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Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) Title: PROTON CONDUCTING MEMBRANES FOR HYDROGEN PRODUCTION AND SEPARATION

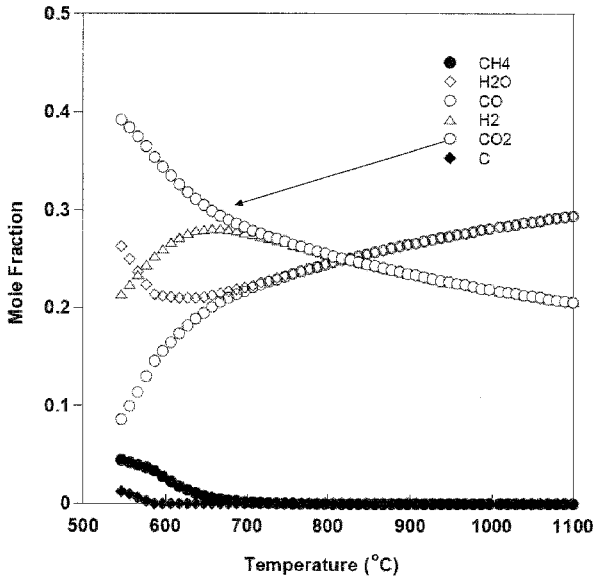


Figure 1

(57) Abstract: In one embodiment, a membrane of proton-electron conducting ceramics that is useful for the conversion of a hydrocarbon and steam to hydrogen has a porous support of M'-Sr_{1-z}-M"$_z$$Ce_{1-x'-y}$$Zr_{x'}$M"'$_y$$O_{3-\delta}$, Al_2O_3, mullite, ZrO_2, CeO_2 or any mixtures thereof where: M' is Ni, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Nb, Mo, W, Zn, Pt. Ru, Rh, Pd, alloys thereof or mixtures thereof; M" is Ba, Ca, Mg, Sm, Eu, Gd, Tb. Dy, Ho, Er, Tm, or Yb; M"' is Ti. V, Cr, Mn, Fe, Co, Ni, Cu, Nb, Mo, W, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm. or Yb; z' is O to about 0.5; x' is O to about 0.5; y' is O to about 0.5; and x' + y' > 0; for example, Ni-$SrCe_{1-X}Zr_{X'}O_{3-\delta}$, where x' is about 0.1 to about 0.3. The porous support is coated with a film of a Perovskite-type oxide of the formula $SrCe_{1-x-y}Zr_{\chi}MO_{3-\delta}$ where M is at least one of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Nb, Mo, W, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm. and Yb, x is 0 to about 0.15 and y is about 0.1 to about 0.3. By including the Zr and M in the oxide in place of Ce, the stability can be improved while maintaining sufficient hydrogen flux for efficient generation of hydrogen. In this manner, the conversion can be carried out by performing steam methane reforming (SMR) and/or water-gas shift reactions (WGS) at high temperature, where the conversion of CO to CO_2 and H_2 is driven by the removal of H_2 to give high conversions. Methods of preparing the membrane cells and a system for use of the membrane cells to prepare hydrogen are presented. A method for sequestering CO_2 by reaction with methane or other hydrocarbon catalyzed by the novel membrane to form a syngas is also presented.

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A. CLASSIFICATION OF SUBJECT MATTER

B01D 71/00(2006.01)i, B01D 69/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC C07C 5/333, 2/04 B01D 53/22, 71/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOPASS(KIPO internal) "membrane, proton-electron conducting ceramics, porous ceramic support,Perovskite-type, hydrogen, reforming, CeO2, Eu2O3"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 06281403 B1 (James H. White, etc.) 28 Aug. 2001 See abstract, columns 1~9, and claims 1~15	1, 4, 7, 21, 22, 24~29, 33, 35~37
Y	US 07001446 B2 (Shane E. Roark, etc.) 21 Feb. 2006 See abstract, columns 1~42, and claims 1~45	1, 4, 7, 21, 22, 24~29, 33, 35~37
Y	US 06214757 B1 (Michael Schwartz, etc.) 10 Apr. 2001 See abstract, columns 1~34, and claims 1~62	22, 24~29, 33, 35~37
A	US 06899744 B2 (Michael V. Mundschau, etc.) 31 May. 2005 See abstract, columns 1~40, and claims 1~86	1~37

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Information on patent family members

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