Direct Reduction of Iron Ore by Ammonia

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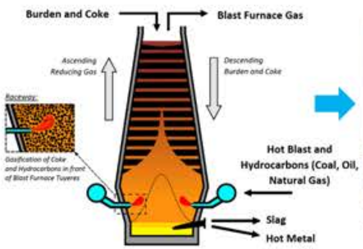
FENEX CRC THEME

Program 2 – Hydrogen Exports and Value Chains

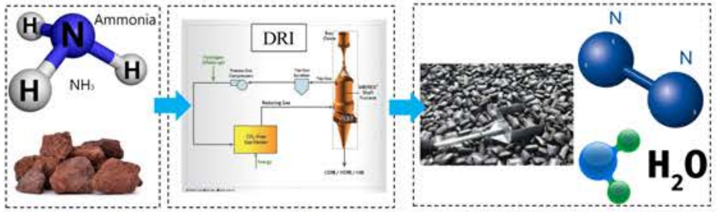
IMPACT AND IMPORTANCE



Blast Furnace

7-8% of global CO_2 emissions

- Pathways to reduce CO_2 emissions from ironmaking:
  - Ore-carbon agglomerates;
  - Carbon capture and storage (CCS);
  - Direct reduction process (e.g. FINEX, MIDREX) + Electron arc furnace (EAF)
  - Carbon-free or renewable reductant (H_2, NH_3 or biomass gas).
- Green H_2 is an effective carbon free ironmaking process. However, the storage and transportation of H_2 encounter the high cost and safe problems.
- Ammonia (NH_3), a carbon free reductant and hydrogen carrier, offers a path to ironmaking decarbonisation and has mature storage and transportation system.
- NH_3 direct reduction of iron ore is not yet fully-developed.
- Huge iron/steel global market offers an opportunity for Australian iron ore, H_2 and NH_3 export.



PROJECT AIMS

Investigation of the behaviour and mechanisms of NH_3 direct ironmaking

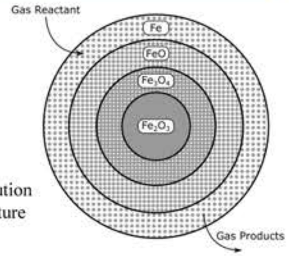
- Determine reaction kinetics for the reduction of iron ores with NH_3.
- Understand reduction behaviour and evolution of phases using characterisation techniques.
- Inspect the conversion of impurities and physical parameters evolution in iron ore and their effects on DRI process.
- Study the low-temperature pyrophoricity and surface passivation of NH_3 DRI.
- Investigate the reduction mechanisms of typical WA iron ore by single particle modelling.
- Examine the products through benchmarking NH_3/H_2 DRI against other reductants.

LITERATURE REVIEW

- Very limited experimental studies on NH_3 reduction of iron ore.
- NH_3 direct reduction of hematite could began from 430 ℃.
- NH_3 would dissociate at high temperatures, as well as the catalysis of iron/iron oxides.
- Produced H_2 contributed further to reduction and could be dominant at high temperatures.
- NOx formation and diminishment at high temperatures in NH_3 DRI process remains unclear.
- The impurities will affect the reduction process in H_2 DRI, but the effect in NH_3 is unclear
- Iron nitride is unstable at low temperatures but could influence the NH_3 dissociation mode.
- Porosity of produced DRI and reduction temperature are important triggers to pyrophoricity.
- The strong endothermicity of the NH_3 reduction presents a key technical challenge.

RESEARCH METHODOLOGY

- Anti-corrosive thermogravimetric analyser
  - Preliminary mechanisms of NH_3/H_2 DRI
  - Determination of rate equations for kinetic study
- Fixed-bed reactor
  - Global reduction behaviour of ore gangues
  - Product gas composition analysis
    - Online GC/MS, FTIR – characterisation
    - NO_X analyser – NO, NO_2
  - Solid product characterisation and impurity evolution
    - XRD – Mineral composition and crystal structure
    - Optical microscope and SEM – Morphology
    - TEM – Crystal information
    - CT/BET – Porosity and pore structure
    - ICP-OES – Chemical composition
- Single particle reaction model



Mechanisms of unreacted shrinking core model of gas-solid reactions

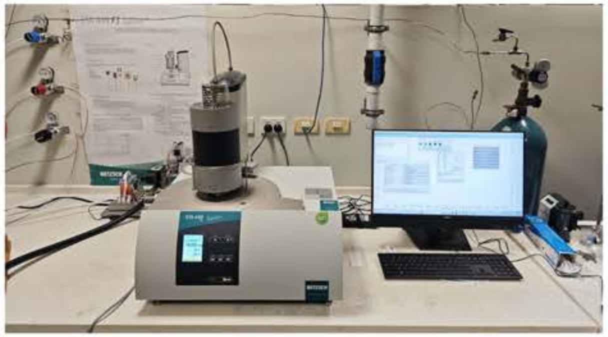


Figure 1 Anti-corrosive thermogravimetric analyser

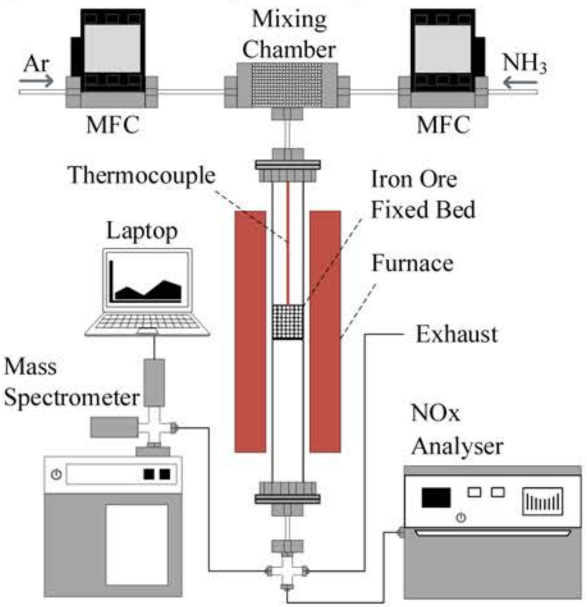


Figure 2 Fixed bed reactor setup

PRELIMINARY WORK

- **Reduction degree of WA iron ore using different H_2 concentration and results of numerical simulation**

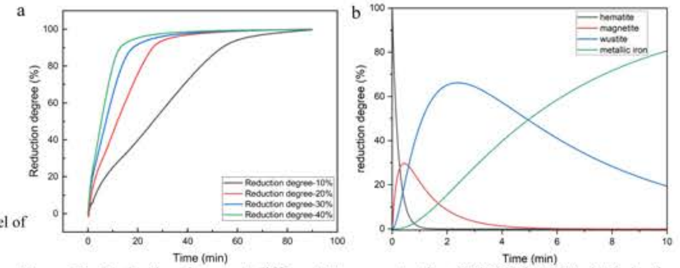


Figure 3 a Reduction degree at different H_2 concentration (700 °C) in TGA; b Reduction degree against time in NH_3 DRI of hematite in COMSOL Multiphysics

- **Optical microscope observation**

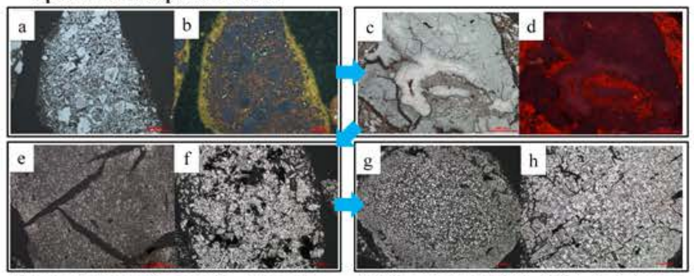


Figure 4 Photomicrographs of samples, a (plain polarized light, PPL) & b (cross polarized light, XPL) raw sample; c (PPL) & d (XPL) control sample; e & f partial reduced sample; g & h reduced sample

- Hematite and goethite are the main ore minerals.
- Before the reduction goethite will convert to hematite due to the dehydration forming cracks.
- Metallic iron will form along the shell of the ore and the edge of the cracks.
- The final product is more porous compared with the partial reduced samples.

PROJECT RESEARCHERS

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- **Environmental Clean Technologies Ltd:** Ashley Moore

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PROJECT ORGANISATIONS

RioTinto ANSTEEL ENVIRONMENTAL CLEAN TECHNOLOGIES LIMITED

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