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Hydrogen plasma smelting reduction of Cr2O3/Chromite: the first step to direct and sustainable production of stainless steel

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By the end of 2050, the European Union aimed to decrease the carbon-based greenhouse gases (CO and CO2) considerably. It was targeted to achieve 80-95% less than the level of emissions in 1990. Hydrogen, as a clean reducing agent, can eliminate the carbon footprint from the steel industry considerably (up to 95%). However, some factors, such as the endothermic nature of H2 reduction, and the thermodynamic resistance of some high-temperature mineral oxides against reduction by H2 hinder such achievement. Hydrogen plasma smelting reduction (HPSR), as an alternative promising method compared to direct H2 and conventional carbon-based reduction methods, has emerged both in the lab and on a pilot-scale plant in the current years. The direct reduction of chromite ore by HPSR, containing both Cr2O3 and Fe2O3 (and FeO), enables single-step production of low-carbon ferrochromium and stainless steel. Chromium is the major alloyed element of stainless steel produced mainly through the primary metallurgy methods from chromite ore. The ore contains different mineral oxides in the spinel phases that complicate the reduction process. Therefore, the study of different factors on the reduction of pure Cr2O3 by the HPSR method is the first step in evaluating the feasibility of ferrochromium production by HPSR. This state of matter provides enough reactivity and heat via the excited species of hydrogen to overcome the mentioned kinetic (THP = 5000-25000 K) and thermodynamic (ΔG°HP ≤ -1500) obstacles. In this paper, the in-situ evaluation of effective parameters, such as hydrogen utilization, reduction degree, etc., by optimizing gas flow rate melting temperature, and activity on pure Cr2O3 and the mixture of it with selective acidic and basic fluxes were studied. Moreover, the required thermodynamic assessments for the experiment were conducted to clarify the feasibility of the reduction process.

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