Exploring Low Temperature Electrolytic Reduction of Iron

A Pathway to Sustainable Steelmaking

Abigail K. Ackerman[1]

[1] Department of Materials, Imperial College London, London, SW7 2BX, UK

*a.ackerman14@imperial.ac.uk

Royal Academy of Engineering

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Motivation

The Steel and Iron industry accounts for roughly **7.2% of global CO_2 emissions**. To meet 2050 emissions goals this must be reduced.

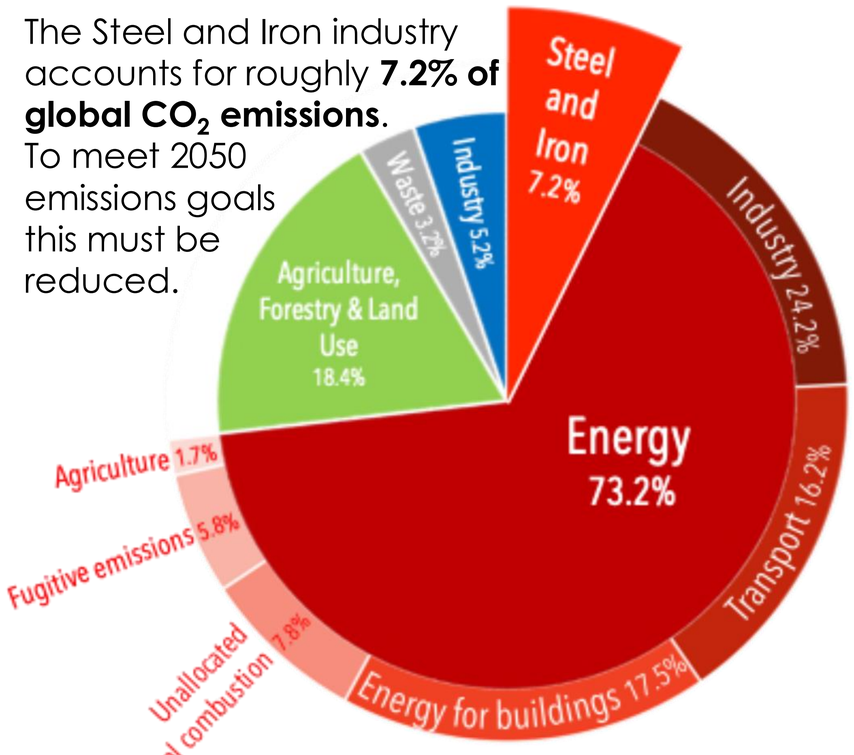

Figure 1: Global CO_2 emissions for 2016 by sector
Source: Climate Watch, the World Resources Institute, 2020

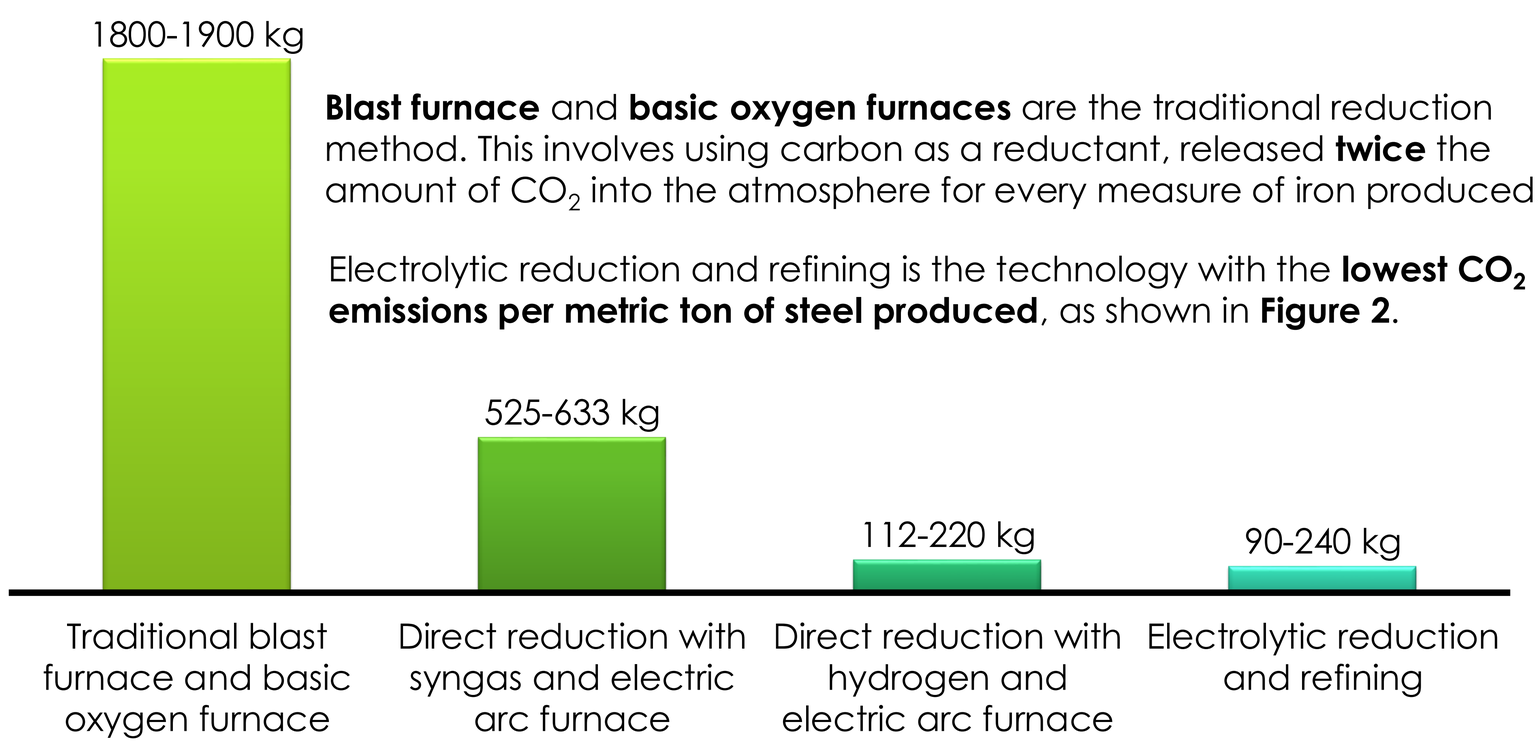

Figure 2: Comparison of CO_2 emissions per metric ton of produced steel for iron reduction techniques
Source: Steel Res. Int. 2020, DOI: 10.1002/srin.202000110

Blast furnace and **basic oxygen furnaces** are the traditional reduction method. This involves using carbon as a reductant, released **twice** the amount of CO_2 into the atmosphere for every measure of iron produced.

Electrolytic reduction and refining is the technology with the **lowest CO_2 emissions per metric ton of steel produced**, as shown in **Figure 2**.

Method

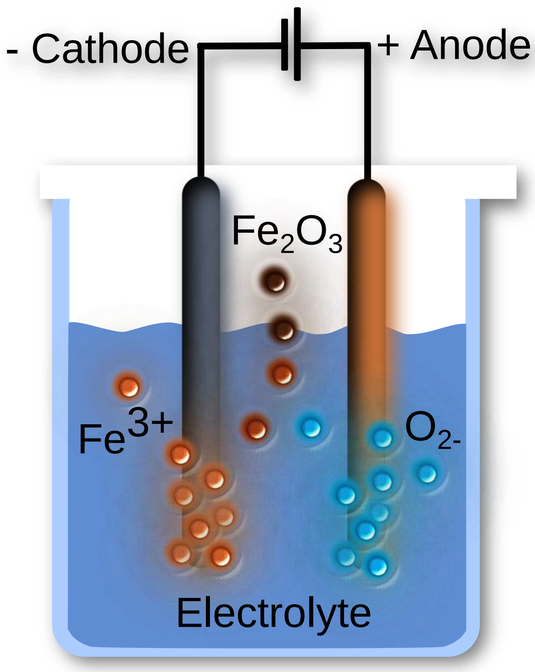

Figure 3: Schematic of iron reduction by electrolysis

Electrolytic reduction **removes** the use of **carbon** in the extraction of iron, preventing the formation of CO_2. **Pure iron** is formed on the working electrode, with **oxygen** forming at the counter electrode, reducing **Hematite (Fe_2O_3)** to its constituent elements.

By not using hydrogen as a reductant the **electricity required** during the complete extraction process **is reduced** compared to direct reduction using hydrogen.

Set Up

Nickel is used as the working electrode, with **Graphite** as the counter electrode. A **Hg/HgO** reference electrode ensures electrical stability. **10 wt.% Hematite** (Fe_2O_3) is combined with ane lectrolyte solution of **50% NaOH**. This is mixed using a magnetic stirrer at **110°C** in a HDPE bottle with a PTFE lid .

A constant voltage of is applied via potentiostat orr**4 hours.**

The electrodes are then washed in distilled water and left to dry overnight.

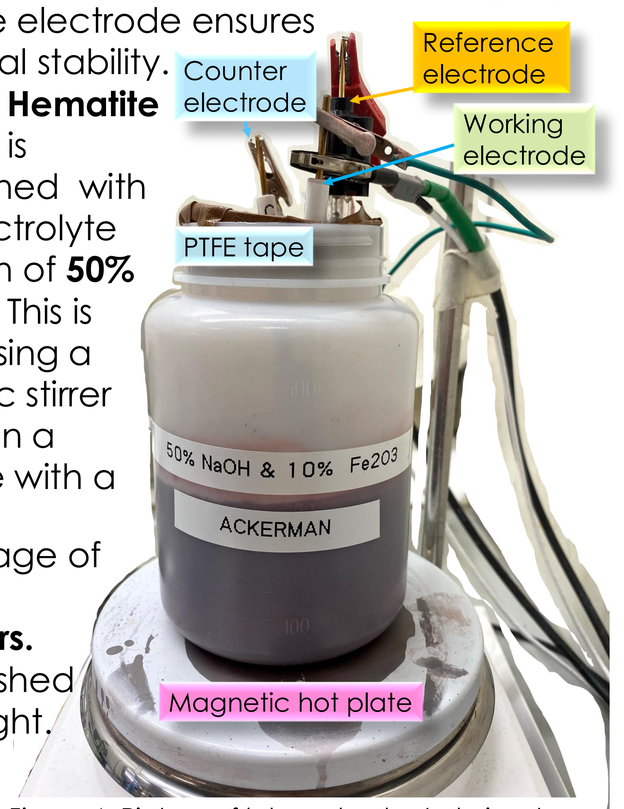

Figure 4: Picture of lab scale electrolysis set up

Results

Scanning Electron Microscopy (**SEM**), **Figure 5**, shows **reduced adhesion of iron** to the nickel electrode, which **improves iron removal** from the electrode. The iron forms as **crystalline dendrites**, which indicates **good current density** and formation of iron where the **local current density on the electrode in highest**.

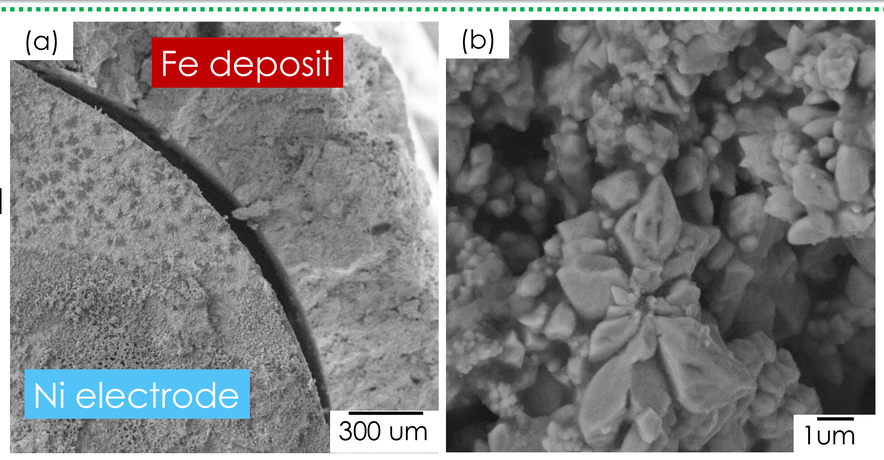

Figure 5: (a) Fe deposits on Ni electrode, (b) Fe crystalline dendrites.

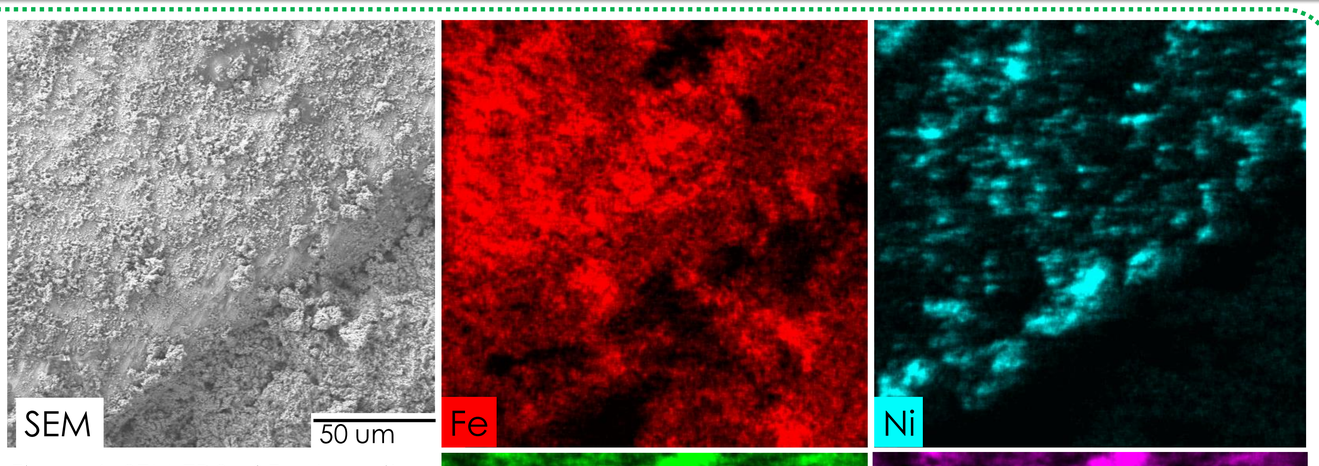

Figure 6: SEM-EDS of Fe deposits on Ni electrode.

Scanning Electron Microscopy – Electron Dispersive Spectroscopy (**SEM-EDS**), **Figure 6**, shows areas of iron with the **absence of oxygen**. This indicates the presence of **pure iron** but will be investigated further using other techniques such as X-Ray Diffraction (**XRD**). The presence of **sodium** shows that more **thorough cleaning** must be done to **remove excess electrolyte**.

Further work includes investigating the **impact of microstructure** on the formation of iron deposits, **alloying** the nickel electrode to **improve corrosion resistance** and understanding the **impact of electrolyte concentration and temperature**.

*This work aims to **revolutionise steel production** by significantly reducing CO_2 emissions and **revitalising the industry** in the United Kingdom.*