FESC Florida Energy Systems Consortium

Thrust Area 4: Solar (PV Integration)
An Integrated Sustainable Transportation System

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Description: The proposed vehicle, operating on biofuel while in transit and charged by the sun while parked, is the ultimate sustainable transportation system operating completely on renewable American energy resources. Moreover, the use of solid oxide fuel cells (SOFCs) rather than an IC engine in this hybrid vehicle results in a dramatic improvement in efficiency and reduction in emissions. SOFCs are the most efficient technology for converting energy from hydrocarbon fuels to electricity on a "well to wheels" basis. In contrast, the more conventional fuel cells require hydrocarbon fuels to first be converted to H_2, with resultant efficiency losses, followed by losses due to H_2 transport and storage. Therefore, on a system-basis SOFCs hold the potential for producing the least CO_2/kWh from conventional fuels, and if designed to operate on biofuel would in effect be carbon neutral and operating on a renewable resource. *If developed this vehicle would be a transformational change in transportation technology.*

Budget: $594,000
Universities: UF
External Collaborators: Solid-State Energy Technology, Inc., Lynntech, Inc., Planar Energy Devices, Inc., CFX Battery, Inc.

Executive Summary

The proposed vehicle, operating on biofuel while in transit and charged by the sun while parked, is the ultimate sustainable transportation system operating completely on renewable American energy resources. Moreover, the use of solid oxide fuel cells (SOFCs) rather than an IC engine in this hybrid vehicle results in a dramatic improvement in efficiency and reduction in emissions. SOFCs are the most efficient technology for converting energy from hydrocarbon fuels to electricity on a "well to wheels" basis. In contrast, the more conventional fuel cells require hydrocarbon fuels to first be converted to H_2, with resultant efficiency losses, followed by losses due to H_2 transport and storage. Therefore, on a system-basis SOFCs hold the potential for producing the least CO_2/kWh from conventional fuels, and if designed to operate on biofuel would in effect be carbon neutral and operating on a renewable resource. *If developed this vehicle would be a transformational change in transportation technology.*

In this project, we made significant gains in the science of energy conversion, from fundamental studies of the atomistic underpinning for materials properties to the engineering of the highest performance solid oxide fuel cells in the literature. Fundamental studies of the two most promising materials for solid electrolytes, using computational modeling, enabled us to determine the optimal potentials to use (the Gotte potential) in predicting materials properties for oxides of interest in this field. Moreover, from a molecular dynamics study of bismuth oxide we were able to confirm that dopant polarizability was the key feature in determining oxygen vacancy mobility in the fluorite system. Undergirded by these results we are now positioned to use our computational tools to further optimize the material properties of known oxygen ion conductors as well as develop new ones with superior performance.

We have also expanded the application of our previously developed continuum-level electrochemical model to describe and predict the performance of SOFCs as a function of electrolyte thickness. We were able to show that, for maximum power density, mixed conducting electrolytes had an optimal thickness below which they were rapidly overwhelmed by electronic conduction and above which their ohmic losses grew. We also are the first ones to predict the drop in open circuit potential with decreasing thickness for these materials.

Our development of record conductivity materials also continued with the highest conductivity ceria based and bismuth oxide based materials reported. We further studied their stability and optimal temperature window for operation. In so doing we have established our institution as the clear leaders in this area.

We are also leading in the area of anode development as the first to develop SOFCs with anode functional layers, which enabled a quantum step in SOFC performance. By comparison, our work on cathode performance is set to take off. We have already developed one of the highest conductivity cathodes (a bismuth ruthenate-bismuth oxide composite) in the literature. However, our fundamental studies on the oxygen reduction reaction (ORR) have positioned us to break further ground towards making a significant performance jump using conventional cathode materials. We have used multiple techniques to investigate the factors governing the ORR and the results of those studies point to new electrode architectures that should both improve performance and increase stability (especially, with respect to chrome poisoning and secondary phase formation).

Finally, we have also found time to complete our research efforts in hydrogen production, which is critical for the realization of a future hydrogen economy. In addition, we moved forward with our work on sensors, by indentifying the factors affecting the sensing process and developing high selectivity sensors with high signal-to-noise ratios. This has garnered interest from industry, leading to collaborations with General Electric (GE) and Energy Management Solutions (aka EPS) and RedOx Fuel Cells.

This project has been completed.