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High-Temperature Water Electrolysis Using Planar Solid Oxide Fuel Cell Technology: A Review

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Abstract

The present global hydrogen demand is met to a large extent by hydrogen from fossil fuels, but hydrogen production via water electrolysis has always been an alternative for production, in niche applications or, on a larger scale, when the electric energy required for the electrolysis reaction was readily available. Conventional alkaline electrolysis or electrolysis with proton-exchange membrane fuel cells are technologically mature processes but limited in energy efficiency to 60–80%. Hydrogen production via water electrolysis could play an increasingly important role in future, for industrial and transportation application and also as a means for storing energy from renewable sources, as a consequence of cost and availability limitations of fossil fuels, if a higher energetic efficiency can be reached. Water electrolysis at high temperature using protonic or ionic conducting electrolytes constitutes an advanced concept aimed at increased electrical-to-chemical energy conversion efficiency. At high temperature (600–900°C), higher efficiencies are achievable owing to favorable thermodynamic conditions and also because of improved kinetics for the electrode reactions, even without the use of precious metal catalysts. The thermodynamic reason for higher efficiencies is a decrease in the molar Gibbs energy of the reaction with increasing temperature while the molar enthalpy remains essentially unchanged. Reversible operation of solid oxide fuel cells as H₂O electrolyzer cells (SOECs) is well known from pioneering work in the 1980s on tubular cells. In recent years, renewed interest has arisen in SOECs, driven by the availability of (tubular or planar) cells with improved performance at lower temperatures. In this chapter, the current state of research on SOECs is briefly summarized, the main actors in the field are mentioned, and potential hurdles for the future development are identified.

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This paper reviews water electrolysis technologies for hydrogen production and also surveys the state of the art of water electrolysis integration with renewable energies. First, attention is paid to the thermodynamic and electrochemical processes to better understand how electrolysis cells work and how they can be combined to build big electrolysis modules. Degradation is one of the most important issues in solid oxide electrolysis cells (SOECs). Its production using high temperature electrolysis is able to reduce the carbon dioxide emissions if performed with renewable resources. This is the case if the electricity needed for the HTSE comes from a wind turbine and the CO₂ needed for the methanation step comes from biogas. A solid oxide electrolyzer cell (SOEC) is a solid oxide fuel cell that runs in regenerative mode to achieve the electrolysis of water (and/or carbon dioxide) by using a solid oxide, or ceramic, electrolyte to produce hydrogen gas (and/or carbon monoxide) and oxygen. The production of pure hydrogen is compelling because it is a clean fuel that can be stored easily, thus making it a potential alternative to batteries, which have a low storage capacity and create high amounts of waste materials