

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

Citation for published version (APA):

Majid, A. I., Tang, Y., Finotello, G., van der Schaaf, J., & Deen, N. G. (2022). *Electrochemical Reduction of Iron Oxide for the Valorization of the Iron Fuel Cycle*. Poster session presented at 1st Workshop on Metal-enabled Cycle of Renewable Energy (MECRE), Eindhoven, Netherlands.

Document status and date:

Published: 01/11/2022

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.



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

Akmal Irfan Majid¹, Yali Tang^{1,3}, Giulia Finotello^{1,3}, John van der Schaaf^{2,3}, Niels G. Deen^{1,3}

¹Power & Flow, Department of Mechanical Engineering, Eindhoven University of Technology-The Netherlands
²Sustainable Process Engineering, Department of Chemical Engineering & Chemistry, Eindhoven University of Technology-The Netherlands
³Eindhoven Institute for Renewable Energy Systems (EIRES), Eindhoven University of Technology-The Netherlands

✉ a.i.majid@tue.nl

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.

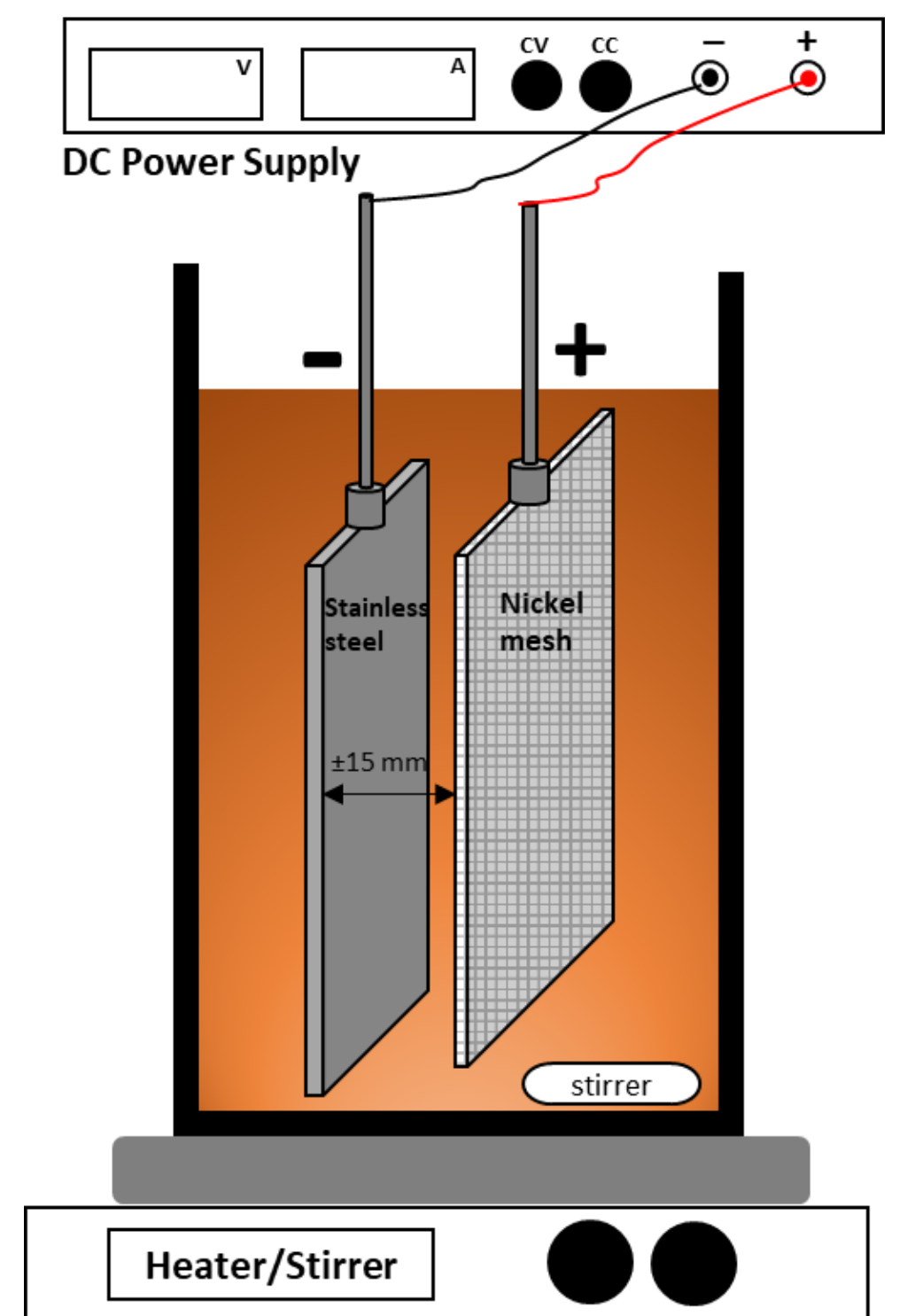
EXPERIMENTS

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

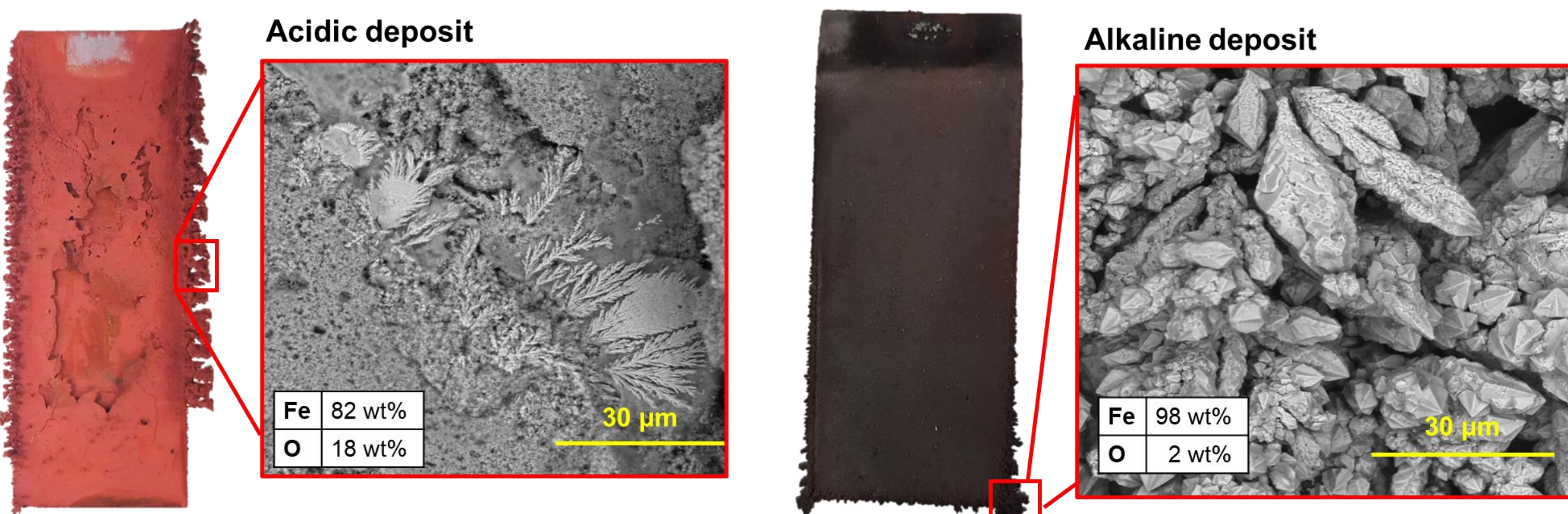
$$\eta = \frac{m_{real}}{m_{faradaic}} = m_{deposit} \cdot \left(\frac{n \cdot F}{M \cdot I \cdot t} \right)$$

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]

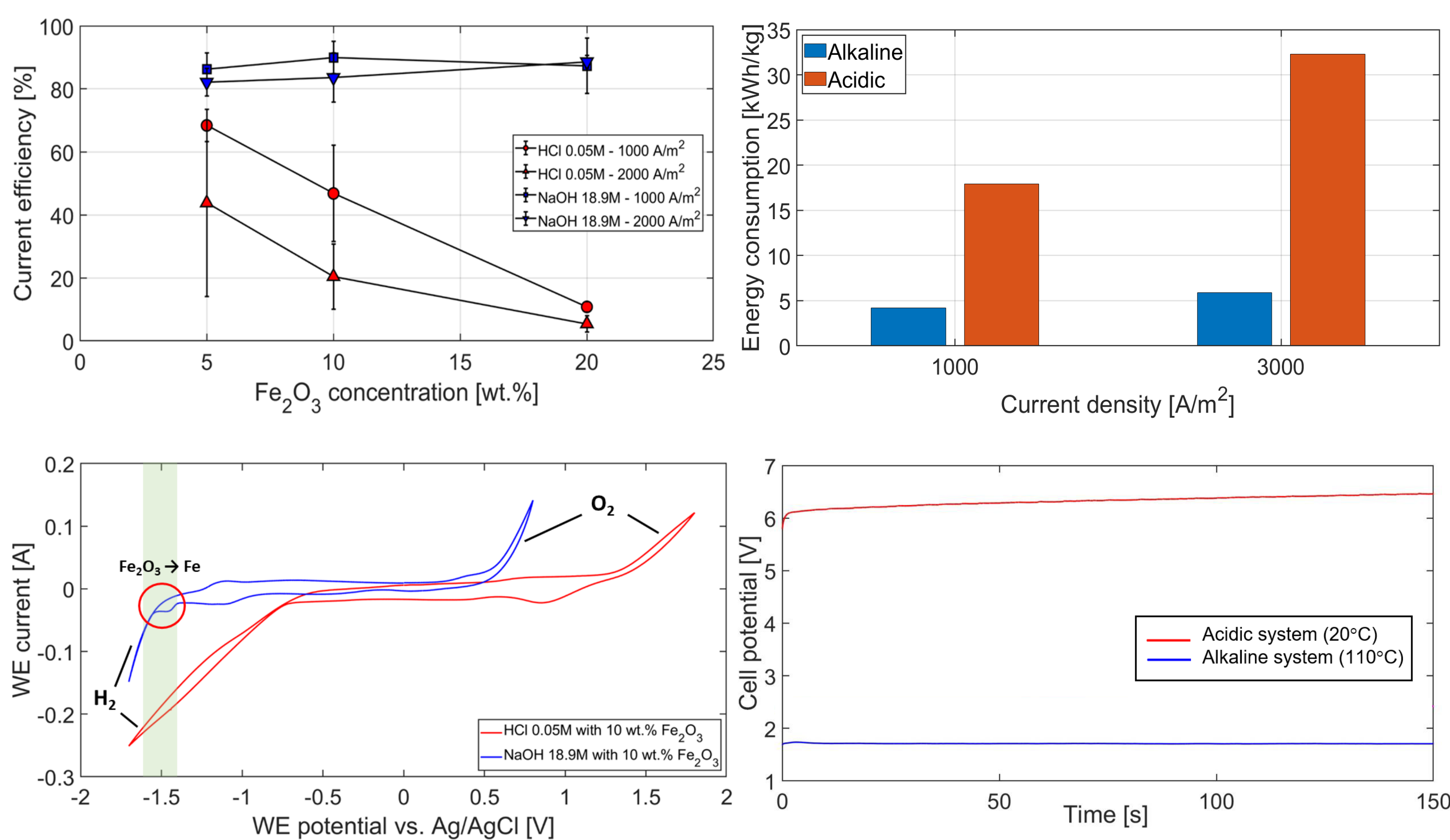


ACIDIC versus ALKALINE ELECTROLYTES^[1]

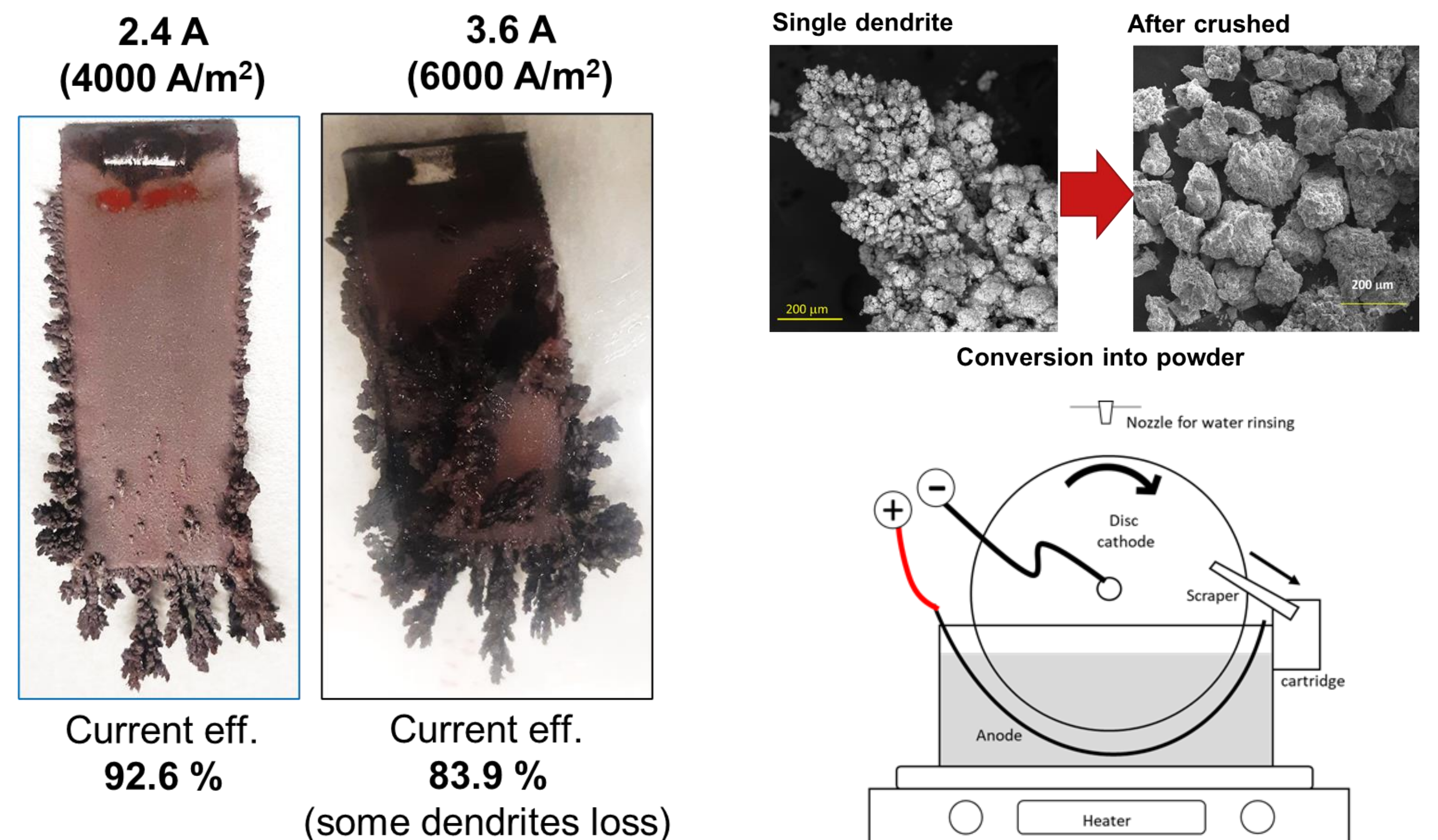
Visual Comparison (Deposit Quality, SEM, Iron Purity)



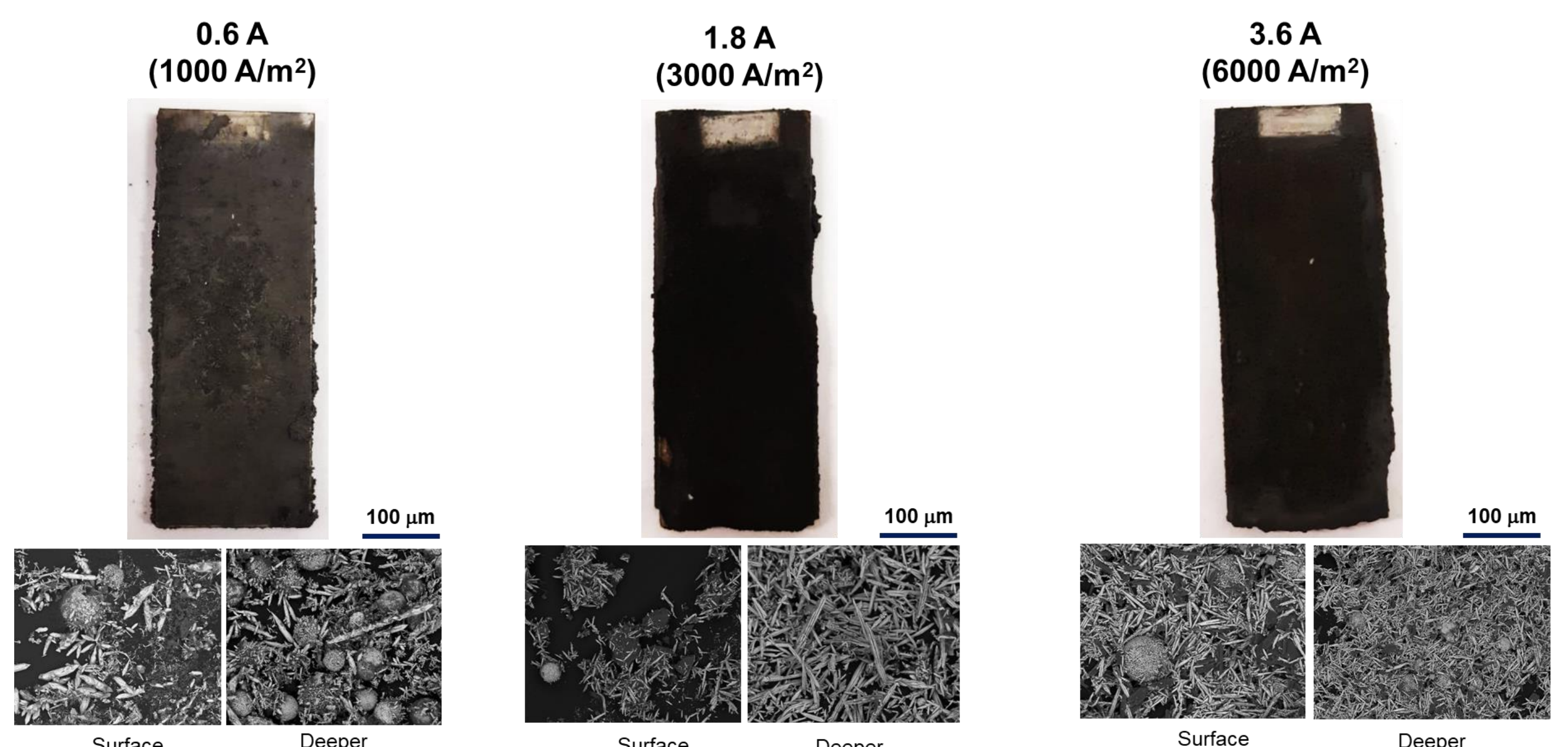
Performance Comparison



EXPERIMENTS IN ALKALINE SYSTEM^[2]



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

Acknowledgement:

Akmal Irfan Majid is a grantee of scholarship and research funding from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia Contract Number: B/823/D3.2/KD.02.01/2019. He also receives a research grant from the Universiteits Fonds Eindhoven (UFE) through a "Heroes for Heroes" funding scheme in 2022.

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