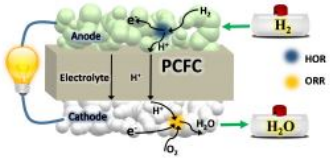
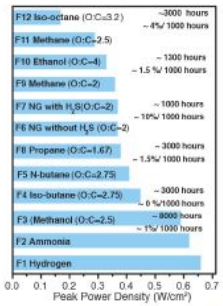
Low-Cost Intermediate-Temperature Fuel Flexible Protonic Ceramic Fuel Cell Stack

Expanded Utility through Manufacturable Processes and More Fuel Options

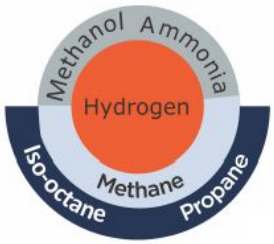
Highly durable protonic ceramic fuel cells



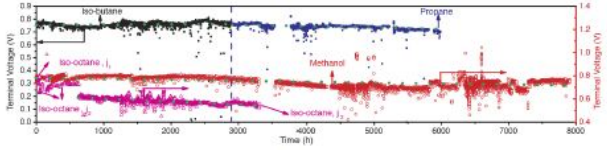
- Intermediate-temperature (400-600 °C)
- Highly durable
- Fuel flexible
- Low-cost
- High-performance
- High coking resistance
- High sulfur tolerance

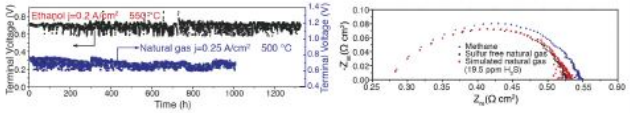


12 different fuel streams



Low-degradation on multiple fuels





FlexPCFC remarkable features
- LONG stability (>8000 hours)
- Fuel-flexible (>10 fuels)
- High-performance with HCs
- High coking resistance
- High sulfur tolerance

- Duan, Chuancheng, et al. Science 349.6254 (2015): 1321-1326.
- Duan, Chuancheng, et al. Nature 557.7704 (2018): 217.
- Duan, Chuancheng, et al. Nature Energy 10.1038/s41560-019-0333-2

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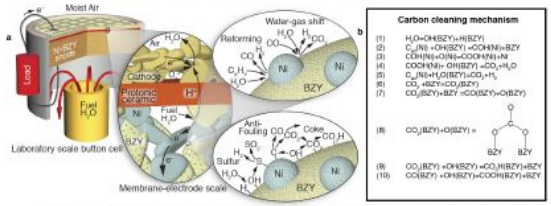
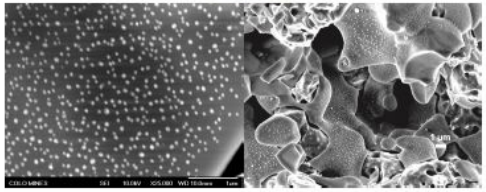
Unique features of protonic ceramic fuel cells

In-situ exsolved Ni nanoparticles

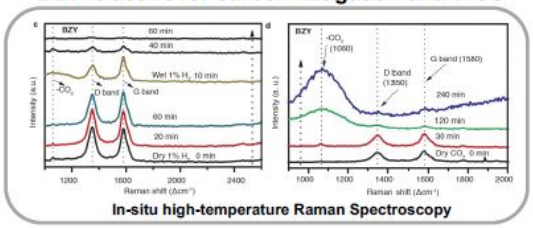


Carbon cleaning mechanism

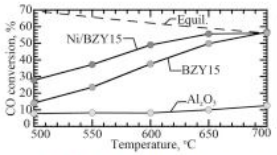
(1) $H_2O+OH(BZY)=H(BZY)$
(2) $C_xH(N)+OH(BZY)=COH(N)+BZY$
(3) $COH(N)+O(N)=COO(H)(N)+N$
(4) $COO(H)(N)+OH(BZY)=CO_2+H_2O$
(5) $C_xH(N)+H_2O(BZY)=CO_2+H_2$
(6) $CO_2+BZY=CO_3(BZY)$
(7) $CO_3(BZY)+BZY=CO(BZY)+O(BZY)$
(8) $CO_3(BZY)+O(BZY)=$
(9) $CO_3(BZY)+OH(BZY)=CO_3H(BZY)+BZY$
(10) $CO(BZY)+OH(BZY)=COOH(BZY)+BZY$



BZY is active for carbon mitigation and WGS



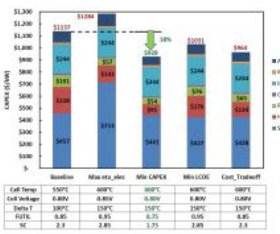
In-situ high-temperature Raman Spectroscopy



FlexPCFC remarkable features
- Engineered anode
- High HCs reforming activity

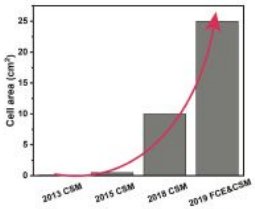
Jennings, Dylan M., et al. *Catalysis Letters* 148.12 (2018): 3592-3607.

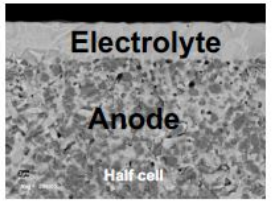
Different system design objectives generate varying optimal PCFC stack parameter selections

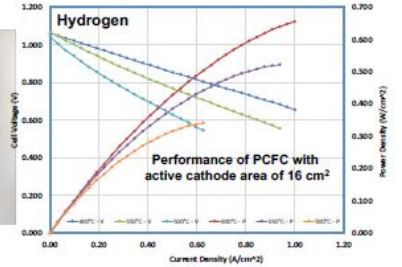


Configuration	Possible use
Max efficiency	Military application
Min CAPEX	Emergency backup
Min LCOE	Residential use
Tradeoff	Recreational use

Scale up







arpa·e CHANGING WHAT'S POSSIBLE

Current Project Status
Industrial Partner
Fuel Cell Energy

2010
US patent Application 14/621, 091, 2015 Development of SSRS Process for PCFCs
US patent Application 62/101, 285, 2016 Development of Triple Conducting Cathode for PCFCs

3 First FlexPCFC Single Cell

4 First FlexPCFC 3-Cell Stack (~1 W Power)

5-6 Pre-commercial "quarter-stack" prototype (~100W)

7 Commercial product prototype for remote DG applications (~1-3 kW)