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INVESTIGATION OF THERMAL CONDUCTIVITY OF OXIDE SCALE OF HYDROGEN-REDUCED HOT COMPACTED IRON USING LIGHT FLASH ANALYSIS METHOD

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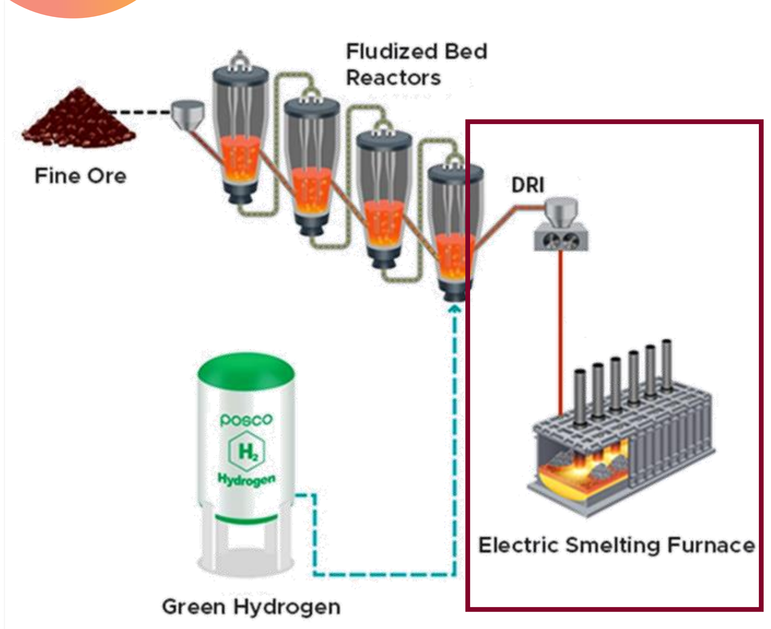
1 INTRODUCTION



1. H2-DRI compacted into H2-HCI
2. H2-HCI being transported before hot-charging
3. H2-HCI hot-charged into the ESF (Electric Smelting Furnace)

Fig 1. POSCO HyREX process

The HyREX process comprises the fluidized bed reactor and the electric smelting furnace (ESF). When fine iron ore particles are reduced by hydrogen gas in the reactor, they are compacted into the hot compacted iron (H2-HCI). Estimating the H2-HCI temperature before hot-charging helps design optimal facilities for better energy efficiency. However, it can be oxidized before hot-charging of the H2-HCI into ESF. It should be noted that the temperature of the H2-HCI can be affected by the morphology and thickness of the oxide scale. There have been several previous research on the measurement of the oxide scale formed on steel products[(1)~(3)]. However, the measured values were all different and few research has been conducted on the measurements of the thermal properties of DRI. According to Göttfert, the thermal conductivity of H-DRI ranges from 1.2~3.6 W/mK and that of H-HBI 13~27 W/mK[(4)]. thermal properties are affected by the presence of gangue materials or porosity of the samples.

- In this work, the thermal conductivity of the oxide scale of the H2-HCI manufactured by HyREX process was investigated using the light flash analysis method.

2 METHODS

1. Sample preparation

Fig 3. H2-HCI sample

Table 1. The composition of H2-HCI (wt%)

T.Fe	M.Fe	FeO	SiO_2	CaO	Al_2O_3	MgO
93.1	84.0	5.44	4.28	0.026	2.42	0.078

Hydrogen-reduced iron ore fines (particle size less than 5 mm) were compacted at 923 K with a pressure of 100 kg/cm^2 for 10 s. The samples were cut into 10 X 10 X 2.5 mm^3 and oxidized in 923 K for 15 min in air. The samples were polished to remove the oxide scale in the lower part of the H2-HCI samples. The thickness of the oxide scale was measured by SEM.

2. Light flash measurements (LFA)

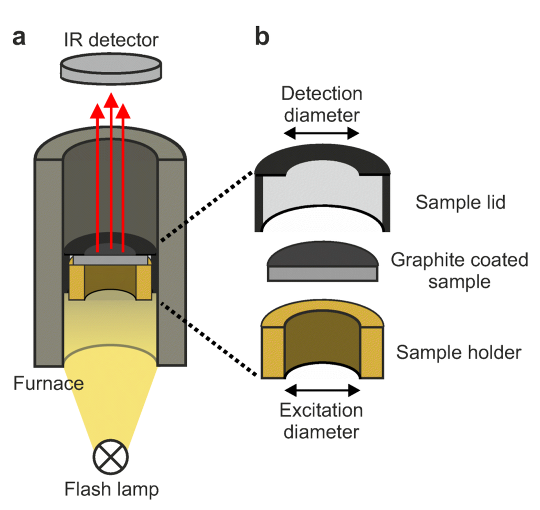


Fig 4. Schematic diagram of LFA

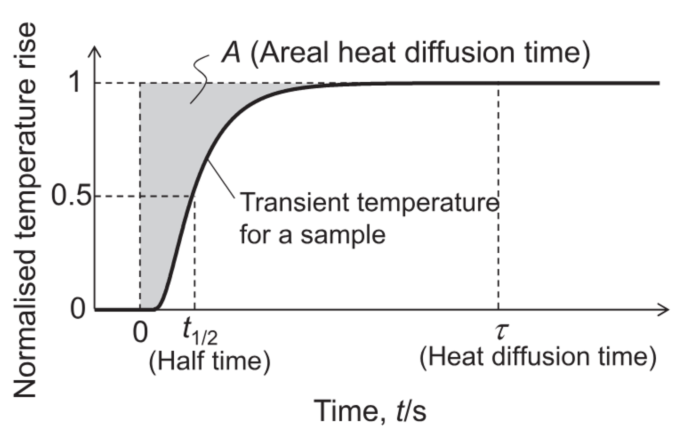


Fig 5. Schematic diagram of temperature change by LFA

The front surface is heated by a light pulse, and the resulting temperature change at the back surface is recorded by a thermometer. The temperature rise curve provides the value of the apparent heat diffusion time. The time when the temperature rises to the maximum is τ, which is converted to apparent thermal diffusivity, D.

3. Microstructure analysis (SEM-EDX)

SEM analysis of the H2-HCI samples was conducted for the observation of the H2-HCI sample, oxide scale thickness measurement, and chemical analysis by Energy Dispersive X-ray Spectroscopy (EDS).

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3 RESULTS

1. Microstructure analysis of the sample

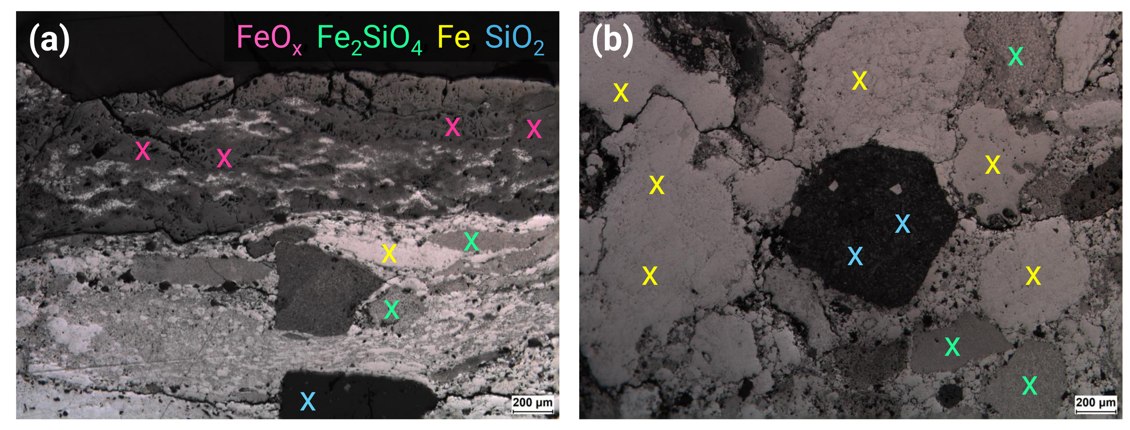


Fig 6. Cross-sectional image of re-oxidized H2-HCI;
(a) Oxide scale formed on the surface of H2-HCI and
(b) different types of particles inside H2-HCI

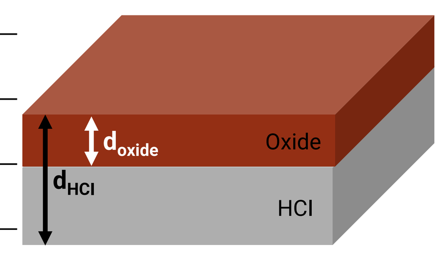
The average thickness of the oxide scale formed on the surface of the H2-HCI sample was 600 μm. Other than the oxide scale (FeO_x), there were many different phases such as metallic Fe, fayalite (Fe_2SiO_4), and SiO_2.

2. Physical properties of H2-HCI samples

The properties of the H2-HCI with and without the oxide scale are shown in Table 2.

Table 2. The properties of unoxidized H2-HCI and partially oxidized H2-HCI at 973 K

Property	Value	Property	Value
$C_{p\ HCI}$*	946 J/kgK	$C_{p\ oxide}$[(1)]	725 J/kgK
ρ_{HCI}*	5433 kg/m^3	ρ_{oxide}[(1)]	7750 kg/m^3
d_{HCI}*	2.458 mm	d_{oxide}*	0.6 mm
D_{HCI}*	1.212 mm^2/s	D_{oxide}*	3.42 X 10^{-7} m^2/s



* The properties of unoxidized and partially oxidized H2-HCI are denoted by the subscript as 'HCI' and 'oxide'

* Measured in present work

4 DISCUSSION

The thermal diffusivity of the oxide scale can be calculated by following equation.

$$A = \frac{(\Gamma_{HCI} + 3\Gamma_{oxide}) * \left(\frac{d_{HCI}^2}{D_{HCI}}\right) + (\Gamma_{oxide} + 3\Gamma_{HCI}) * \left(\frac{d_{oxide}^2}{D_{oxide}}\right)}{6(\Gamma_{HCI} + \Gamma_{oxide})}$$

$$A = \frac{\tau}{6} \qquad \Gamma = Cp * \rho * d$$

$$\lambda_{oxide} = C_{poxide} * \rho_{oxide} * D_{oxide}$$

The thermal diffusivity and thermal conductivity of the H2-HCI were **1.21 X 10^{-6} m^2/s and 6.23 W/mK**, and those of the oxide scale on the surface of the H2-HCI sample were **3.42 X 10^{-7} m^2/s and 1.92 W/mK.**

	H2-HCI Present work	**Oxide scale** Present work	**30% Fe_3O_4-70% FeO** Endo et al(2014)[(1)]	**FeO** Li et al(2017)[(2)]	**$Fe_{1-x}O$** Endo et al(2020)[(3)]	**H-DRI** Göttfert (2023)[(4)]	**H-HBI** Göttfert (2023)[(4)]
Diffusivity [m^2/s]	1.21X10^{-6}	3.42X10^{-7}	7.30X10^{-6}	4.75X10^{-7}	4.00X10^{-7}	9.00X10^{-7}	5.00X10^{-6}
Conductivity [W/mK]	6.23	1.92	3.8	1.65	1.6	2.4	20

5 CONCLUSION

- The thermal diffusivity and conductivity of the H2-HCI was 1.21 X 10^{-6} m^2/s and 6.23 W/mK which was larger than that of H-DRI[(4)] but smaller than that of H-HBI[(4)].
- The thermal conductivity of the oxide scale was 1.92 W/mK, which was 49% smaller than that of the 30% Fe_3O_4-70% FeO scale[(1)].
- Larger thermal conductivity of H2-HCI means faster cooling while transported, but it is also possible to enhance heating properties after hot-charging in the ESF.
- Future works will be done on the simulation of the temperature change of the HCI on transportation.

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