Cobalt oxide-based foams for thermochemical solar energy storage

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Abstract

Thermochemical Storage (TCS) of solar energy exploits the heat effects of reversible chemical reactions. Solar heat produced during on-sun operation of Concentrated Solar Power (CSP) plants is used to power an endothermic chemical reaction; if this reaction is completely reversible the thermal energy can be entirely recovered by the reverse reaction during off-sun operation. Among such possible reversible gas-solid chemical reactions, the utilization of a pair of reduction-oxidation (redox) reactions of solid oxides of multivalent metals can be directly coupled to CSP plants employing air as the heat transfer fluid.

The concept of employing for this application ceramic foam structures made partially or entirely from the redox oxide materials has been set forth and implemented. The proposed concept combines the demonstrated capabilities of oxide redox pair materials for thermochemical cycling with the inherent heat transfer characteristics of foam structures and promotes them one step further to the development of an integrated receiver/reactor/heat exchanger configuration with enhanced heat storage characteristics. Thermo-Gravimetric Analysis experiments demonstrated that the redox pair of cobalt oxides Co_3O_4/CoO can operate in a completely reversible, cyclic redox mode within the temperature range 800-1000°C. In this respect at first Co_3O_4-coated ceramic foams were prepared and subsequently, promoting this idea one step further, the manufacture of ceramic foams entirely from Co_3O_4 was attempted successfully. Both Co_3O_4-coated, as well as foams made entirely of Co_3O_4 demonstrated cyclic, long-term redox operation, exploiting the entire amount of Co_3O_4 employed. However, such structures are subjected to “chemically”-induced stresses due to the expansion-contraction of the cobalt oxide lattice during oxygen release/uptake. Design issues concern optimizing their structure and density to maximize redox performance maintaining simultaneously their structural integrity. The results are used for the manufacture of such pilot-scale foam-based reactors/heat exchangers for testing on a solar simulator facility.