Enhanced Hydrogen Production Process from Coal Integrated with CO_2 Separation Using Dual Chemical Looping

GHGT10

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Conclusions/Summary

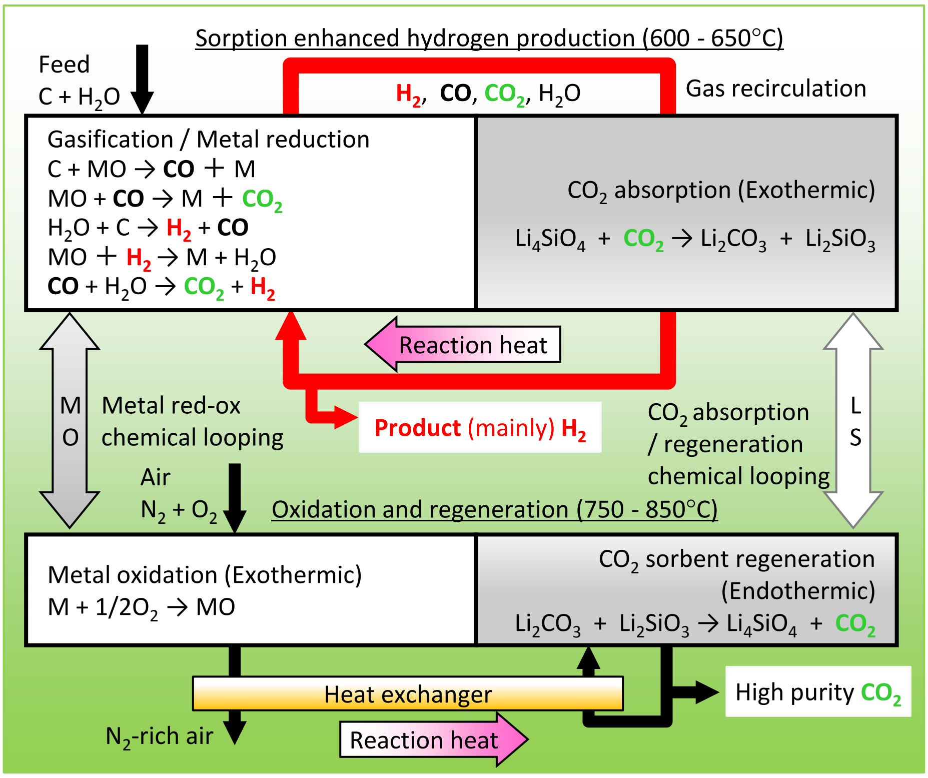
An advanced hydrogen production system integrated with CO_2 separation is introduced in this research, which is based on HyPr-RING and enhanced by dual chemical looping. The first chemical looping is for CO_2 separation using lithium ortho-silicate (Li_4SiO_4) as a solid CO_2 sorbent which can absorb CO_2 around 650°C with an exothermic reaction and regenerate around 850°C. This sorbent has high capacity of 30wt% and reduce the energy penalty due to temperature swing for CO_2 separation. Another chemical looping by red-ox reaction of a metal oxide is applied to oxygen carrier in the gasification reactor to cut off the electric power due to the air separation plant and the exothermic heat of oxidation is used for regeneration of the sorbent.

Copper oxide (CuO) is one of the suitable materials for oxygen carrier because reduction of CuO by carbon is exothermic reaction which benefits energy balance.

Hydrogen production from dry mixtures of CuO and graphite was confirmed even at around temperature of CO_2 absorption, but in any test conditions, a simple mixture of them mainly produced CO_2 by complete oxidation.

In the case of hematite (Fe_2O_3), hydrogen yield remarkably increased, but gas production rate decreased even at 700°C.

Hydrogen production / CO_2 separation system

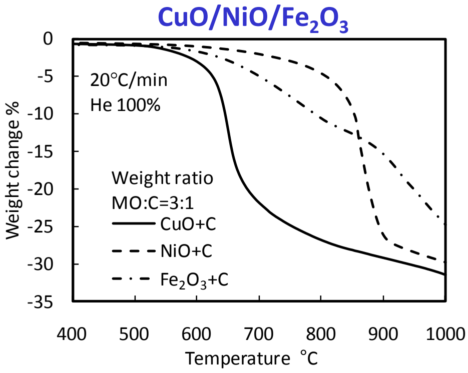


Thermodynamic data of reactions

Eq.	Reactions	$\Delta H°_{923}$ kJ/mol	$\Delta G°_{923}$ kJ/mol
(1)	$Li_4SiO_4 + CO_2 \rightarrow Li_2SiO_3 + Li_2CO_3$	-63.8	-5.8
(2)	$C + CuO \rightarrow Cu + CO$	40.9	-119.3
(3)	$CO + H_2O \rightarrow CO_2 + H_2$	-34.6	-5.9
(4)	$C + H_2O \rightarrow CO + H_2$	135.7	3.4
(5)	$C + 2CuO \rightarrow 2Cu + CO_2$	-88.6	-338.7
(6)	$CO + CuO \rightarrow Cu + CO_2$	-129.5	-128.6
(2)'	$C + NiO \rightarrow Ni + CO$	126.1	-40.4
(5)'	$C + 2NiO \rightarrow 2Ni + CO_2$	81.9	-90.1
(6)'	$CO + NiO \rightarrow Ni + CO_2$	-44.2	-49.7
(2)''	$C + 3Fe_2O_3 \rightarrow 2Fe_3O_4 + CO$	227.3	-214.2
(5)''	$C + 6Fe_2O_3 \rightarrow 4Fe_3O_4 + CO_2$	284.3	-437.8
(6)''	$CO + 3Fe_2O_3 \rightarrow 2Fe_3O_4 + CO_2$	57.0	-223.5

Reaction path	$\Delta H°_{923}$ kJ/mol			H_2 production
	CuO	NiO	Fe_2O_3	yield mol / C mol
Eqs. (2) → (3) → (1)	-57.5	27.8	129.0	1
Eqs. (4) → (6) → (1)				
Eqs. (4) → (3) → (1)	37.4			2

Graphite oxidation with $CuO/NiO/Fe_2O_3$



CO_2 absorption performance of lithium silicate

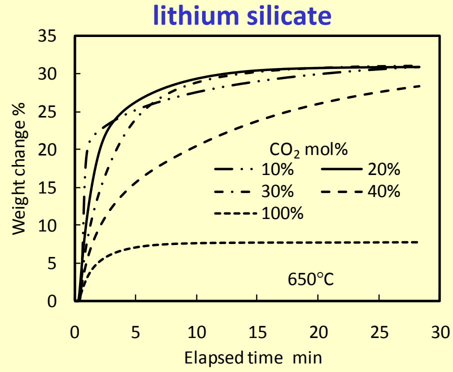
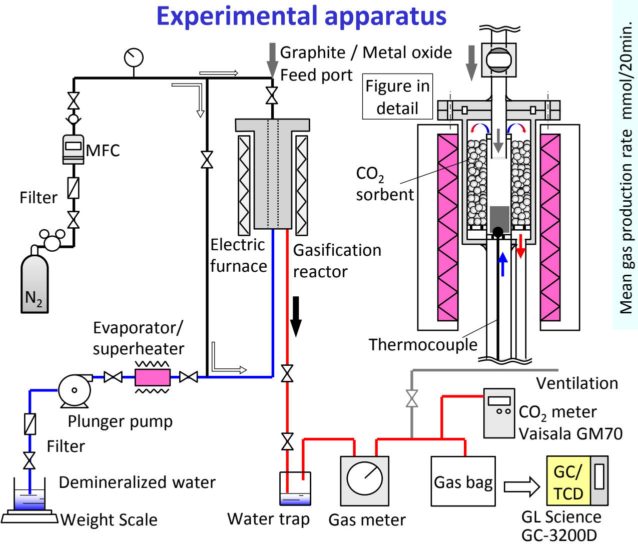


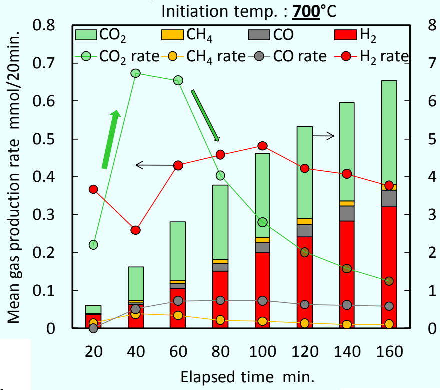
Photo:
Li_4SiO_4 sorbent promoted by potassium carbonate additive (Prepared in our laboratory)
*Patented by Toshiba

Experimental apparatus



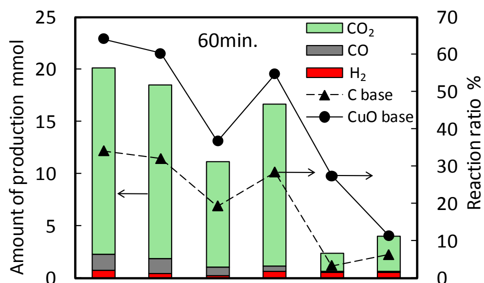
Gasification with Fe_2O_3

Feed: C/Fe_2O_3=0.0567/0.0189mol, H_2O=0.5g/min.
Initiation temp. : **700**°C



$3Fe_2O_3 + C \rightarrow CO + 2Fe_3O_4$
$3Fe_2O_3 + CO \rightarrow CO_2 + 2Fe_3O_4$
$CO + H_2O \rightarrow CO_2 + H_2$
(Approx. 1hr.)
$3Fe_2O_3 + H_2 \leftarrow H_2O + 2Fe_3O_4$
$3Fe_2O_3 + CO \leftarrow CO_2 + 2Fe_3O_4$
(Re-oxidation) (Decrease)

Gasification with CuO



Run No.		1	2	3	4	5	6
Amount of feed material	C mol	0.0567				0.1	0.0567
	CuO mol	0.0567				0.02	0.0567
	H_2O g/min.	0.3				0.5	
Sieve mesh size	C	325					
	CuO	250					10
Initiation temp. °C		620	600	580	600		

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