The role of microstructure in green steel production via hydrogen-based direct reduction of iron oxides

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Iron- and steelmaking stand for about 7-8% of all global greenhouse gas emissions, accelerating global warming. This staggering environmental damage is caused by the use of fossil carbon carriers as precursor materials for the reduction of iron oxides. Carbon is turned in blast furnaces into CO and – through the redox processes behind iron making – into CO_2, producing about 2 tons CO_2 for each ton of steel produced.

One mitigation strategy consists in the replacement of fossil carbon carriers by hydrogen as alternative reductant, to massively cut these CO_2 emissions, thereby lying the foundations for transforming a 3000 years old industry within a few years [1].

As the sustainable production of hydrogen using renewable energy is currently expensive, thus acting as a severe bottleneck in green steel making, at least during the next decade, the gigantic annual steel production of 1.85 billion tons requires strategies to use hydrogen very efficiently and to yield high metallization at fast reduction kinetic.

In this presentation we therefore discuss some recent progress in understanding the governing mechanisms of hydrogen-based direct reduction of iron oxides [2-4].

Metallization degree, reduction kinetics and their dependence on the underlying solid state redox reactions in hydrogen-containing direct reduction strongly depend on mass transport kinetics, Kirkendall effects, nucleation phenomena during the multiple phase transformations, chemical and stress partitioning, the oxide's chemistry and microstructure, the acquired (from sintering) and evolving (from oxygen loss) porosity, crystal plasticity, damage and fracture effects associated with the phase transformation phenomena occurring during reduction. Understanding these effects – together with external boundary conditions such as reductant gas mixtures, oxide feedstock composition, pressure and temperature – is key to produce hydrogen-based green steel and design corresponding direct reduction shaft or fluidized bed reactors, enabling the required massive $C0_2$ reductions at affordable costs. Possible simulation approaches that are capable of capturing some of these phenomena and their interplay are also discussed [6].

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