

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

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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.

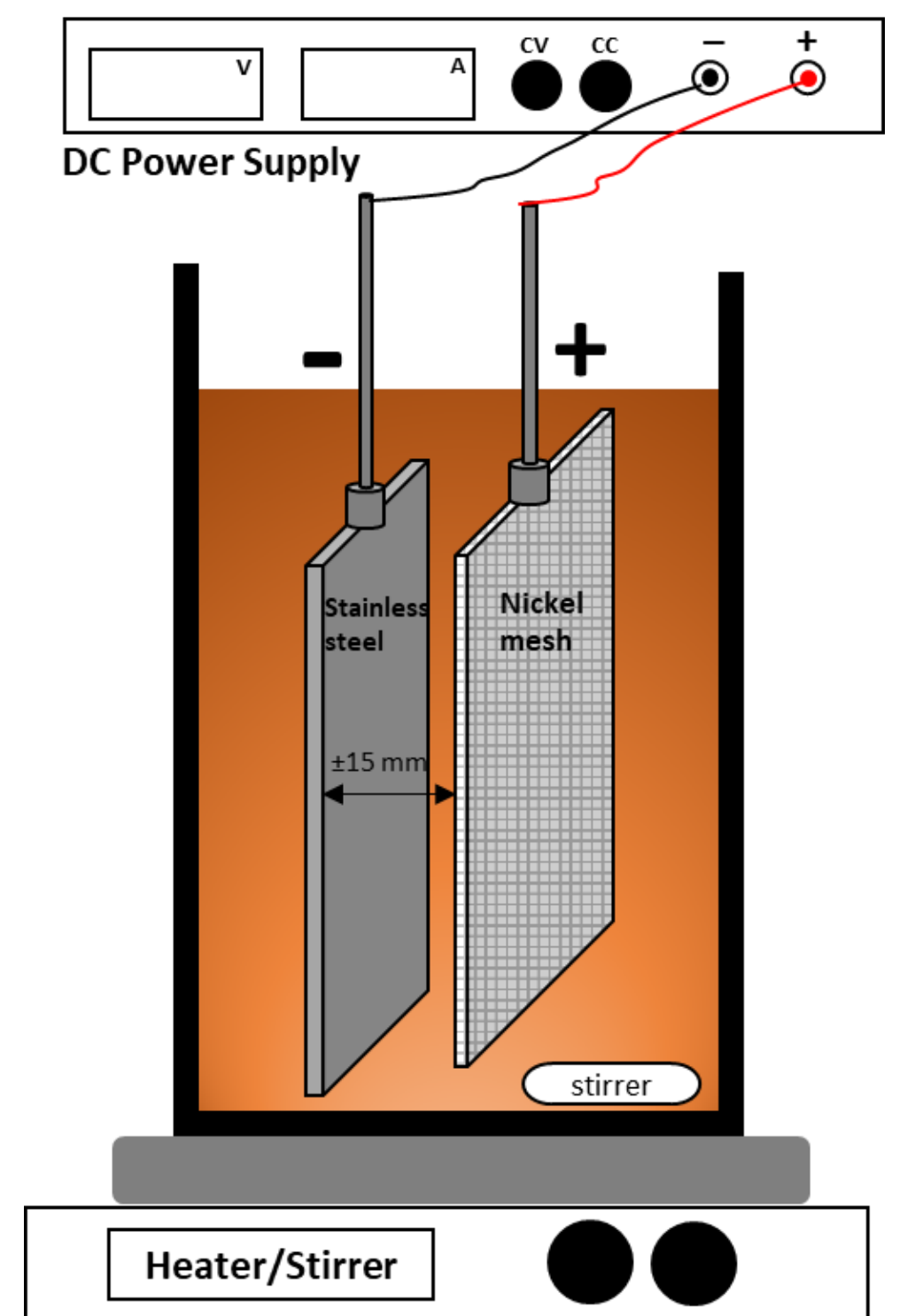
EXPERIMENTS

Powder : Fe₂O₃ powder (size ≤ 5 μm, ≥ 96%)
 Combusted iron (size ≤ 32-75 μm)
 Electrolyte : NaOH (50 wt%; 18 M), HCl (0.05 M)
 Fe₂O₃ 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

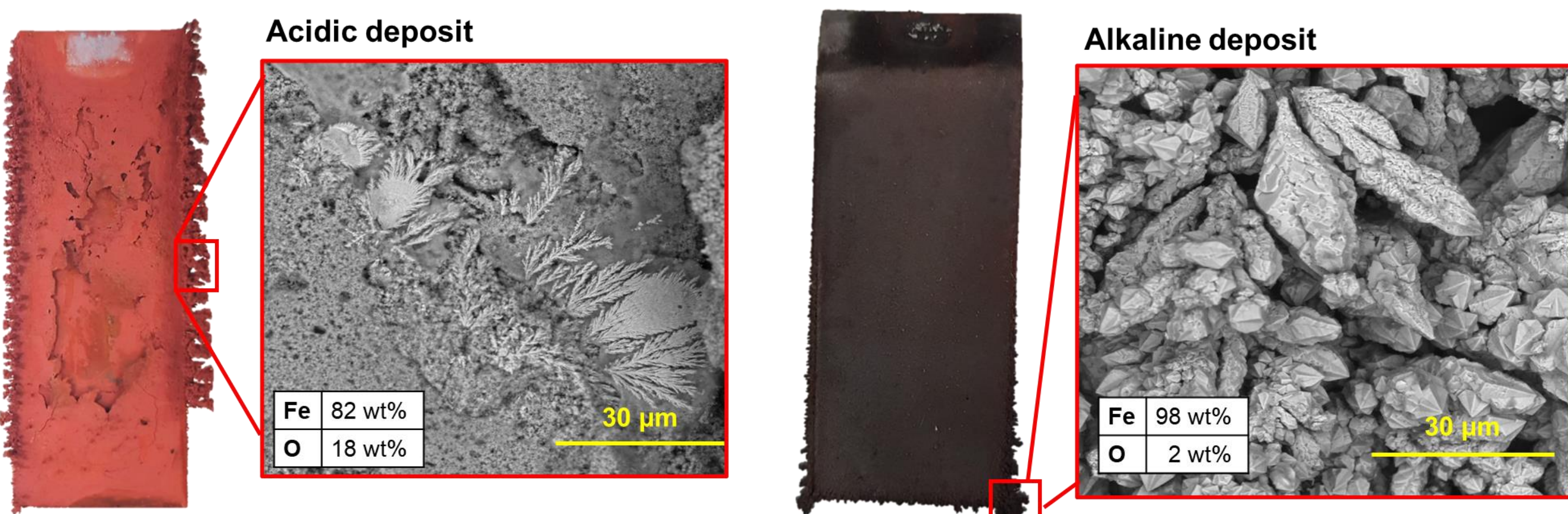
$$\eta = \frac{m_{real}}{m_{faradaic}} = m_{deposit} \cdot \left(\frac{n \cdot F}{M \cdot I \cdot t} \right)$$

n : number of electrons [3: Fe³⁺→Fe⁰] I : Current supply [A]
 F : Faraday constant [96485 sA/mol] t : Duration [s]
 M : Iron molar mass [55.85 gr/mol]

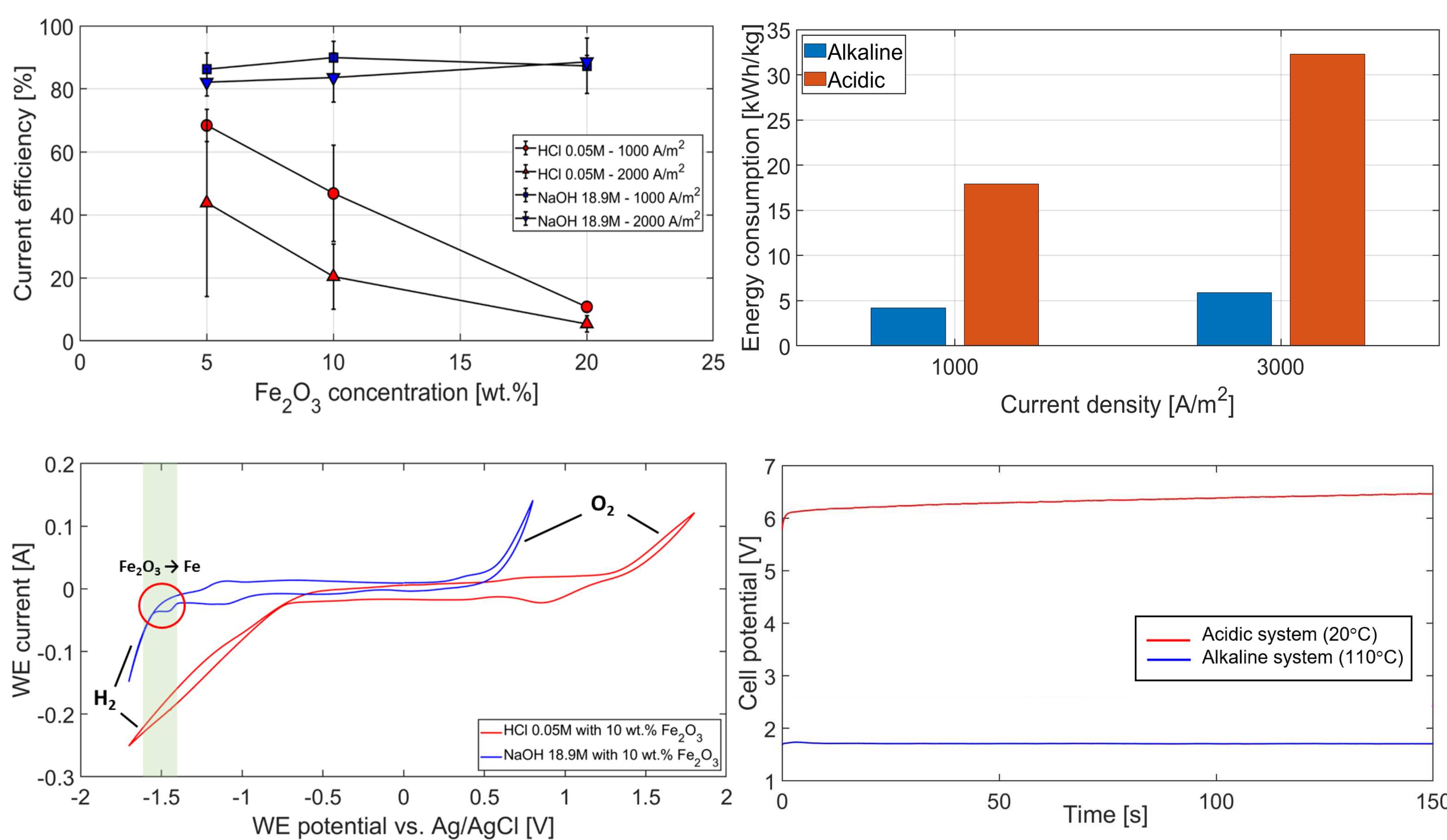


ACIDIC versus ALKALINE ELECTROLYTES^[1]

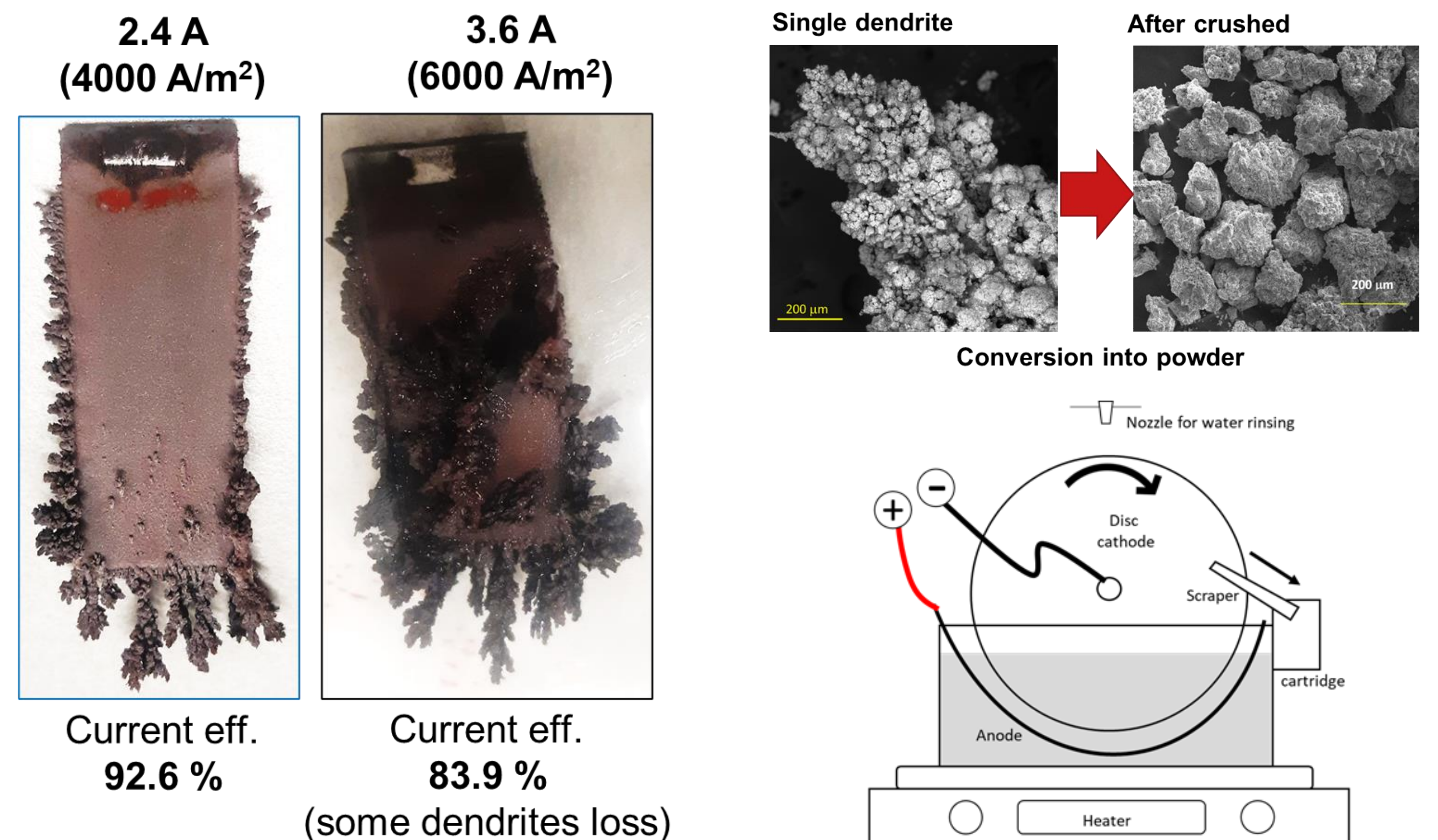
Visual Comparison (Deposit Quality, SEM, Iron Purity)



Performance Comparison

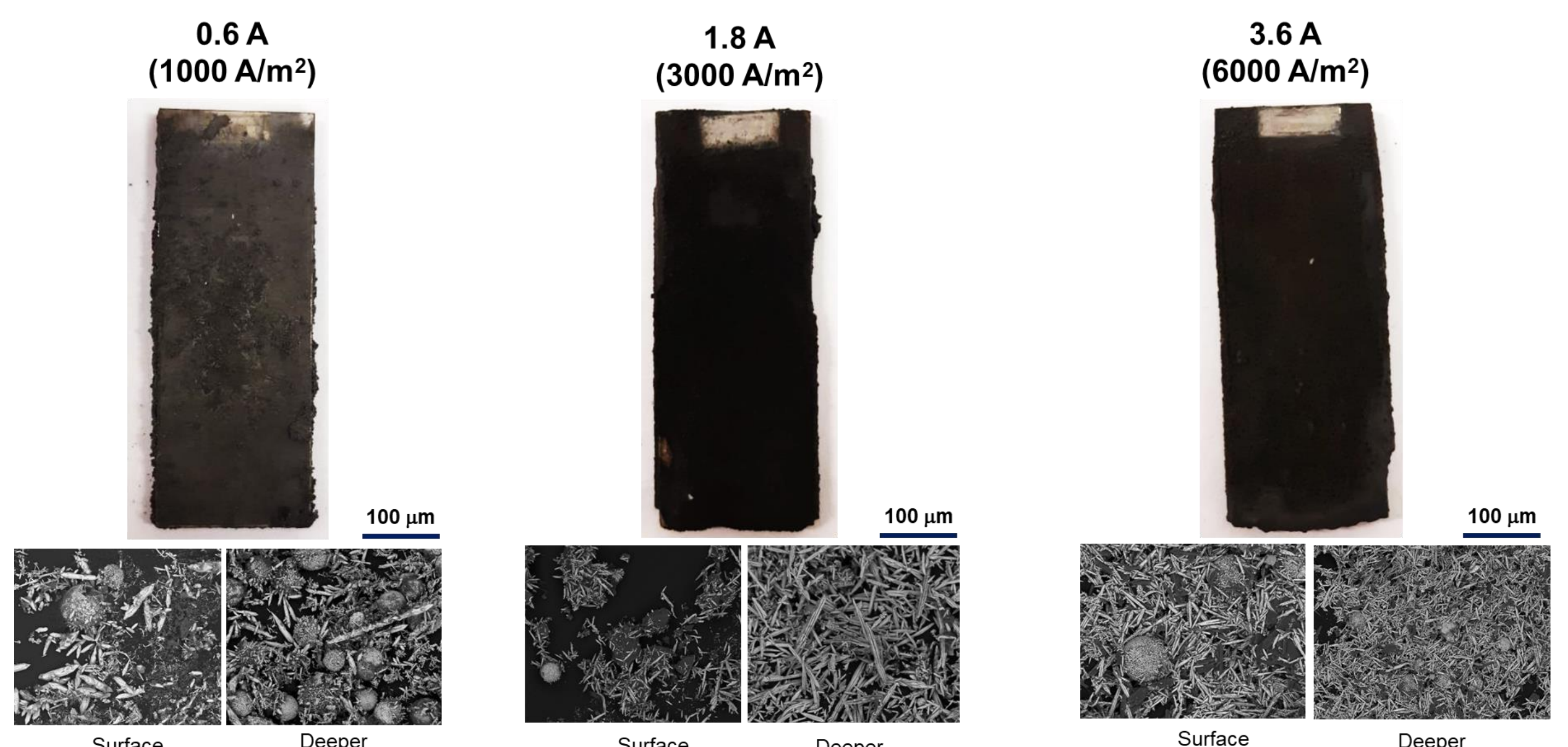


EXPERIMENTS IN ALKALINE SYSTEM^[2]



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