DIRECT COAL CONVERSION USING LIQUID TIN ANODE SOFC
ALTERNATIVE SYSTEM CONFIGURATIONS

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The Liquid Tin Anode (LTA) Fuel Cell can operate on gaseous, liquid and solid fuels containing hydrogen, carbon or hydrocarbon compounds. Power production in the LTA occurs during the conversion of liquid tin to tin oxide using a solid oxide electrolyte:

$$Sn(l) + 2\ O_2- \ = SnO_2\ (s) \ + 4\ e \qquad [1]$$

A solid fuel such as carbon, coal or biomass can be used to reduce tin oxide back to tin via one of the following pathways:

$$SnO_2(s) + 2\ C = 2\ CO(g) + Sn \qquad [2]$$

$$SnO_2(s) + C = 2\ CO_2(g) + Sn \qquad [3]$$

$$CO_2(g) + C = 2\ CO(g) \qquad [4]$$

$$SnO_2(s) + CO(g) = CO_2(g) + Sn \qquad [5]$$

The LTA has also demonstrated the ability to operate in the presence of sulfur and under sooting conditions. This poster provides an update on the development of two possible configurations for direct coal/biomass conversion using LTA technology. In both cases power is produced with a liquid tin anode according to Eqs 1 to 5. However the two configurations use different methods to supply fuel to the anode, one with a stationary thin tin layer and other a circulated tin bath. This poster will compare and contrast these two direct coal/biomass concepts and discuss the progress of technical evaluations of each.

1. **Electrochemical Looping Configuration – circulating tin bath**. In this configuration each fuel cell consists of a tubular or flat tube cathode-electrolyte assembly. A bundle of tubes is immersed in a flowing tin "bath" which serves as a common anode. In the power production process, tin oxide is formed according to [1]. Tin oxide flows to a separate tin-coal reactor and is converted back to tin by the introduction of coal or other hydrocarbon fuel (including biomass) according to [2] and [3]. A primary advantage of this concept is that direct contact between fuel and anode leads to high projected efficiency up to 63%.. A key technical challenge for this configuration is the possibility of fuel borne contaminants reacting with fuel cell components, particularly the anode, electrolyte and sealing components. Under SECA SBIR and Cooperative Agreements, CellTech has evaluated the partioning of coal contaminants following introduction into the tin anode.

2. **In-situ Gasification Configuration – stationary thin tin layer.** In this configuration the cell reaction products (CO_2 and water) are used to drive an internal gasification process. The cell layout is based on CellTech's successful Gen 3.1 geometry for portable power. In this cell geometry, the tin anode is trapped in a thin layer next to the electrolyte. A porous ceramic provides containment of the tin anode and allows only gaseous products to interact with the tin. Fuel is introduced into an anode chamber surrounding the fuel cell bundle. Eq [4] describes the internal gasification process (if the fuel is a hydrocarbon, H_2 is also produced) . CO (and hydrogen) migrate to the anode through a porous separator and reduce tin oxide back to tin [5]. This process has been used to produce power directly from diesel and military logistics fuel (JP-8) for over 450 hours with peak efficiency greater than 50%. Both coal and biomass biochar were also tested in single cells. Under SECA and NSF SBIR funding CellTech is studying the behavior of ash from coal and biomass. Fuel chemistry plays an important role in ash behavior. Some biomass ash is very rich in volatile alkaline compounds such as potassium oxide which becomes liquid at fuel cell operational temperatures and may significantly influence conversion, power density or durability.

These different configurations have unique advantages and challenges. The ElectroChemical Looping configuration provides more opportunities for dealing with coal ash and contaminants but requires circulation of large amounts of tin/tin oxide. The In-situ Gasification configuration uses a scaled up version of an existing cell design and provides electrical isolation for each cell. More evaluation is required for both configurations to determine suitability for direct coal and biomass power conversion. This poster summarizes the outstanding features of each configuration and some of the unknown aspects which still require more research.