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Iron Oxide Reduction Using Solar Concentration and Carbon-Free Reducers

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Abstract : The need to develop clean production processes is a key challenge of any industry. Steel and iron industries are particularly concerned since they emit 6.8% of global anthropogenic greenhouse gas emissions. One key step of the process is the high-temperature reduction of iron ore using coke, leading to large amounts of CO2 emissions. One route to decrease impacts is to get rid of fossil fuels by changing both the heat source and the reducer. The present work aims at investigating experimentally the possibility to use concentrated solar energy and carbon-free reducing agents. Two sets of experimentations were realized. First, in situ X-ray diffraction on pure and industrial powder of hematite was realized to study the phase evolution as a function of temperature during reduction under hydrogen and ammonia. Secondly, experiments were performed on industrial iron ore pellets, which were reduced by NH3 or H2 into a “solar furnace” composed of a controllable 1600W Xenon lamp to simulate and control the solar concentrated irradiation of a glass reactor and of a diaphragm to control light flux. Temperature and pressure were recorded during each experiment via thermocouples and pressure sensors. The percentage of iron oxide converted to iron (called thereafter “reduction ratio”) was found through Rietveld refinement. The power of the light source and the reduction time were varied. Results obtained in the diffractometer reaction chamber show that iron begins to form at 300°C with pure Fe2O3 powder and 400°C with industrial iron ore when maintained at this temperature for 60 minutes and 80 minutes, respectively. Magnetite and wuestite are detected on both powders during the reduction under hydrogen; under ammonia, iron nitride is also detected for temperatures between400°C and 600°C. All the iron oxide was converted to iron for a reaction of 60 min at 500°C, whereas a conversion ratio of 96% was reached with industrial powder for a reaction of 240 min at 600°C under hydrogen. Under ammonia, full conversion was also reached after 240 min of reduction at 600 °C. For experimentations into the solar furnace with iron ore pellets, the lamp power and the shutter opening were varied. An 83.2% conversion ratio was obtained with a light power of 67 W/cm2 without turning over the pellets. Nevertheless, under the same conditions, turning over the pellets in the middle of the experiment permits to reach a conversion ratio of 86.4%. A reduction ratio of 95% was reached with an exposure of 16 min by turning over pellets at half time with a flux of 169W/cm2. Similar or slightly better results were obtained under an ammonia reducing atmosphere. Under the same flux, the highest reduction yield of 97.3% was obtained under ammonia after 28 minutes of exposure. The chemical reaction itself, including the solar heat source, does not produce any greenhouse gases, so solar metallurgy represents a serious way to reduce greenhouse gas emission of metallurgy industry. Nevertheless, the ecological impact of the reducers must be investigated, which will be done in future work.

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