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The Role of Pre-Oxidation Degree, Particle Size, and Ore Composition in Optimizing Hydrogen-Based Reduction Efficiency of Magnetite Ores

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The transition to fossil-free iron production necessitates innovative approaches to direct reduction processes utilizing hydrogen as a sustainable reductant. This study investigates the impact of pre-oxidation on the hydrogen-based reduction kinetics of magnetite ores, a critical step toward optimizing the efficiency of hydrogen-driven direct reduced iron (DRI) production. Four distinct magnetite ores were sieved into different size fractions and subjected to controlled oxidation in air at 600℃, generating samples with low and high oxidation degrees. These pre-oxidized samples were subsequently reduced in a hydrogen atmosphere under isothermal conditions, with reduction efficiency monitored via thermogravimetric analysis (TGA). Primary findings reveal a strong correlation between oxidation degree and reduction kinetics, with highly oxidized samples exhibiting accelerated reduction rates compared to partially oxidized ones. Particle size and ore composition further influence reaction dynamics, highlighting the interaction between mineralogy, pretreatment, and reducibility. X-ray diffraction (XRD) and scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS) analyses reveal phase evolution, morphological changes, and elemental redistribution during oxidation and reduction. These results will clarify the mechanistic role of pre-oxidation in mitigating kinetic barriers and enhancing hydrogen utilization. This work advances the understanding of process-structure-property relationships in hydrogen-based DRI systems, providing actionable insights for achieving sustainable ironmaking technologies aligned with global decarbonization goals.

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