UNIVERSITY OF FLORIDA

Solar Fuels for Thermochemical Cycles at Low Pressures

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Description: Using concentrated solar energy to produce hydrogen-rich, carbon-neutral energy carriers via two-step thermochemical cycles is an intriguing concept for tomorrow's energy economy. Concentrated solar energy drives high temperature endothermic metal oxide (MO) reduction reactions. Reaction products are used to produce hydrogen from water or CO from CO_2. In turn, hydrogen and CO may be used to synthesize carbon neutral methanol or methane. At atmospheric pressures, temperatures above 2000 K are necessary for the MO reduction reactions, causing a range of material and design issues. This project aims at lowering the MO reduction temperature by reducing the reaction pressure. M/MO redox reactions at low pressures will be experimentally investigated in a state-of-the art high flux solar simulator. Furthermore, undesired product recombination is less likely under rarefied conditions. Associated efforts will be directed at developing chemical kinetics and multi-phase, multi-scale process models. Process temperature reduction and a better understanding of the underlying physicochemical phenomena will move solar thermochemistry towards commercialization and make it attractive for Florida's high-technology and energy industry.

Budget: $ 100,000
Universities: UF
External Collaborators: NA

Progress Summary

Research Objectives for Current Reporting Period: The main research objective of the current report period was designing and manufacturing a high flux solar simulator for the experimental investigation of metal/metal oxide cycles at low pressures. The solar simulator must provide peak flux levels exceeding 5000 kW/ m^2 and be compatible with low pressure experimentation. Furthermore, a literature review and thermodynamic calculations were carried out to come up with a shortlist of redox pairs for further investigation.

Progress Made Toward Objectives During Reporting Period: A high flux solar simulator consisting of seven 6 kWe Xenon arc lamps (Osram XBO 6000 HSLA), each close-coupled to an ellipsoidal mirror has been modeled and designed. The mirrors are arranged in a hexagonal grid. The mirrors have a diameter of 0.8 m, a focal distance of 1.8 m, and an opening cone angle of 50°. Each Xenon arc lamp is positioned at the focal point of one mirror.

The mirrors are oriented such that their second focal points coincide in a single point. The overall cone angle of the arrangement is 52°. Monte Carlo ray tracing simulations have been carried out to predict flux levels at the common focal point. Peak fluxes exceeding 5000 kW/m^2 are predicted, this is equivalent to blackbody stagnation temperatures exceeding 3000 K.

Currently, components are being manufactured. The mirrors are spun from Aluminum sheet metal, polished, vacuum plated, and equipped with a high temperature resistant protective polymer coating to minimize degradation of the optical surface during experimentation. Each lamp-mirror assembly is equipped with a fan that provides cooling air, ensuring that the bulb temperature remains below 1000 K.