International Institute for Carbon-Neutral Energy Research

I2CNER

Hydrogen Storage
Revised Roadmap
(Revised version (tentative))

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KYUSHU UNIVERSITY

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Division Objectives

- **Research and develop new carrier materials for hydrogen mobile and stationary storage as well as for hydrogen delivery.**
- **For <u>mobile storage</u> the material based storage system must meet the needs of hydrogen fuel cell vehicles (HFCV) in terms of volume, weight percent hydrogen, cost, flexibility in tank design, fast charging and discharging, and durability with high well to wheel energy efficiency. Other mobile applications may have similar needs.**
- **Material based <u>stationary hydrogen storage</u> applications must be more safe, compact, cost effective and energy efficient than conventional pressurized gaseous hydrogen storage or uniquely meet particular requirements of specific stationary applications especially those require free from legal restrictions.**

Division Projects, Objectives, Research Efforts

Projects	Objective	Research Efforts	Expected application	Researchers
Project 1 On board hydrogen storage project	Development of light-weight hydrogen storage materials and tank system for on board (FCV) application	Validation of candidate materials such as carbon based materials and fabrication of tank system with car industry	FCV/NEDO	E. Akiba, H. W. Li, H. Shao (+ pos-doc, students)
Project 2 Stationary hydrogen storage using boro-hydrides / Mg-based materials	Fundamental research of light-weight hydrogen storage materials	Fundamental research on intermediates of decomposition reaction of borohydride and development of novel Mg-based materials	H2 stationary storage, H2 for energy storage	H. W. Li, H. Shao, E. Akiba (+students)
Project 3 Project for application of HPT	Development of materials for mobile and stationary applications using HPT technique	Improvement of hydrogen storage behavior of metallic hydrides for accommodation of fluctuating H2 production from renewable energy	H2 on board application, H2 stationary storage, H2 for energy storage	Z. Horita, K. Edalati, H. Emami, J. Matsuda (+students)

Milestones

On board hydrogen storage project

	2014-2020	2021-2030	2031-2050

Project 1

On board hydrogen storage project

Volume Density: 178L
Weight Density: 5 wt %
Shape: Cylindrical tank
Cost: ~500,000 Yen

150 L
5 wt %
Cylindrical tank
~200,000 Yen

100 L
7.5 wt %
Flexible Design
<100,000 Yen

Expanding of FCV market
Applied for various FCVs

as a system for 5 kg of hydrogen on board

Carbon based materials suitable for hybrid hydrogen tank
Increase capacity up to 4 wt%
Reduce hydrogen pressure 20-25MPa

Tests and tuning for application (Hybrid hydrogen tank) under a national project with car industry

Validation for on board application
Start of large-scale production of FCV

Expanding of FCV market
Applied for various FCVs

Development of board hydrogen storage system using storage materials

Validate candidate materials for on board application
Develop hybrid tank system with car industry

Validation of tank system with car industry

Validation realistic system for on board application
Start of large-scale production of FCV

Applied for various FCVs

Process to apply storage material system to FCV

Milestones

Stationary hydrogen storage using boro-hydrides / Mg-based materials

Project 2 — Boro-hydrides

2014-2020

- Investigation of thermodynamics and kinetics of intermediate compounds
- Define relationship between formation of intermediates and de-/re-hydrogenation of boro-hydrides

2021-2030

- Determine boro-hydride composition with tuning thermodynamics
- Develop Boro-hydrides having 10 wt% hydrogen under 100ºC and 10 MPa with optimized thermodynamics and kinetics

2031-2050

- Demonstration for stationary energy storage application

Project 2 — Mg-based materials

2014-2020

- Kinetics and cycle ability improvement in nanoscale, at working temperature around 300-400ºC
- Design and control of Mg-based hydrogen storage materials from aspects of capacity, thermodynamics and thermal conductivity

2021-2030

- Over 7wt% capacity, cycling stability over 10000 times remaining >90% capacity and other proper properties, cost-effective materials ready for system development

2031-2050

- Apply for intermittent renewable energy storage

Milestones

Project for Application of HPT

	2014-2020 (short)	2021-2030 (mid)	2031-2050 (long)
Project 3: **Project for Application of HPT**	HPT'ed Mg based alloys for on board application HPT'ed TiFe: kinetics & impurity effects Scale-up HPT process to produce large quantity	Start commercialization of HPT-processed TiFe for stationary application and HPT-processed Mg alloys for on board application	･Safe operation of H2 station with TiFe ･Safe use of Mg based alloys for on board application

Ultimate Targets

	Ultimate targets	Current Benchmarks
Project 1 On board hydrogen storage project	• 100 L • 7.5 wt % • Flexible Design • <100,000 Yen as a system for 5 kg of hydrogen on board	• Using Ti-based BCC alloy developed by Akiba@AIST and Iba@Toyota, TOYOTA developed hybrid tank technology (2.2 wt% under 20-25 MPa as system and 2.8 wt% at RT under 20-25 MPa as material)
Project 2 Stationary hydrogen storage using boro-hydrides / Mg-based materials	• Borohydrides: as materials 10 wt% H2 uptake at 100ºC under 10 MPa • Mg-based materials with > 7 wt% capacity, cycle ability over 10000 times remaining >90% capacity, cost-effective for intermittent renewable energy storage • Competitive cost	• LiBH4 combined with MgH2 with addition of TiCl3 developed by J. Vajo @ HRL Laboratories (USA) (10 wt% @ 400ºC under 10 MPa) • McPhy Energy Company developed Mg-based materials with ca. 5 wt% capacity, absorption in 5 min, no significant capacity loss within 4000 cycles. • TOSHIBA developed H2One™ using metal hydride without legal restrictions and proved the system is cost effective.
Project 3 Project for application of HPT	• Start commercialization of HPT-processed TiFe for stationary application to accommodate fluctuating H2 production from renewable energy • Safe use of Mg based alloys for on board application	• TiFe activated by HPT processing at room temperature in air and it is not deactivated even after exposure to air. (hydrogen content 1.7wt%) , developed by Edalati, Matsuda, Iwaoka, Toh, Akiba and Horita in hydrogen storage group.