Strategy of Hydrogen Research in AIST

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Hydrogen technology for zero-emission society

Development of technology is necessary for
- Distribution and utilization of imported hydrogen
- Domestic hydrogen production for utilizing surplus RE

Production
- Water electrolysis
- Artificial photosynthesis
- Fossil fuel reforming

Storage
- Hydrogen carrier
- Hydrogen storage materials
- High pressure hydrogen
- Liquid hydrogen

Utilization
- Fuel cell
- Recovery of hydrogen from carrier
- Combustion of hydrogen and energy carrier

Assessment
- Sustainability assessment
- Chemical and physical risk assessment

Comprehensive Research for Hydrogen technology
Research Activity of Hydrogen Technology in AIST
R&D for Hydrogen production (1)

Water electrolysis

【Renewable Hydrogen Production】
(Single cell to Scalable)

Improvement of hydrogen production system for utilizing variable electricity

【Direct Coupled Photovoltaic-Electrolyzer】

Establish effective hydrogen production system from variable renewable electricity

【PEM Water Electrolyzer】
(Catalysts, Evaluation protocols)

Development of catalysts and evaluation protocols

【High temperature water vapor electrolysis】

High performance hydrogen production

Alkaline electrolyzer

PEM

SOEC
R&D for Hydrogen production (2)

**Artificial Photosynthesis**

*(Co-production of hydrogen and oxidized chemicals)*

- **Chemicals**
  - Persulfate
  - Hydrogen peroxide
  - Hypochlorous acid
  - Periodate

- **Precursors**
  - Sulfuric acid
  - Water
  - Salt
  - Iodate

Effect of valuable chemicals:
- Purification of organic pollutants
- Sterilizing
- Bleaching, Cleaning
- Selective organic conversion

For economical solar energy utilization

- Solar light
- Water or precursors
- Various chemicals
- Photoelectrode
- Counter electrode
- Low voltage

CH₄ → 2H₂ + C (s)

**Fossil Fuel Reforming**

*(Hydrogen production by direct decomposition of methane)*

Development of catalyst and optimization of reactor
R&D for Hydrogen storage (1)

Energy carrier

【Hydrogenation/Dehydrogenation of Organic Chemical Hydride】

Development of catalyst for usage under variable hydrogen feed

【CO₂/formic acid Cycle】

Development of efficient catalysts for interconversion between CO₂/H₂ and formic acid.

【Ammonia Synthesis】

Demonstration of catalytic process for using renewable hydrogen

【High efficiency Methanation system with co-electrolysis】

・High-performance materials/interfaces
・High stability and reliability
・High-efficiency Power to X technology
R&D for Hydrogen storage (2)

- **Liquid H₂**
  - Development of devices for liquid hydrogen storage tanks

- **High pressure H₂ (100MPa)**
  - Investigation of the hydrogen embrittlement mechanism for metals

- **R&D for liq H₂ devices**
  - Development of devices for liquid hydrogen storage tanks

- **Hydrogen embrittlement**
  - SPM observation for crack surface

- **R&D for metal hydride**
  - Development of hydrogen storage materials for energy storage

- **Hydrogen storage materials**
  - H₂ loading (below 1MPa)
  - Unloading (~0.1MPa)
  - 90~100 g H₂/L before hydrogenation
  - Metal after hydrogenation
R&D for Hydrogen utilization (1)

**Hydrogen recovery**

**[High-pressure H₂ supply from formic acid]**

*Proof-of-concept for High-pressure hydrogen production (> 100 MPa) from formic acid*

**[Thermochemical H₂ compressor]**

*Development of hydrogen compression system and hydrogen storage materials for compression*
R&D for Hydrogen utilization (2)

**Fuel cell**
- **Reversible Fuel cell**
  - Polymer electrolyte type
  - Renewable Energy
  - H₂ storage
  - Solid Oxide type
  - Development of efficient catalysts and electrodes

**Combustion**
- **Hydrogen Single/Multi-Fuel Combustion Engine**
  - R-H₂
  - Dehydrogenation
  - By-product H₂
  - Biofuel
  - 1kW~1MW
  - Development of hydrogen co-firing engine generator
    - Achieved operation of more than 1000 hours at a power output of 300-500kW (hydrogen energy share ratio of 40-60%)

**Ammonia Gas-Turbine**
- Development of ammonia gas turbine
  - Achieved the world first power generation with 100% ammonia combustion in the micro gas turbine
R&Ds for Hydrogen Assessment

Sustainability assessment

Energy resources
- Imported fuel
- Domestic fuel
- Renewables

H2 source

Transformation technology
- Coal refinery
- Oil refinery
- Gas refinery
- Power generation
- Heat supply

H2 production

Secondary energy
- Coal
- Oil product
- City gas
- Electricity
- Heat

H2

Transport / Distribution
- Tanker
- Tank truck
- Pipeline
- Transmission
- Regional heat supply

H2 infrastructure

Energy demand
- Industry
- Business
- Household
- Transport

H2 technology

[Energy system analysis]

Future energy system

Energy Model

Scenario

Emissions

Technology deployment

Cost

etc...

Dominant factors

Constraints
- Technology development
- Resource supply
- Social structure

etc...

The role of hydrogen in the whole energy system

Emissions quantification from H2 supply chain

Indirect CO2 can be attributed to H2 supply chain

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R&Ds for Hydrogen Assessment

[Quantitative Risk Assessment (QRA) for Hydrogen Refueling Station (HRS) and public perception survey]

- Simulation of blast wave
- Contour map of HRS risk
- Amount and frequency of gasoline spill

[Development of explosion safety technology for hydrogen utilization system]

- Understanding of combustion behavior by explosion experiments
- Elucidation of mechanism of explosion damage reduction and system design
- Design of pressure resistance for transportation system assuming unexpected combustion
- Risk analysis of hydrogen production / storage / handling facilities and evaluation of safety measures

Chemical substance risk assessment

Physical risk assessment

H₂ infrastructure

H₂ technology
Demonstration of Hydrogen Energy System

at FREA (Fukushima Renewable Energy Institute, AIST)

Building and energy management system by using hydrogen derived from renewable energy has been realized.
Research and Development for Power to X Technology in AIST
Development of Power to X (Methanol)

【Methanol synthesis from CO₂ at < 100 ℃】

Challenges:
- Catalyst development
  - High selectivity
  - High conversion rate
  - Robustness
  - Low temperature

H₂ Carrier
Fuel
Chemicals

H₂
Electricity

MeOH

GZR (Global Zero Emission Research Center)
Demonstration of Power to X (Ammonia)

【Value chain of ammonia energy carrier system】

Green-ammonia was synthesized and combusted by gas turbine.

Electrolysis ⇒ Renewable H₂

Renewable electricity

Ammonia gas turbine

Ammonia synthesis

Green-ammonia was synthesized and combusted by gas turbine.
Summary

- R&D for individual hydrogen technology needed in the future zero emission society is on going.

- Development for renewable hydrogen utilization system is carried out by integration of hydrogen technologies