International Institute for Carbon-Neutral Energy Research

Powering the Future
Internationalizing Research

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Urban Nexus: Harnessing Science, Technology and Innovation for Sustainable Urban Cities
AAAS Annual Meeting 2018, Austin, TX

KYUSHU UNIVERSITY

wpi World Premier International Research Center Initiative

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

For the First Time in History….

Commercial fuel cell cars are here
Over 3,500 sold or leased in the United States
About 2200 sold in Japan

- ✓ **No petroleum, no pollution**
- ✓ **Refuels in minutes**
- ✓ **More than 360 mi driving range**
- ✓ **Over 60 mpgge**

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies Office, 02/17/2018

Hydrogen Refueling Stations: strong State support

California

Over 30 open retail

Funding for 100

Northeast

Approx. 12 to 25 stations planned

2 commissioned

Others with interest: Hawaii, Ohio, Texas, Colorado, South Carolina, and others

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies Office, 02/17/2018

Optimization Analysis on Deployment of Hydrogen Refueling Stations

Objectives

- To find prospective sites for locating hydrogen refueling stations (HRSs)
- To guide relevant stakeholders in siting HRSs

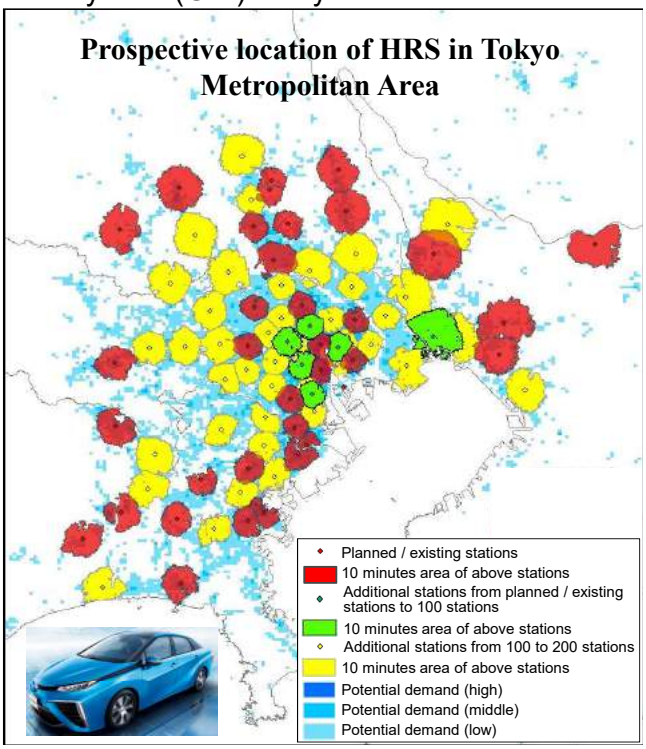
Analytical method

- Location optimization by Geographic Information System (GIS) analysis

Refueling Stations
101 in 2017
160 for 2020
320 for 2025
900 for 2030

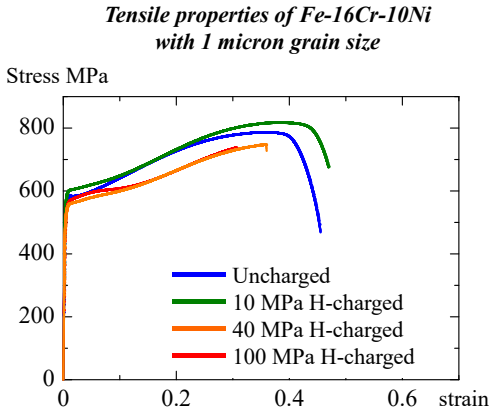
Prospective location of HRS in Japan nationwide

Prospective location of HRS in Tokyo Metropolitan Area



Next-Generation High-strength, Low Cost Alloy for Hydrogen Service

- New class of steels with superb strength and resistance to hydrogen degradation
- Commercially available stainless steels have yield strength less than 300 MPa
- I²CNER steel has yield strength 600 MPa which reduces the component cost for fuel cell vehicles & refueling stations by 65%
- Used by Nippon Steel for ultra-fine grained SUS304 sheets for micro-components
- Takaki group



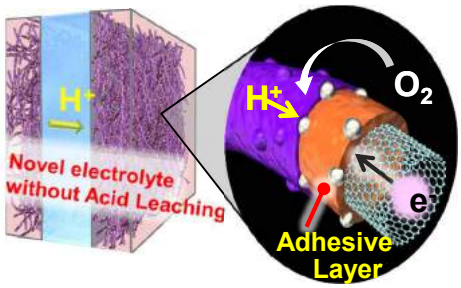
Discovered that ultra-fine grain processing of 16Cr-10Ni stainless steel dramatically increases strength without compromising fracture resistance in hydrogen

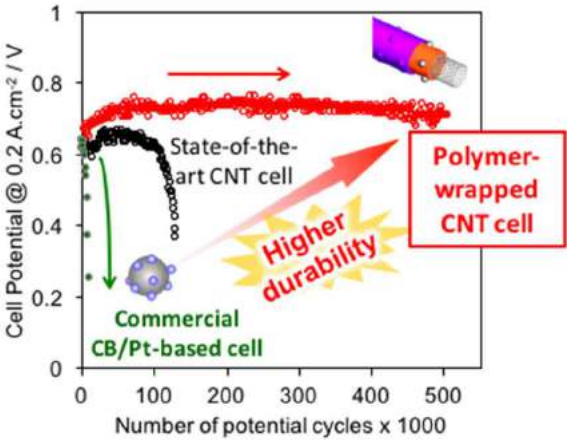
A. Macadre *et al.*, Int. J. Hydrog. Energ., 40 (2015), 10697-10703

Durable and Efficient Polymer Electrolyte Fuel Cells

EI/LCI

- New idea: polymer-wrapped carbon nanotube catalysts
- Record durability fuel cells developed
- Operate well under dry or wet conditions at 90-120 C for higher efficiency
- Discussion with a major automobile company in progress
- Nakashima group discovery





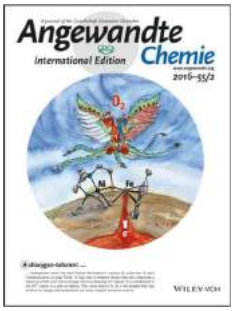
N. Nakashima ***Scientific Reports***. art. No.16711, 2015

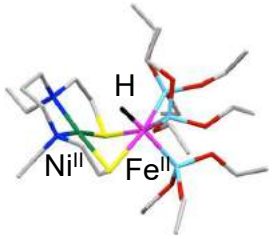
Nakashima et al., *ChemCatChem*, 2015, 7, 808-813.

Chemistry of Small Molecules for Energy Generation

LCI

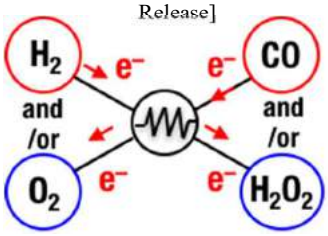
- Developed biomimetic catalysts
- Platinum-free molecular fuel cell
- CO, H_2O_2, now fuel and oxidizer, not poisons
- Commercialization by Daihatsu Motor Co. in progress
- Ogo group



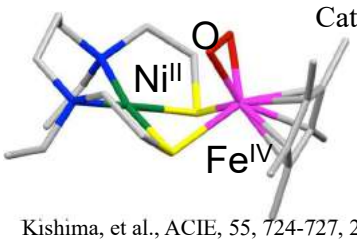


Anode

Ogo et al. Science 339, 682-684,2013, [Press Release]



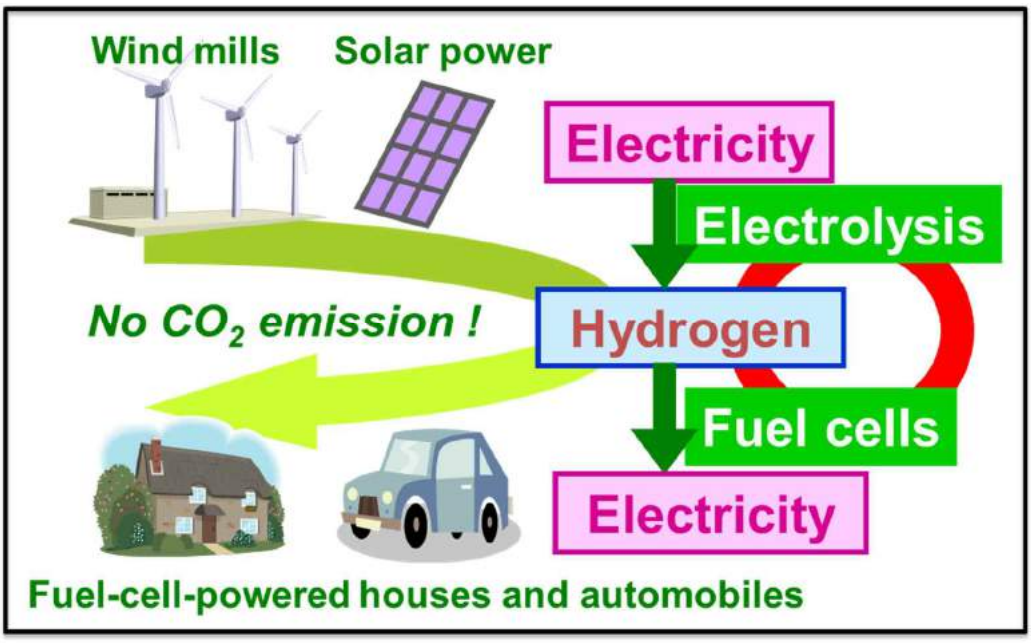
Matsumoto et al, Angew. Chem. 50, 11202-11205,(2011)

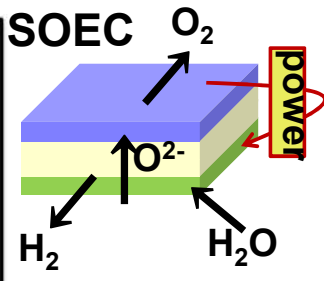


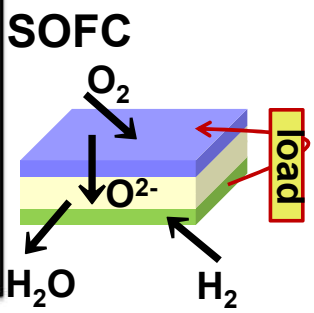
Cathode

Kishima, et al., ACIE, 55, 724-727, 2016, [Press Release]

Reversible Solid Oxide Cells for Grid-Scale Storage







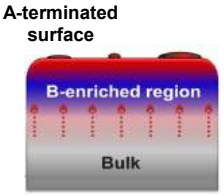
Challenges and Opportunities

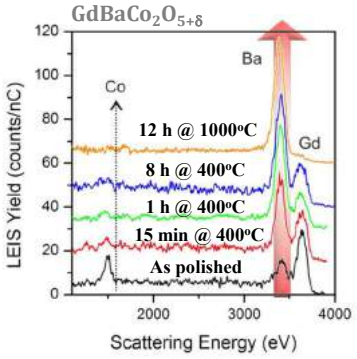
- materials integration
- extending lifetime and mitigating degradation

Understanding Solid Oxide Fuel Cells
Surface Properties of Top Atom-layer

- Permits engineered design of improved solid oxide electrodes
- Oxygen transport kinetics understood in solid oxide fuel cells
- Advanced characterization coupled with fundamental theory
- Developed advanced characterization methods now used at Hitachi
- Kilner and Ishihara groups

ABO_3 perovskite



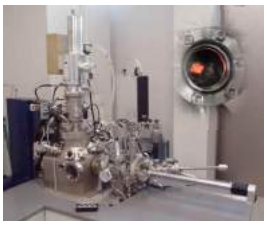


Téllez, et al, *Faraday Discuss.*, 182, 145 (2015)

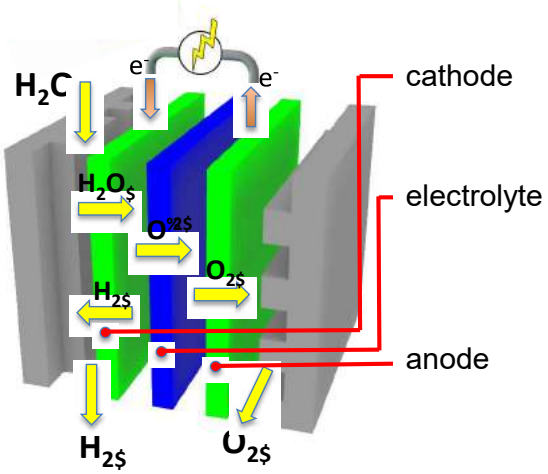
Illinois-Kyushu NSF-JSPS PIRE Program
Partnerships for International Research and Education

INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING FOR ACTIVE MATERIALS AND INTERFACES IN CHEMICAL FUEL PRODUCTION

NCSA Blue Waters
sustained petascale computing, Illinois



High-brightness LEIS
I²CNER, Kyushu



- Computational (led by Illinois, NCSA) and experimental (led by Kyushu) program; additional members from Northwestern, Berkeley, Imperial College. PIs: Aluru, Sofronis, Ertekin, Hammes-Schiffer (Illinois); Barnett (Northwestern); Ishihara, Matsumoto, Perry (Kyushu)
- "Global Citizenry to Power the Future": Fully-integrated education, research, and cultural exchange, including 10 week summer exchange for undergraduates (~60 students), graduate student exchange (~10 students), post-docs (~5 students)
- Funding level: ~$4.75 million from NSF for 5 years (possibility of renewal), additional from JSPS (49.5 million JPY)

Acknowledgments

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Kyushu University, University of Illinois

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