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Kinetic Study and Mechanism of SiO2 Reduction and Si Pick-up Reactions under Electric Smelting Furnace Conditions

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The hydrogen reduction iron- and steelmaking route is attracting global attention as an eco-friendly process for reducing carbon dioxide (CO2) emissions. It produces hot metal by melting hydrogen-based direct-reduced iron (H2-DRI) in an electric smelting furnace (ESF). In conventional blast furnace (BF) processes, the Si content of the hot metal is used as an indicator of hot metal quality and BF operating conditions and can be used to predict the impact on subsequent converter steelmaking processes. Similarly, Si content in hot metal is believed to be an important parameter in ESF operation. Therefore, in the present study, we confirmed that Si transfer from slag to molten iron under ESF conditions occurs through the SiO2 reduction reaction, which produces SiO gas at the slag/metal interface, and the Si pick-up reaction, in which the SiO gas reacts with carbon in the molten iron. We also conducted a kinetic analysis to evaluate how temperature, initial slag basicity, and sulfur content in hot metal influence the SiO2 reduction and Si pick-up rates at the slag/metal interface. The SiO2 reduction reaction exhibited a maximum reduction rate within an appropriate temperature range, and the reduction rate increased with decreasing slag basicity. The rate of the SiO2 reduction reaction is affected by the stability of the gas layer at the slag/metal interface, and an unstable gas layer accelerates the SiO2 reduction rate. The Si pick-up reaction rate increased with increasing temperature or decreasing slag basicity, and the activation energy for this reaction was 238.3 kJ/mol. Increasing the [S] content in hot metal, the SiO2 reduction rate and Si pick-up rate decreased and then increased again due to surface coverage effect and activity of CaS in the slag. The present study provides a systematic understanding of the reactions occurring at the slag/metal interface during the electric smelting furnace process.

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