Liquid Tin Anode Fuel Cell Direct Coal Conversion

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CellTech Power
Fuel Cells for Real Fuels

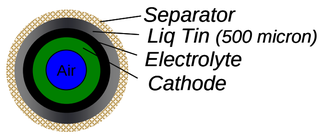
ABSTRACT

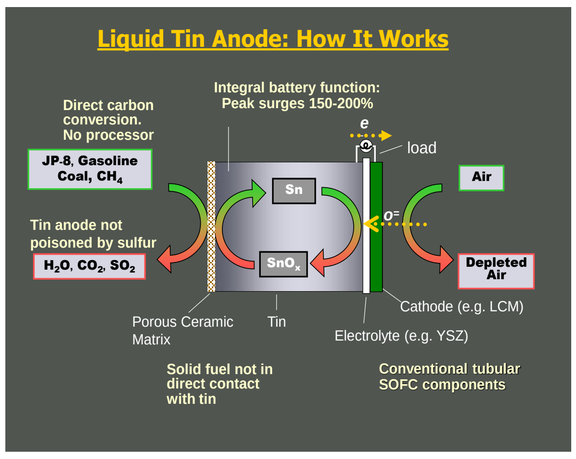
The Liquid Tin Anode Solid Oxide Fuel Cell (LTA-SOFC) is a direct conversion fuel cell and does not require fuel processing, reforming or water.[1,2,3,4] Power is generated directly from any solid, liquid or gaseous carbonaceous fuel. Sulfur and carbon species are fuel not a poison to the LTA-SOFC. CellTech's LTA-SOFC is the only known fuel cell capable of direct operation on heavy hydrocarbons such as military logistics fuel. Its versatility and fuel flexibility allow applications ranging from compact sub-kilowatt portable/mobile power units to stationary MW-scale power plants. This poster will discuss technology development activities which address major opportunities in direct coal conversion:

References:
1. Advancement in Liquid Tin Anode - Solid Oxide Fuel Cell Technology Thomas Tao, et al, ECS Trans. 12 (1), 681 (2008).
2. Anode Polarization in Liquid Tin Anode Solid Oxide Fuel Cell Thomas Tao, et al, ECS Trans. 7 (1), 1389 (2007).
3. Liquid Tin Anode Solid Oxide Fuel Cell for Direct Carbonaceous Fuel Conversion Thomas Tao, et al, ECS Trans. 5 (1), 463 (2007).
4. Performance of the Gen 3.1 Liquid Tin Anode SOFC On Direct JP-8 Fuel, M. T. Koslowske et al., Advances in Solid Oxide Fuel Cells IV, Ceramic Engineering and Science Proceedings, Volume 29, Issue 5, 2008, pg. 39.
5. Program on Technology Innovation: Systems Assessment of Direct Carbon Fuel Cells Technology, EPRI report 1016170, April 2008.

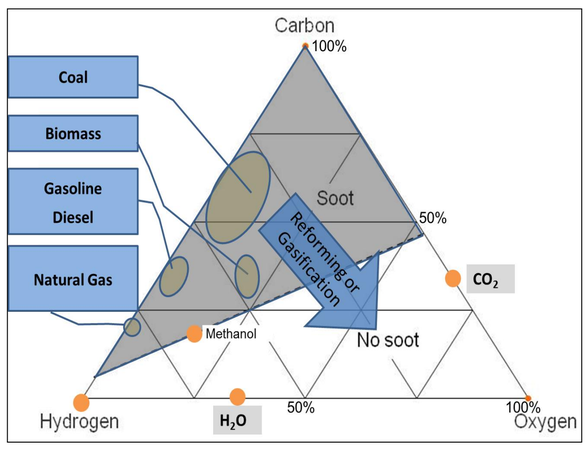
CELL OPERATION

- Tubular cell geometry with internal cathode →
- Anode is liquid tin contained by porous ceramic which allows fuel transport to tin surface
- Sn to SnO_x redox transport facilitates operation





Direct Fuel Conversion of simple and complex fuels, such as biomass, JP-8 and coal is possible in both the soot forming and non-sooting regimes.

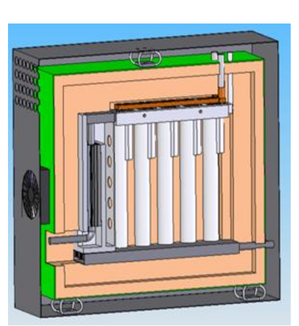


CELL, STACK and SYSTEM DEVELOPMENT:

Parallel efforts for logistic fuel and biomass funded by DOD and NSF allow Liquid Tin Anode SOFC technologies mature.

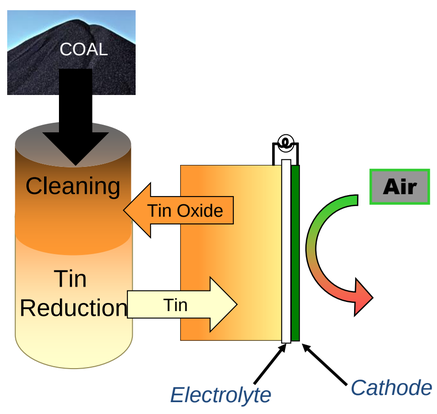
5-Cell panel

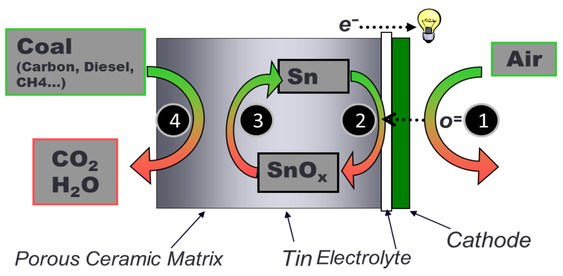
60 Watt JP-8 Battery Charger



Electrochemical Looping

Based on Coal-Tin Reactor
DE-NT0004111, DE-ER85006



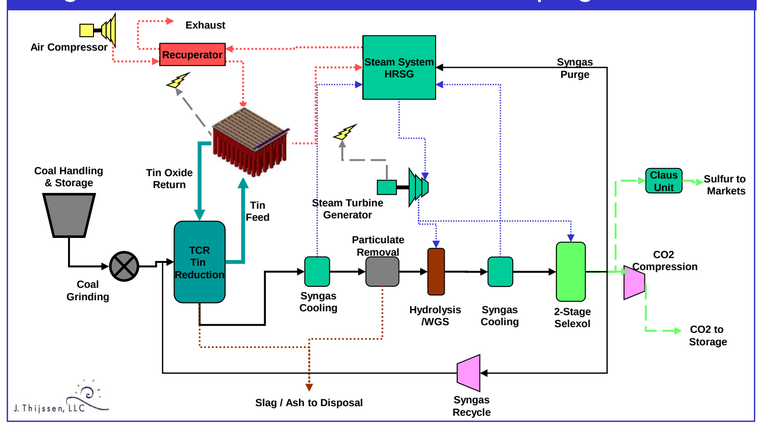


1. Oxygen ions extracted from air by cathode and cross the electrolyte
2. Ions react with tin, releasing electrons and forming tin oxide
3. Tin oxide is independently reduced back to tin by reaction with fuel
4. Fuel directly contacts tin

Most thoroughly analyzed concept to-date

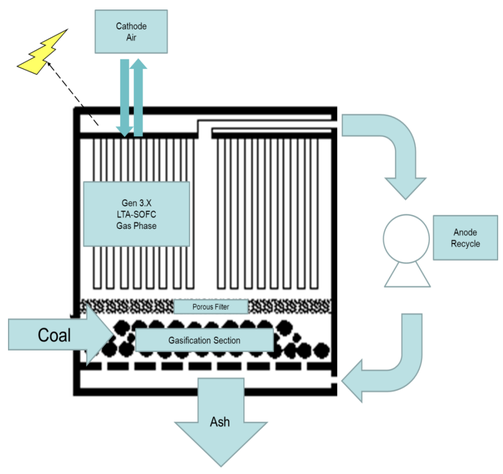
- 63% System efficiency with CO2 capture and compression
- System CAPEX: $1400 – 2400/kW (similar to IGCF)
- Near 100% CO2 capture
- Tin provides separation of ash/impurities
- Requires development of Tin Coal Reactor similar to liquid metal gasifiers
- High tin recirculation rate required to meet O_2 transport requirements.
- Tin anode requires electric current break

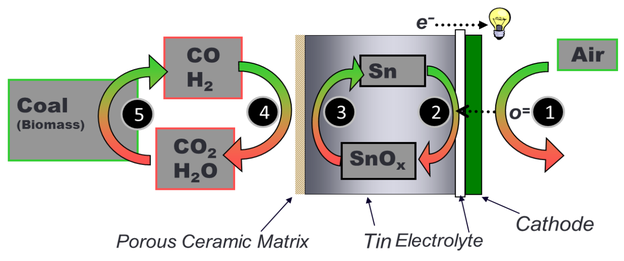
High Level PFD of Electro Chem Looping with CCS



Insitu Gasifier

Based on Portable Power Cell
DE-ER95350S10



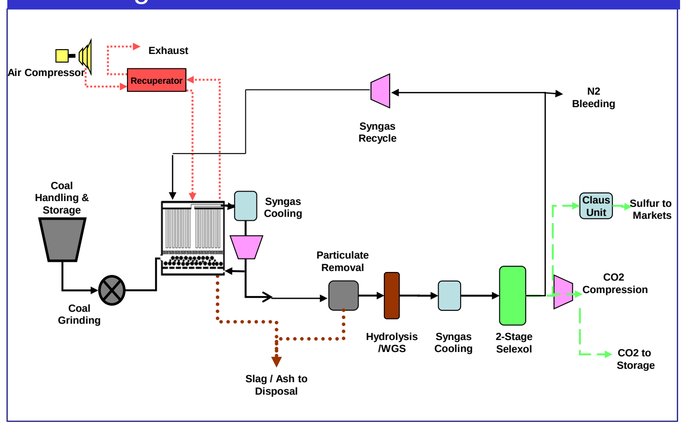


1. Oxygen ions extracted from air by cathode and cross the electrolyte
2. Ions react with tin, releasing electrons and forming tin oxide
3. Tin oxide is independently reduced back to tin by reaction with fuel
4. Tin-fuel interaction can occur inside tin or across a porous ceramic membrane
5. Coal or other solid fuel is gasified insitu by the cell reaction products

Uses cells with porous separator, like existing CellTech Gen 3 design

- No direct contact between tin anode and solid fuel.
- Gasification is driven by CO_2 and H_20 produced by cells (no Oxy plant required).
- Isolated anodes allow cell voltage build up.
- Ash, tar and carbon clogging of separator could be an issue.
- Volatile metal oxides in coal impact on cells unknown.
- Could test concept with Gen 3.1 cells and lab gasifier.
- Cathode air flow may increase to remove cell heat load.

High Level of PFD of Insitu Gasifier



Direct Coal Summary

OPPORTUNITY:

- Previously reported studies have projected that LTA-SOFC can achieve 63% efficiency in a large direct coal power plant with carbon capture[5].

KEY RISKS:

- Cell component degradation during operation on very high (ca. 4%) sulfur levels.
- Impact of coal ash creation and residual contaminants on long term material stability.

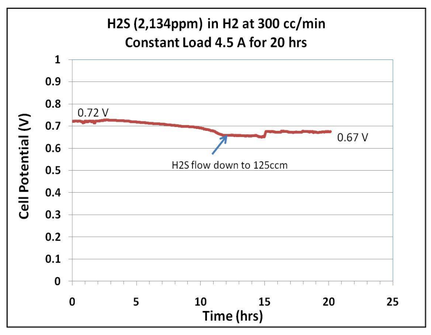
PROGRAM OBJECTIVES:

The focus of the coal effort is to identify cell durability liabilities in coal contaminant environments through long-term testing of single cell test articles. Cell testing will be conducted using both a tin bath reactor and internal gasification methods.

Internal Gasification Test:

Determine the effect of high sulfur content on LTA-SOFC operation.

- Simulate a high sulfur coal environment, Illinois #6 coal (DECS-24) - 4.8 wt% sulfur, using H_2S (2,134ppm, 3.5wt%) in H_2.
- **Goal: 20 hr operation**

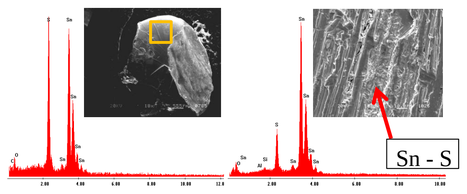


Results:

- Completed 20 hour test
- Total Sulfur = 1.1 gram
- Fuel delivery inconsistency contributed to decrease in performance.
- Cell Stable for last 5 hours.
- Sulfur remains on / in tin

High sulfur content on tin surface

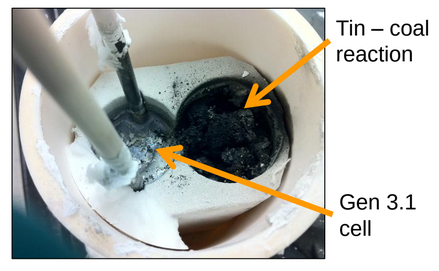
Sulfur localized in bulk tin



Tin Bath Reactor Test:

Determine the effect of ash on direct tin coal interaction.

- Illinois #6 coal (DECS-24) with 4.8 wt% sulfur was fed onto tin surface for 24 hours.



Results:

Average Power	**0.97**	**Watts**
Runtime at load	1412.00	Minutes
Total Coal Input (Illinois #6)	20.36	grams
Average Flow Rate	18.36	mg/min
LHV Illinois #6	28453.96	J/g