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A new bifunctional solid oxide fuel cell for power generation and energy storage

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Recent development of a dual-functionality solid oxide fuel cell (SOFC) system has attracted increasing interest in energy research community. The new bifunctional SOFC system utilizes the fuel cell and electrolyzer mode of a reversible SOFC to electrically charge and discharge the battery while electricity is being stored in a metal/metal-oxide redox couple bed (energy storage bed or ESB) through oxide-ion based redox chemistry. A unique oxygen shuttle gas H_2-H_2O is present between RSOFC and ESB to enable energy (oxygen) transfer at fast rate and high capacity. A full discharge and charge cycle can be described as follows. During the discharge, Me is oxidized by H_2O to form MeO_x and H_2; the latter is then electrochemically oxidized into H_2O at the anode of RSOFC operating as a fuel cell, and the formed H_2O diffuses back to ESB and reacts with Me, producing more H_2 to sustain the electrochemical oxidation (and discharge cycle). When all Me (or a controlled portion) is oxidized, the discharge cycle is stopped, and the battery needs to be recharged. During the charge, RSOFC operates as an electrolyzer with electricity as energy input to split H_2O into H_2 at the anode; the formed H_2 then diffuses back to ESB and reduces MeO_x into Me, producing more H_2O to sustain electrochemical reduction for H_2 (and charge cycle). When all MeO_x (or a controlled portion) is reduced, the battery is ready for the next-round discharge cycle. Some important features of the battery include decoupled RSOFC and ESB units, allowing independent design of power and energy, system modularity and scalability, and operational safety. The model ESB is Fe-FeOx, which presents a good balance between oxidation and reduction kinetics, and more importantly is earth abundant and inexpensive. The presentation will give a complete technical overview on the development of this new type of storage battery conducted in the presenter's lab in the past 4 years, ranging from battery materials, battery assembly, electrical testing to theoretical modeling.

Keywords: fuel cell; battery; redox couple; energy storage; power generation