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Materials engineering and science in the development of solid oxide cell technology for power generation and hydrogen production

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Plenary: Solid oxide cell (SOC) technology is currently under development for clean and efficient power generation and hydrogen production. A SOC, a high-temperature (600 ºC -1000 ºC), all-solid-state cell, consists of a fully-dense ion-conducting oxide electrolyte sandwiched between two porous electrodes (an anode and a cathode). The cell, when operating in power generation or fuel cell mode (referred to as solid oxide fuel cell or SOFC) generates electricity by electrochemically combining a fuel (e.g., hydrogen, hydrocarbons, alcohols) with air across the oxide electrolyte and when operating in electrolysis mode (referred to as solid oxide electrolysis cell or SOEC), electrochemically splits a gaseous feed (e.g., steam) across the electrolyte to produce hydrogen (and oxygen). Any SOC cell designed for and manufactured from a selected set of materials must have desired physical, mechanical, chemical, electrical and electrochemical properties and characteristics set by the operating requirements of the intended application. At present, the most common materials for the SOC are yttria-stabilized zirconia (YSZ) for the electrolyte, nickel (Ni)/YSZ for the hydrogen electrode (anode in fuel cell mode or cathode in electrolysis mode) and perovskite oxide such as strontium-doped lanthanum strontium cobaltite perovskite (LSC) for the oxygen electrode (cathode in fuel cell mode or anode in electrolysis mode). These materials have been formed into desired cell structures by conventional fabrication processes such as tape casting and screen printing. This paper discusses certain material science and engineering advancements in the manufacture and the performance, reliability and cost of the SOC. Selected examples include the development of a process based on sputtering for the manufacture of thin-film SOCs with improved operating characteristics and reduced cost, exsolved nickel hydrogen electrodes for increased performance and durability, and 3D Ni/YSZ hydrogen electrode supports for redox (reduction-oxidation) resistance to enhance cell reliability.