Electrochemical Reduction of Iron Oxide for the Valorization of the Iron Fuel Cycle

ELECTROCHEMICAL REDUCTION OF IRON OXIDE FOR THE VALORIZATION OF THE IRON FUEL CYCLE

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INTRODUCTION

- **IRON FUEL CYCLE:** energy is generated by iron powder combustion and the iron oxide can be collected and reduced to complete the fuel cycle.
- **ELECTROCHEMICAL REDUCTION** of iron oxide can be a feasible reduction method as it directly converts electrical energy to metallic iron with a low contribution of thermal energy.
- **OUR PROPOSALS:**
  - Production of iron deposits that consist of dendritic structures.
  - Study and tailor the contributing factors to allow the optimum iron deposition.
  - Design a continuous electrolytic iron powder production system.

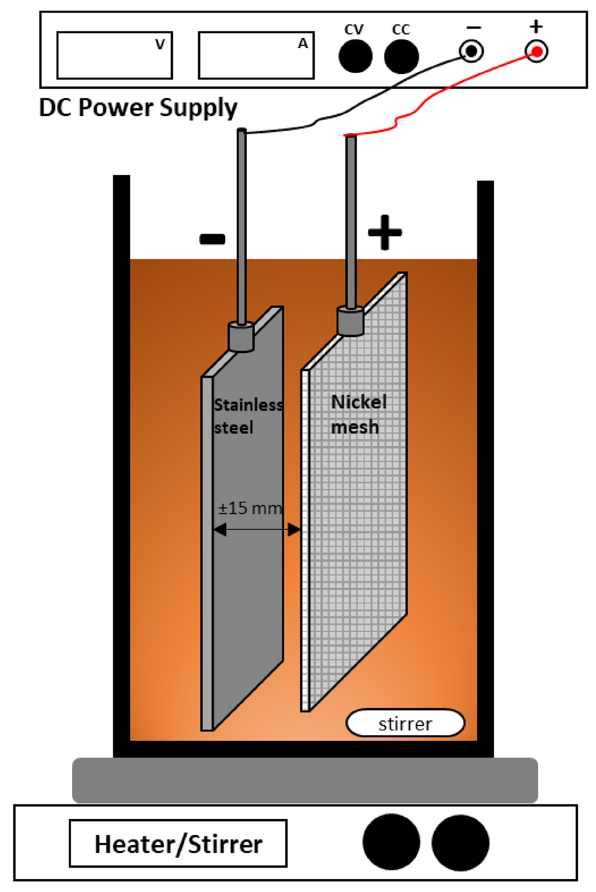
EXPERIMENTS

Powder	: Fe_2O_3 powder (size ≤ 5 μm, ≥ 96%) Combusted iron (size ≤ 32-75 μm)
Electrolyte	: NaOH (50 wt%; 18 M), HCl (0.05 M)
Fe_2O_3 content (ϕ)	: 5 – 20 wt.%
Current density (σ)	: 1000 – 4000 A/m² (0.6 – 2.4 A)
Temperature	: 110 ± 5°C (alkaline), 20°C (acidic)
Duration	: 1 hour (3600 seconds)

Current efficiency

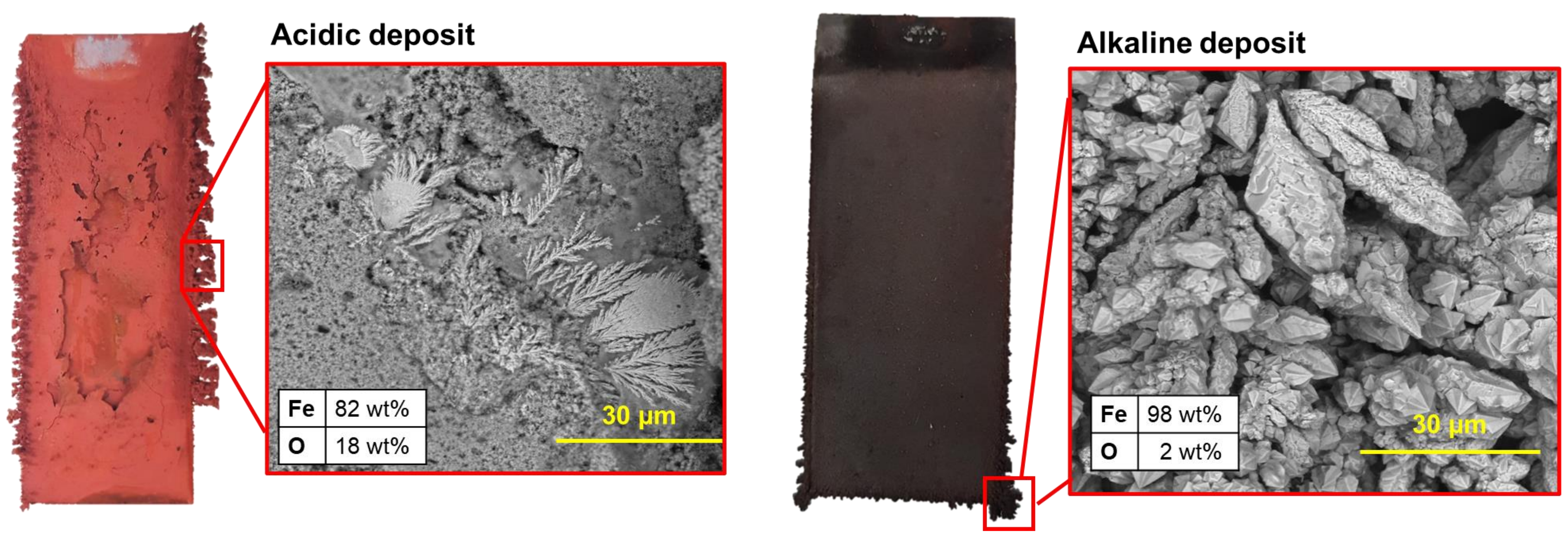
$$\eta = \frac{m_{real}}{m_{faradaic}} = m_{deposit} \cdot \left(\frac{n \cdot F}{M \cdot I \cdot t}\right)$$

n : number of electrons [3: $Fe^{3+} \rightarrow Fe^0$]
F : Faraday constant [96485 sA/mol]
M : Iron molar mass [55.85 gr/mol]
I : Current supply [A]
t : Duration [s]

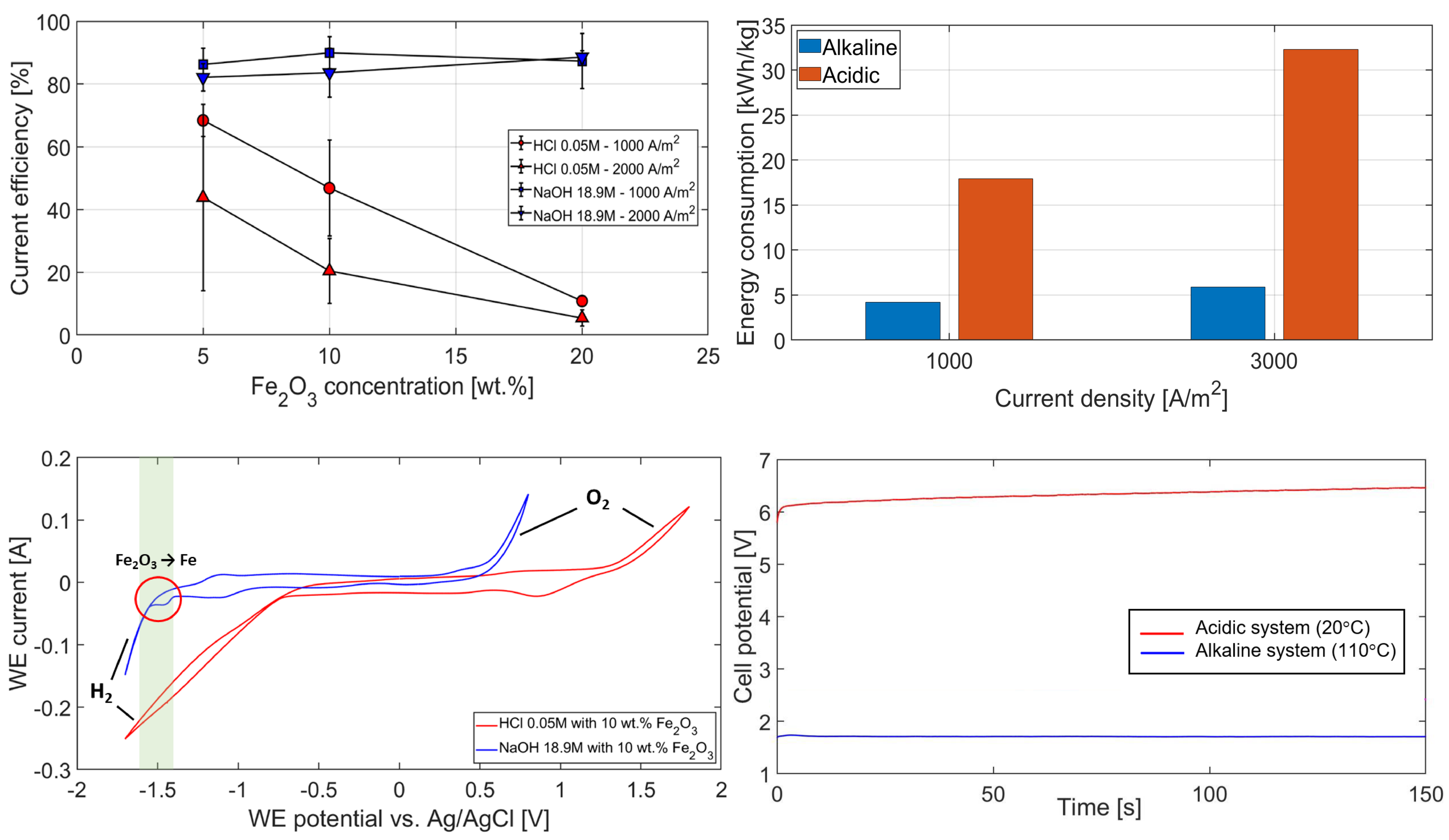


ACIDIC versus ALKALINE ELECTROLYTES[1]

Visual Comparison (Deposit Quality, SEM, Iron Purity)



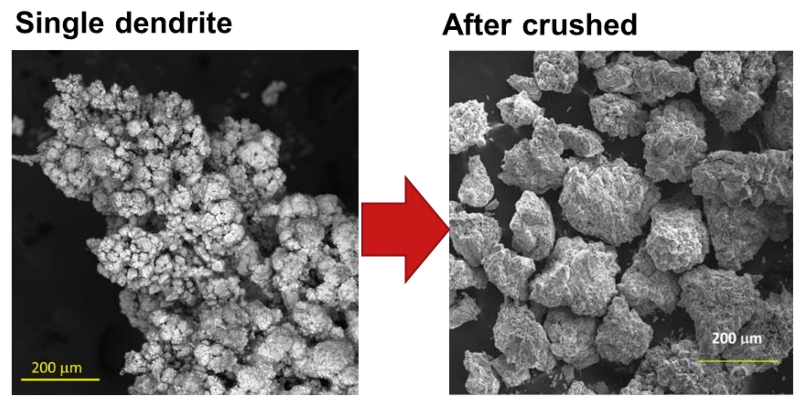
Performance Comparison



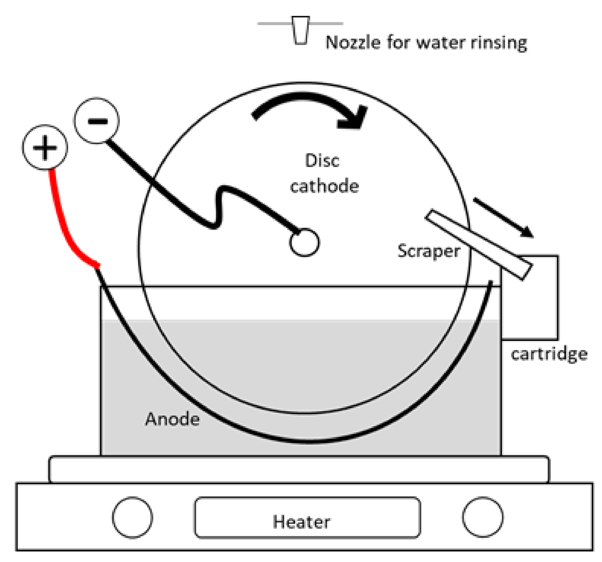
EXPERIMENTS IN ALKALINE SYSTEM[2]

Current eff. 92.6 %

Current eff. 83.9 % (some dendrites loss)

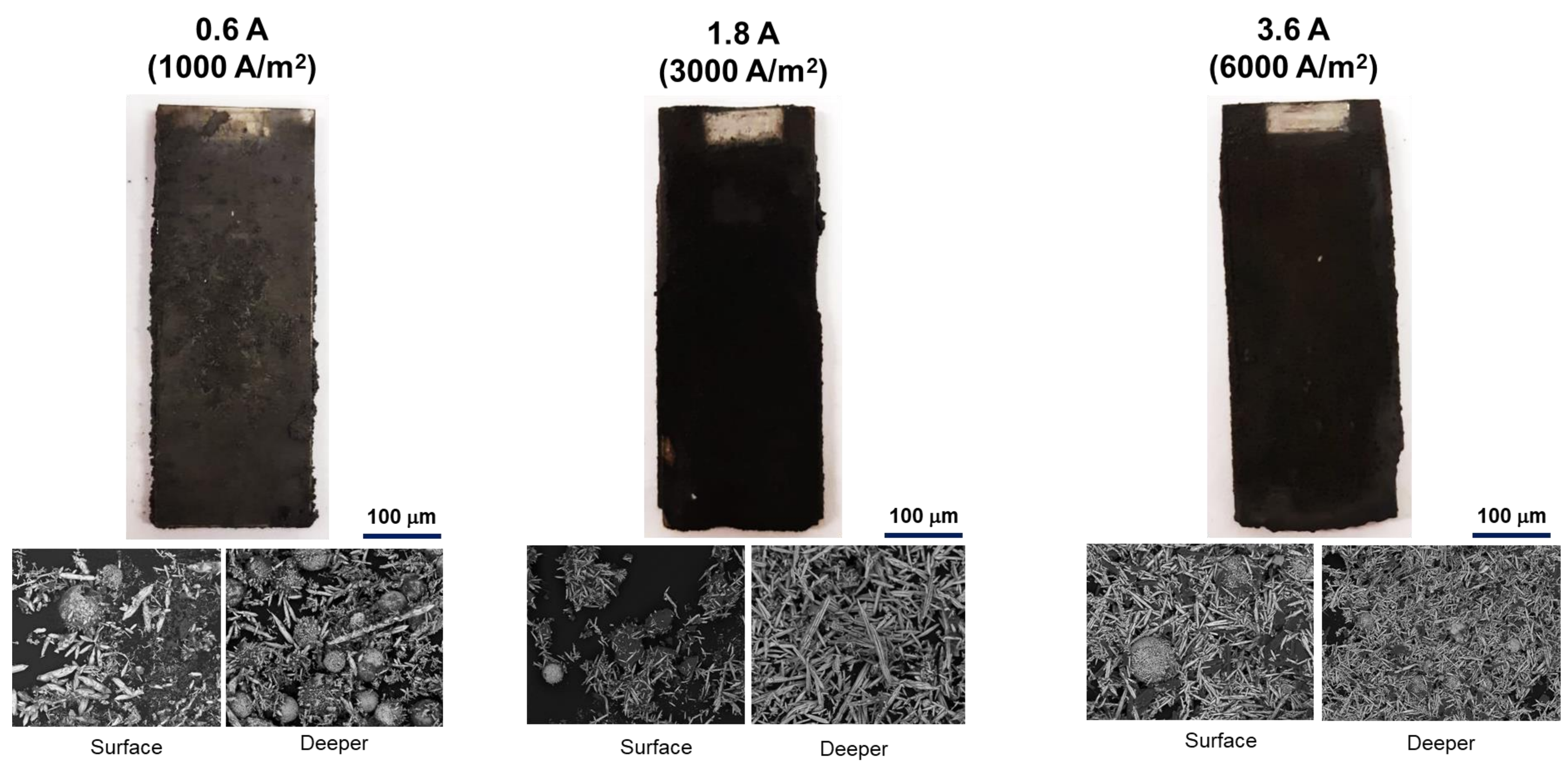


Conversion into powder



Proposed reactor for continuous powder production [3]

EXPERIMENTS WITH COMBUSTED IRON



CONCLUSIONS

- Electrochemical method was **capable to reduce iron oxide** to metallic iron with high current efficiency (>90%), high iron purity (>95%), and low energy (<6 kWh/kg).
- It can be an **alternative method** to regenerate **combusted iron** powders.
- **Potential method** to reach a continuous and direct electrolytic iron powder production

OUTLOOK

- Understanding the reduction mechanism, mass transfer, and reaction kinetics.
- Further development of reactor design.
- Combustion performance using the reduced/electrolytic iron powder

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PUBLICATIONS:

[1] Majid et al., "*Electroreduction of Iron Oxide in Different Aqueous Electrolytes*", in preparation (2022)
[2] Majid, et al., "*On the formation of dendritic iron from alkaline electrochemical reduction of iron oxide for metal fuels application*", in preparation (2022)
[3] Majid et al. (2022), "*System and method for continuous electrolytic production of metallic iron*", US Provisional Patent number 63/363,637