Supporting information

Dense Ceramic Catalytic Membranes and Membrane Reactors for Energy and Environmental Applications

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Table S1. Typical MIEC membranes and their performance for partial oxidation of methane.

Membrane materials	Membrane configurations/ thickness (mm)	Temperature (^{o}C)	Oxygen flux ($mL \cdot cm^{-2} \cdot min^{-1}$)	Operation time (h)	Membrane environments	Catalysts	Ref.
Single Phase							
$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$	disk/1.5	875	11.5	500	Air/50%CH_4+He	$LiLaNiO_x/\gamma$-Al_2O_3	1,2
$Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$	tubular/-	875	8.0	500	Air/CH_4	$LiLaNiO_x/\gamma$-Al_2O_3	3
$Ba_{0.5}Sr_{0.5}Zn_{0.2}Fe_{0.8}O_{3-\delta}$	disk/1.25	900	2.55	65	Air/50%CH_4	Ni based	4
$BaCo_{0.4}Fe_{0.4}Zr_{0.2}O_{3-\delta}$	disk/1.0	850	5.4~5.8	2200	Air/50%CH_4+He	$LiLaNiO_x/\gamma$-Al_2O_3	5
$BaCo_{0.4}Fe_{0.5}Ta_{0.1}O_{3-\delta}$	disk/0.7	900	16~17	400	Air/CH_4+He	Ni based	6,7
$BaCo_{0.7}Fe_{0.2}Nb_{0.1}O_{3-\delta}$	disk/1.0	900	~20	700	Air/CH_4	Pt, Rh, Ru/$MgAlO_x$	8-10
$SrCo_{0.4}Fe_{0.4}Zr_{0.1}O_{3-\delta}$	disk/0.2	850	6.2	>1000	Air/CH_4+He	Ni/Al_2O_3	11
$Sr_{1.7}La_{0.3}GaFeO_{5+\delta}$	disk/1.7	900	1~1.3	>1000	Air/CH_4	Ni based	12
$La_{0.5}Sr_{0.5}Ga_{0.2}Fe_{0.8}O_{3-\delta}$	tubular/0.15	850	0.336	696	Air/CH_4	Rh/Al_2O_3	13
$Sr_{1.7}La_{0.3}Al_{0.6}Fe_{1.4}O_{5+\delta}$	tubular/0.8~1.0	900	4.2	3400	Air/CH_4+He	Ni/Al_2O_3	14
$A_xA'_{1-x}B_yB'_{1-y}O_{5+\delta}$	tubular/-	900	10~12	>8760	Air/CH_4	Metal/ MIEC oxide	15
$BaCe_{0.15}Fe_{0.85}O_{3-\delta}$	disk/1.5	850	3.0	160	Air/CH_4+He	$LiLaNiO_x/\gamma$-Al_2O_3	16
$BaCe_{0.1}Co_{0.4}Fe_{0.5}O_{3-\delta}$	disk/1.0	875	8.9	>1000	Air/CH_4	$LiLaNiO_x/\gamma$-Al_2O_3	17
$La_{0.5}Sr_{0.5}FeO_{3-\delta}$	tubular/1.0	850	~3.0	7500	Air/CH_4	Ni based	18
Multiple Phase							
9 wt.% YSZ-$SrCo_{0.4}Fe_{0.6}O_{3-\delta}$	disk/1.8	850	4.5	220	Air/CH_4+He	Ni/Al_2O_3	19
3wt.%Al_2O_3-$SrCo_{0.8}Fe_{0.2}O_{3-\delta}$	disk/1.3	850	~2.3	>500	Air/CH_4+He	Ni/Al_2O_3	20
5wt.%$SrAl_2O_4$-$SrCo_{0.8}Fe_{0.2}O_{3-\delta}$	disk/1.0	850	8.0	1200	Air/CH_4+He	Ni/Al_2O_3	21

Membrane materials	Membrane configurations/ thickness (mm)	Temperature (^{o}C)	Oxygen flux ($mL \cdot cm^{-2} \cdot min^{-1}$)	Operation time (h)	Membrane environments	Catalysts	Ref.
$(SrFe)_{0.7}(SrAl_2)_{0.3}Oz$	disk/0.9	850	-	~200	Air/50%CH_4+He	Pt/Al_2O_3	22
$(SrFe)_{0.7}(SrAl_2)_{0.3}Oz$	tubular/1.25	850~900	-	280	Air/CH_4+CO_2+He	$Pt/LaNiO_3/Al_2O_3$	23
Dual-phase Membrane							
$Ce_{0.8}Gd_{0.2}O_{2-\delta}$-$Ga_{0.7}Sr_{0.3}FeO_{3-\delta}$	disk/0.5	950	2~5	450	Air/CH_4	$LiLaNiO_x/\gamma$-Al_2O_3	24
$Ce_{0.85}Sm_{0.15}O_{2-\delta}$-$Sm_{0.6}Sr_{0.4}FeO_{3-\delta}$	disk/0.6	950	~4	630	Air/CH_4	$LiLaNiO_x/\gamma$-Al_2O_3	25
$Ce_{0.85}Sm_{0.15}O_{2-\delta}$-$Sm_{0.6}Sr_{0.4}Fe_{0.7}Al_{0.3}O_{3-\delta}$	disk/0.5	950	4.3	1100	Air/CH_4	$LiLaNiO_x/\gamma$-Al_2O_3	26

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