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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 H₂ 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, BaPrO₃-based, LaGaO₃-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., H₂ 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	2
1.1. Importance of hydrogen fuel in practical applications	3
1.2. Hydrogen separation membrane technologies and their associated materials	3
1.3. Advanced proton-conducting ceramic membranes and their associated materials	5
1.4. Necessity of and perspectives on developing advanced proton–electron conducting ceramic materials and their associated membranes	6
2. Fundamental understanding of the H ₂ separation process and material performance through both theoretical and experimental analysis	7
2.1. Hydrogen separation process	7
2.2. Theoretical understanding of H ₂ transport mechanisms	9
2.3. Theoretical and experimental analyses to investigate the hydrogen transport mechanisms in ceramic membranes	10
3. Development of dense proton–electron conducting ceramic materials and their associated membranes for hydrogen separation	13
3.1. Synthesis, characterization, and performance of single-phase ceramic mixed materials and their associated membranes	14
3.2. Synthesis, characterization, and performance of Ni and proton-conducting material composed materials and their associated membranes	16
3.3. Synthesis, characterization, and performance of fluorite-structure materials and their associated membranes	17
3.4. Synthesis, characterization and performance of tungstate-based materials and their associated membranes	20
3.5. Synthesis, characterization, and performance of BaPrO ₃ -based materials and their associated membranes	22
3.6. Synthesis, characterization, and performance of LaGaO ₃ -based materials and their associated membranes	24
3.7. Synthesis, characterization, and performance of niobate/tantalite composite metal oxide-based materials and their associated membranes	24
3.8. Synthesis, characterization, and performance of ceramic asymmetric membranes	25
3.9. Synthesis, characterization, and performance of ceramic hollow fibers	30
3.10. Modifying the surface of a hydrogen separation membrane	32
3.11. Stability of hydrogen separation materials	32
4. Ceramic membrane-based H ₂ separation systems design and fabrication	36
5. Challenges of H ₂ separation using dense proton–electron conducting ceramic materials/membranes	38
6. Summary and proposed research directions	40
Acknowledgments	44
References	44

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 CO₂), 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 (H₂) has been recognized as one of the most appealing because it can be produced mainly

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