COLLEGE OF ENGINEERING
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ME Department Seminar

Reactive and Inert Oxide Particles for Capturing and Storing Solar Energy

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Abstract

Oxide particles can provide a robust thermal energy storage (TES) media for concentrating solar power (CSP) as well as other high-temperature thermal applications. Reactive oxides, like doped $CaMnO_3$ perovskites, can reduce at temperatures attainable in central-tower solar receivers with the potential for storing as much energy in endothermic reduction as in sensible heating. However, such high reduction for high specific TES requires a sweep gas flow with O_2 partial pressures of 0.01 bar or less. This presentation compares the advantages and disadvantages of using reactive oxides, in particular Sr-doped $CaMnO_3$ relative to low-cost inert oxides like aluminosilicate for TES in CSP applications. Thermodynamic and kinetic material characterization provides a basis for assessing the performance of reactive perovskite particles in comparison to inert particles. Results show that endothermic point-defect reduction kinetics of doped $CaMnO_3$ require significant residence times in solar receivers to achieve a high percentage of the chemical energy during particle heating. Modeling of a simple indirect particle receiver based on a unique narrow-channel, counterflow fluidized bed explores how sweep gas for O_2 release and the particle morphology of the reducing perovskite can impact its viability for improved energy storage relative to the inert oxide. These results are then placed within the context of an entire TES system for a next-generation CSP plant with a supercritical-CO_2 power block. Results suggest pathways to get to 90% solar receiver efficiencies and the importance of utilizing particle flows that sustain high particle-to-wall heat transfer coefficients (> 1000 $W/m^2 \cdot K$) to drive cost-effective solar energy capture and storage.

Bio

Prof. Greg Jackson has served in academia for over 20 years. He served as the Dept. Head of Mechanical Engineering at Mines from 2013-2017. Before joining Mines in 2013, Jackson was a faculty member for 15 years at the University of Maryland in Mechanical Engineering and the campus-wide Energy Research Center for which he served as Associate Director for several years. At Mines, Dr. Jackson manages a research group active in concentrated solar energy storage and solid-oxide electrochemical systems. He currently leads a broad effort on reactive and inert oxide particles for high-temperature energy storage for concentrating solar power applications. He has published broadly on materials and processes for high-temperature catalysis and electrochemistry for a range of energy applications and currently serves on the Board of Directors of the Electrochemical Society. He received his Ph.D. from Cornell University where he performed research on liquid-fuel combustion. After his Ph.D., he worked at Precision Combustion Inc. where he led research and development on catalytic reactors for low-NOx combustion and aircraft engine ignition.