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15.7.2024



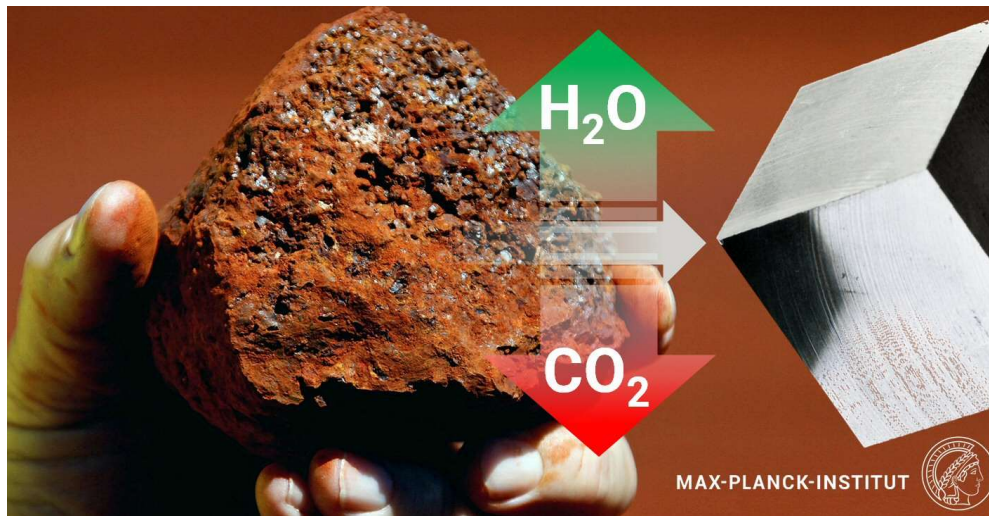
Some Materials Science Aspects behind Sustainable Steel Production

Iron- and steelmaking stand for about 8% of all global greenhouse gas emissions, which qualifies this sector as the biggest single cause of global warming [1,2]. This originates from the use of fossil carbon carriers as precursors for the reduction of iron oxides. Carbon is turned in blast furnaces into CO and – through the redox processes reducing iron oxide – into CO₂, producing about 2 tons CO₂ for each ton of steel produced.

Mitigation strategies pursue the replacement of fossil carbon carriers by sustainably produced hydrogen and / or electrons as alternative reductants, to massively cut these CO₂ emissions, thereby laying the foundations for transforming a 3000 years old industry within a few years [1,2].

As the sustainable production of hydrogen using renewable energy is a severe bottleneck in green steel making, at least during the next decade (transforming this industry would need about 300 Million tons of green hydrogen each year, i.e. about 5 orders of magnitude more than produced around the globe today), the gigantic annual steel production of 1.85 billion tons requires strategies to use hydrogen and / or electrons very efficiently and to yield high metallization at fast reduction kinetic.

The lecture discusses governing mechanisms of hydrogen-based direct reduction and plasma reduction of iron oxides [2-5]. The metallization degree, reduction kinetics and their dependence on the underlying redox reactions in hydrogen-containing direct and plasma reduction depend on mass transport kinetics, Kirkendall effects, nucleation phenomena, multiple phase transformations, chemical and stress partitioning, the oxide's chemistry and microstructure, porosity, plasticity, damage and fracture effects occurring during reduction [5-8]. Understanding these effects and the influence of external conditions such as reductant gas mixtures (including also ammonia [8]), oxide feedstock, pressure and temperature, is key to produce hydrogen-based green steel and design corresponding direct reduction shaft or fluidized bed reactors (with and without plasma support), enabling the required massive CO₂ reductions at affordable costs. Possible simulation approaches that are capable of capturing some of these phenomena and their interplay are also discussed [3-8].



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