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Ca-Ce-Ti-Mn-O Perovskites for Solar Thermochemical Water and Carbon Dioxide Splitting

Background

Thermochemical cycles (TCCs) for water or carbon dioxide splitting involve redox active metal oxides and use high temperatures sourced from concentrated solar power or other renewable pathways to produce either hydrogen and oxygen from water, or carbon monoxide and oxygen from carbon dioxide with no direct greenhouse gas emissions. In the first step of a traditional two-step TCC, a metal oxide is reduced at 1700-2000K by absorption of radiation from either concentrated sunlight or radiative heater lamps, producing oxygen vacancies and O2 gas. In the second step, the reduced metal oxide is cooled to approximately 900-1400K and oxidized by H2O or CO2 gas, regenerating the stoichiometric metal oxide and producing H2 and CO gas.

The current state-of-the-art reactant material for the two-step TCC is ceria or cerium oxide (CeO2), but new materials are needed that would maximize the redox capacity during the first step to improve the efficiency of TCC H2O or CO2 splitting.

Invention Description

Researchers at Arizona State University have developed a novel perovskite compound with a formula of Ca1-xCexTiyMn1-yO3 that is A-site redox active and has multiple redox-active cations in the same compound. For this compound, initial results found that having x between 0.3 to 0.35 and y between 0.25 and 0.35 improves the redox capacity and the efficiency of TCC water and carbon dioxide splitting. This compound has a lower reduction enthalpy than CeO2 via simultaneous reduction of Ce4+ to Ce3+ and Mn4+ to Mn3+ and potentially Mn2+ with potential for redox on Ti upon oxygen vacancy formation. Adding the Ti and reducing the amount of Ce in the material stabilizes the overall compound.

Potential Applications

- Solar thermochemical reactors
- Hydrogen/carbon monoxide production from water/carbon dioxide splitting

Benefits & Advantages

- Lower reduction enthalpy than CeO2 (improves redox capacity)
- Higher water/carbon dioxide splitting efficiency
- Intrinsic high entropy keeps melting point high enough to enable cyclability
- Provides stability for Ca-Ce-Mn-O

Related Publication: Exploring Ca–Ce–M–O (M = 3d Transition Metal) Oxide