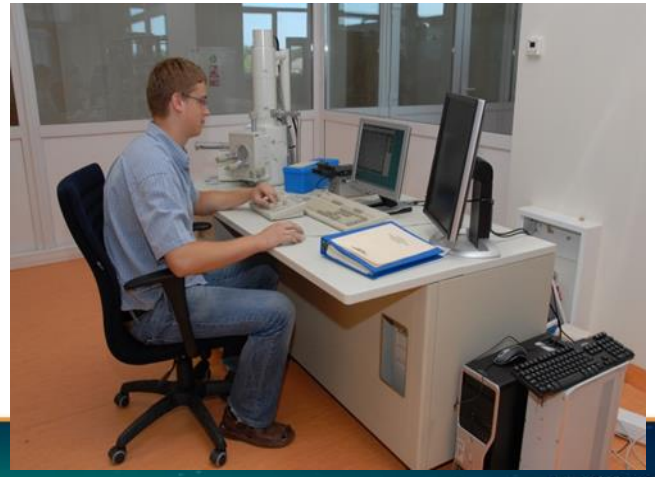
Mg2Ni

Mg2NiH4

c-Mg2NiH4 – m-Mg2NiH4

Metalų hidridai šilumos saugojimui: LEI, IFE

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