**Supplementary Section**

# Fully Electric Hydrogen-Driven Direct Reduction Process for Zero-Carbon Green Steel Production

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**This PDF file includes:**

**Figs. S1** to **S4**

**Table. S1, S2 and S3**

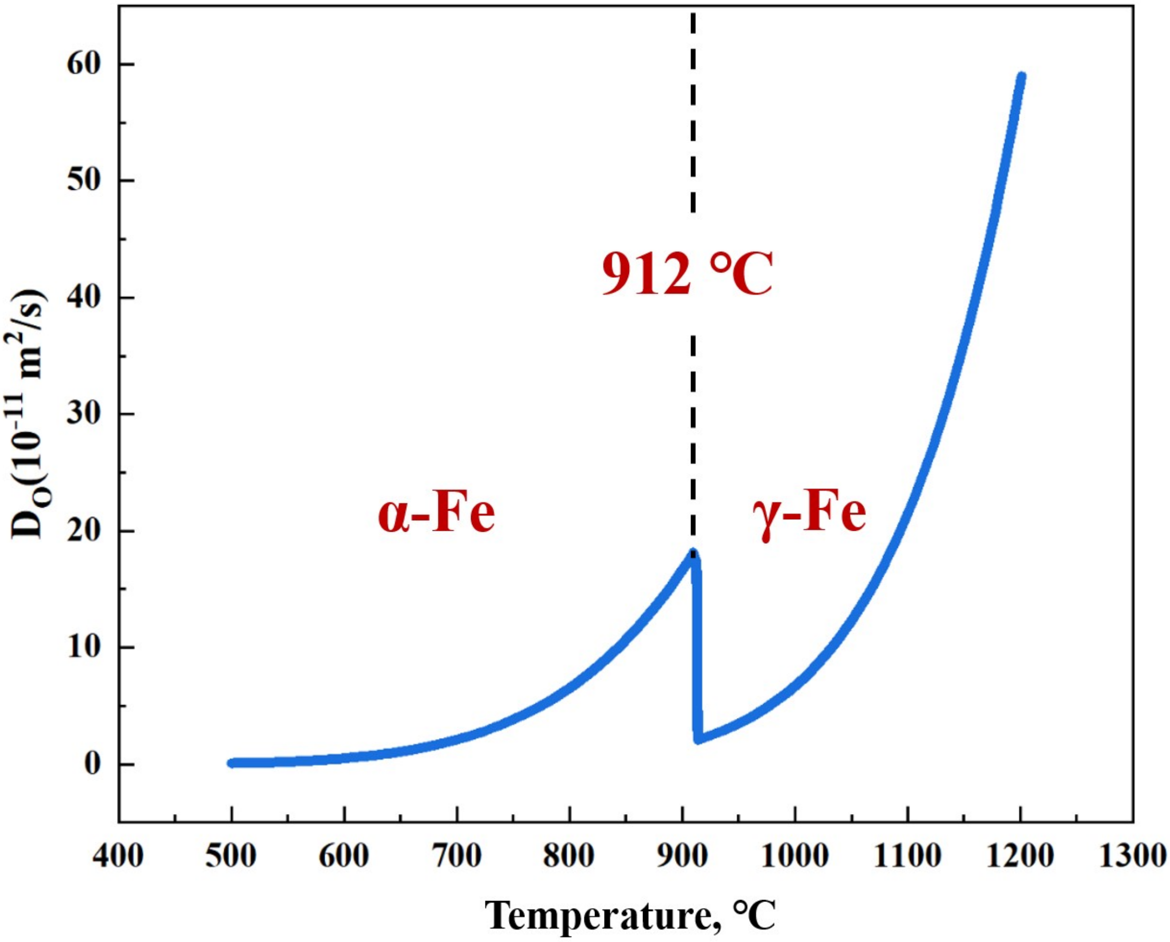


**Fig. S1.** Evolution of Diffusion Coefficients Due to Iron Phase Changes

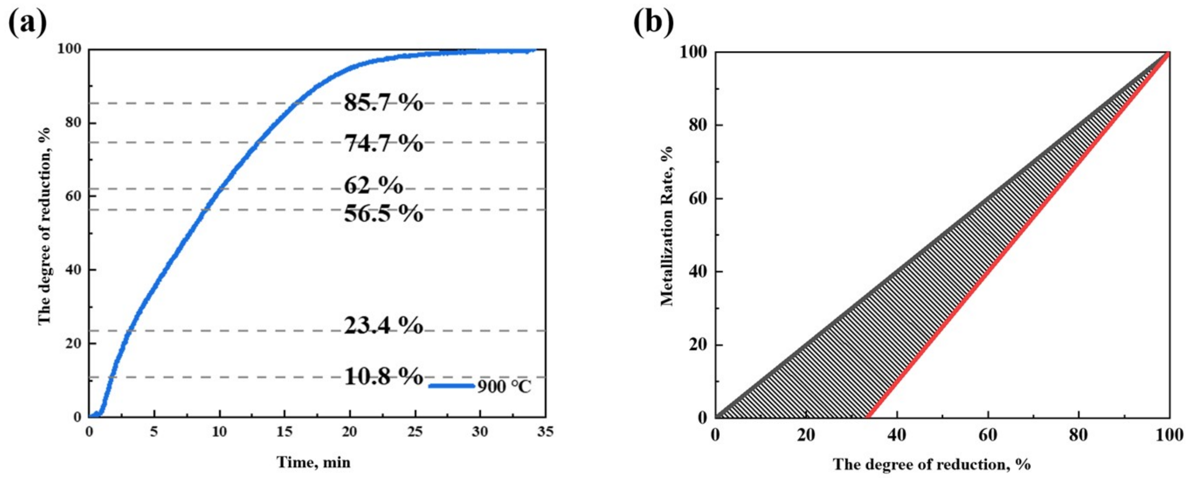


**Fig. S2.** (a) Sampling at Different Degrees of Reduction for Induction Heating Comparison; (b) Approximate Relationship Between Degree of Reduction and Metallization Rate

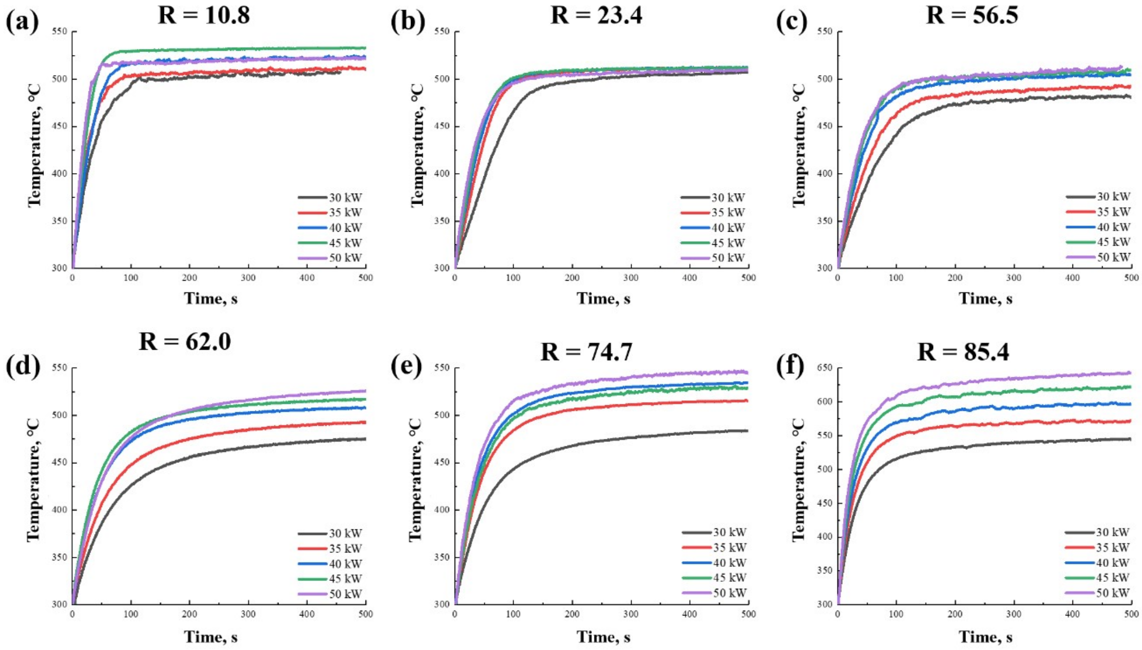


**Fig. S3.** Temporal Evolution of Induction Heating Temperature for Samples at Different Reduction Degrees: (a) 10.8%; (b) 23.4%; (c) 56.5%; (d) 62.0%; (e) 74.7%; (f) 85.4%

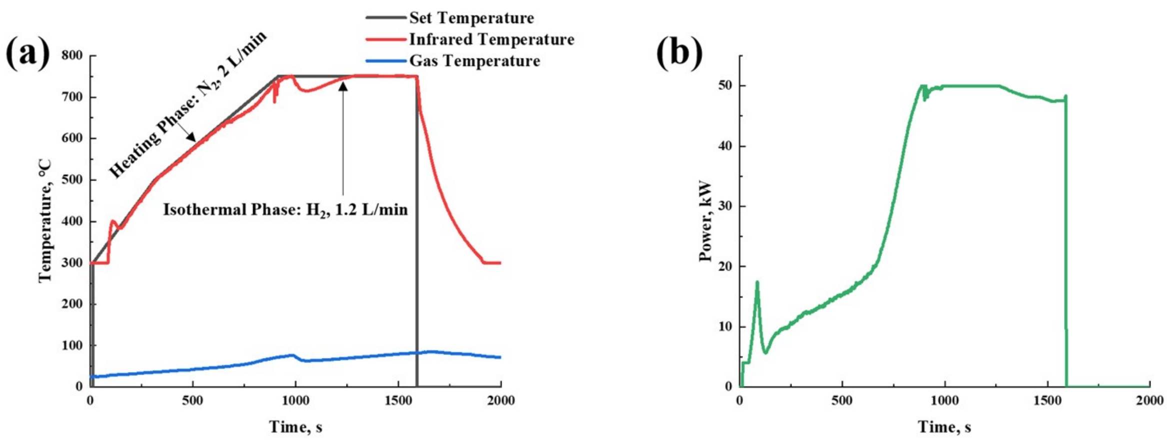


**Fig. S4.** (a) Temperature and Gas Control during Induction Heating-Hydrogen Reduction Experiments; (b) Variation of Equipment Power

**Table S1.** Temperature and Gas Flow Control Scheme for Hydrogen Reduction Experiments

| No. | Temperature (°C) | Gas Flow Rate (L/min) |
|---|---|---|
| 1 | 850 | 0.5 |
| 2 | 850 | 1 |
| 3 | 850 | 1.5 |
| 4 | 850 | 2 |
| 5 | 850 | 3 |
| 6 | 800 | 1.5 |
| 7 | 900 | 1.5 |
| 8 | 950 | 1.5 |
| 9 | 1000 | 1.5 |

**Table S2.** Initial Mass, Reaction Time, Final Mass, and Weight Loss of Samples in Induction Heating-Hydrogen Reduction Experiments

| No. | Temperature (°C) | Initial Weight (g) | Reaction Time (min) | Final Weight (g) | Weight Loss (g) | Weight Loss Rate (%) | Degree of Reduction (%) |
|---|---|---|---|---|---|---|---|
| 1 | 750 | 7.589 | 5 | 7.075 | 0.514 | 0.06773 | 0.2479 |
| 2 | 750 | 7.619 | 10 | 6.798 | 0.821 | 0.107757 | 0.3967 |
| 3 | 750 | 7.547 | 15 | 6.381 | 1.166 | 0.154498 | 0.5684 |
| 4 | 750 | 7.252 | 20 | 5.547 | 1.705 | 0.235108 | 0.8645 |
| 5 | 750 | 7.075 | 40 | 5.227 | 1.848 | 0.261201 | 0.9604 |
| 6 | 700 | 7.423 | 5 | 7.132 | 0.291 | 0.039202 | 0.1449 |
| 7 | 700 | 7.610 | 10 | 6.865 | 0.745 | 0.097898 | 0.3605 |
| 8 | 700 | 7.369 | 15 | 6.465 | 0.904 | 0.122676 | 0.4515 |
| 9 | 700 | 7.4171 | 20 | 6.086 | 1.3311 | 0.179464 | 0.5567 |
| 10 | 700 | 7.664 | 40 | 5.976 | 1.688 | 0.220251 | 0.8099 |
| 11 | 650 | 7.398 | 5 | 7.293 | 0.105 | 0.014193 | 0.053 |
| 12 | 650 | 7.597 | 10 | 7.297 | 0.3 | 0.039489 | 0.1474 |
| 13 | 650 | 7.382 | 15 | 7.035 | 0.347 | 0.047006 | 0.1736 |
| 14 | 650 | 7.309 | 20 | 6.721 | 0.588 | 0.080449 | 0.2964 |
| 15 | 650 | 7.113 | 40 | 6.177 | 0.936 | 0.131590 | 0.4843 |

**Table S3 Comparative Analysis of $CO_2$ Emissions, Renewable Energy Utilization, and Hazard Risks Across Direct Reduction Ironmaking Processes**

| Green Chemistry Metric | IH-DR | $H_2$-DR | MIDREX |
|---|---|---|---|
| $CO_2$ Emissions (t/t Fe) | 0.05 | 0.05 | 0.45-0.90 |
| Energy Source | 100% Renewable | 90-94% Renewable | 13-17% Renewable |
| Hazard Risk | Low (300°C $H_2$) | High (1050°C $H_2$) | Moderate (900°C NG) |