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A review of advanced proton-conducting materials for hydrogen separation

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ABSTRACT

This paper provides a comprehensive overview of developments and recent trends in H_2 separation technology that uses dense proton–electron conducting ceramic materials and their associated membranes. Various proton–electron conducting materials and their associated membranes are summarized and classified into several important categories, such as Ni-composite proton-conducting materials, as well as tungstate-based, $BaPrO_3$-based, $LaGaO_3$-based, and niobate/tantalite composite metal oxide-based ceramic materials/membranes. Various membrane designs, including asymmetric ceramic membranes (supported and self-supported) and surface-modified membranes, are also reviewed. Several important properties of ceramic materials and membranes, such as proton and electron conductivity and performance (i.e., H_2 transport flux and lifetime stability), are also discussed. To highlight the technical progress in this area, all possible ceramic materials and associated membranes are summarized, along with their properties and performance, to help readers quickly locate the information they are looking for. Based on this review, several challenges hindering the maturation of this technology are analyzed in depth, and possible research directions for overcoming these challenges are suggested.

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Contents

1. Introduction

In today's world, clean-energy science and technology, which include energy storage and conversion, are the most important R&D topics for the sustainable development of human society, and are also becoming the most critical elements in overcoming fossil fuel depletion and global pollution. The rate of fossil fuel depletion is accelerating due to increased energy consumption in people's daily lives and in industry processes. For example, it is expected that our present energy consumption rate will double by 2050 [1]. In terms of environmental impacts, fossil fuel consumption contributes air emissions of ~65 trillion tons of carbon (in the form of CO_2), as well as considerable quantities of other polluting gases such as SO_X, NO_X, VOCs, and sulfur-containing substances [2–4]. Thus, to maintain human life and development on earth, clean and sustainable energy sources must be urgently explored and utilized without delay. Among various potential clean and sustainable energy sources, hydrogen (H_2) has been recognized as one of the most appealing because it can be produced mainly