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## Temperature and pressure effects on the electrochemical CO<sub>2</sub> reduction

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## List of publications

### Chapter 2

R.E. Vos, M.T.M. Koper

The Effect of Temperature on the Cation-Promoted Electrochemical CO<sub>2</sub> Reduction on Gold

*ChemElectroChem* **9** e202200239 (2022)

### Chapter 3

R.E. Vos, K.E. Kolmeijer, T.S. Jacobs, W van der Stam, B.M. Weckhuysen, M.T.M. Koper  
How Temperature Affects the Selectivity of the Electrochemical CO<sub>2</sub> Reduction on Copper

*ACS Catalysis* **13** 8080-8091 (2023)

### Chapter 4

R.E. Vos, J.S. Smaak, M.T.M. Koper

The Temperature Dependence of Electrochemical CO<sub>2</sub> Reduction on Ag and CuAg alloys

*Journal of Catalysis* 115613 (2024)

### Chapter 5

R.E. Vos, M.T.M. Koper

Nickel as Electrocatalyst for CO<sub>2</sub> Reduction: Effect of Temperature, Potential, Partial Pressure, and Electrolyte Composition

*ACS Catalysis* **14** 4432-4440 (2024)

### Chapter 6

A.H.M. da Silva, R.E. Vos, R.J.C. Schrama, M.T.M. Koper

Design of a Rotating Disk Electrode setup operating under high pressure and temperature: application to CO<sub>2</sub> reduction on gold

*Electrochimica Acta* 144612 (2024)

### Chapter 7

R.E. Vos, D. Schauer mann, Pengfei Sun, Selwyn R. Hanselman, M.T.M. Koper

Change in the C-C coupling mechanism during CO<sub>2</sub> electroreduction on Cu at elevated temperature and pressure

In preparation

**Chapter 8**

R.E. Vos, M.T.M. Koper

Screening of Various Metal Catalysts for Electrochemical CO<sub>2</sub> Reduction at Elevated Temperatures and Pressures

In preparation

**Other publications**

I.E.L. Stephens, et al.

2022 Roadmap on Low Temperature Electrochemical CO<sub>2</sub> reduction

*Journal of Physics: Energy* **4** 042003 (2022)

A. Shih, et al.

Water Electrolysis

*Nature Reviews Methods Primers* **2** 84 (2022)

A.H.M. da Silva, Q. Lenne, R.E. Vos, M.T.M. Koper

Competition of CO and Acetaldehyde Adsorption and Reduction on Copper Electrodes and Its Impact on n-Propanol Formation

*ACS Catalysis* **13** 4339-4347 (2023)

A.H.M. da Silva, G. Karaiskakis, R.E. Vos, M.T.M. Koper

Mechanistic Insights into the Formation of Hydroxyacetone, Acetone, and 1,2-Propanediol from Electrochemical CO<sub>2</sub> Reduction on Copper

*Journal of the American Chemical Society* **145** 15343-15352 (2023)

O. van der Heijden, S. Park, R.E.Vos, J.J.J. Eggebeen, M.T.M. Koper

Tafel Slope Plot as a Tool to Analyze Electrocatalytic Reactions

*ACS Energy Letters* **9** 1871-1879 (2024)

M.R. Pinto, R.E. Vos, R. Nagao, M.T.M. Koper

Electrolyte Effects on Electrochemical CO<sub>2</sub> Reduction at Sn Metallic Electrode

*Journal of Physical Chemistry C*, in revision

O. van der Heijden, R.E. Vos, A.H.M da Silva, M.T.M. Koper

Determination of the Temperature Dependent Tafel Slope, Activation Energy and Transfer Coefficients for the Alkaline Oxygen Evolution Reaction on NiFeOOH

In preparation

O. van der Heijden, A.H.M da Silva, R.E. Vos, M.T.M. Koper

Effects of Pressure on the Oxygen Evolution Reaction

In preparation

### Curriculum vitae

Rafaël Vos was born on the 28<sup>th</sup> of November 1995 in Almere, the Netherlands, where he lived the first 18 years of his life. He went to high school at het Oostvaarders College (OVC) from 2008 to 2014 and graduated the gymnasium cum laude with a curriculum of both 'nature and health' and 'nature and technology' extended with economics and French. After high school he moved to Leiden to start his university education.

From 2014 to 2017, Rafaël followed the bachelor Molecular Science and Technology (MST), which is a joint degree of the TU Delft and Leiden University combining Chemistry and Chemical Engineering. He was always interested in sustainability and his first introduction with electrochemistry and with prof. Marc Koper was during an interview for a course in the extracurricular Honours Program. This sparked his interest for electrochemistry and resulted in a bachelor thesis in the CASC research group researching the effect of the carbon substrate on the electrochemical CO<sub>2</sub> reduction on indium protoporphyrins under supervision of Yuvraj Birdja.

After graduating his bachelor summa cum laude, Rafaël started the master Chemistry in Leiden. He chose the 'Energy and Sustainability' specialization and pursued both the Research and Business track. This entailed that besides 60 ECTS of Chemistry courses, which were mainly focused on physical and inorganic chemistry, he also followed business courses such as Finance and Strategy. Rafaël performed his master thesis again in the CASC research group. This time he studied the reduction and adsorption mode of acetylpyridine on Au under supervision of dr. Christoph Bondü. After his master thesis, he carried out a second research internship in the research group of prof. Alexis Bell in Berkeley, USA. Here he researched the electrochemical CO<sub>2</sub> reduction to C<sub>2</sub>+ products on Cu foils. Besides two research internships, Rafaël also performed a business internship at nlmt, at that point a small consulting firm focusing on sustainability and specialized in the energy sector. Moreover, Rafaël participated in the Leiden Leadership Programme, an extracurricular programme focusing on self-development via seminars, workshops, group projects and much self-reflection. Due to these extra activities, Rafaël obtained his master cum laude in three years (2017-2020).

For his PhD, Rafaël stayed in Leiden and specifically the CASC research group under supervision of Prof. Marc Koper. He started during the COVID-19 epidemic in 2020 and his research was part of the TRANSCRIPT (Transforming carbon-rich industrial waste gases of metallurgical plants into valuable products) project. This project was cofunded by the Netherlands Organization for Scientific Research

(NWO), Materials Innovation Institute (M2i) and Tata Steel. Besides Rafaël, also one PhD candidate, two postdocs in Leiden and three PhD candidates in Utrecht were part of this project. The project of Rafaël focused on the effect of temperature on the electrochemical CO<sub>2</sub> reduction and he co-developed the high-pressure, high-temperature electrochemical cell. Besides research, Rafaël also supervised several bachelor and master students during their thesis or other internships in the group. Moreover, he supervised bachelor students during their first practical course (Basic Practical Skills) and small lab internships, and assisted during a seminar for chemistry bachelor students.

Furthermore, several courses were followed by Rafaël during his PhD. Besides 'Visualize your Science' (Visualize your science) and 'High Impact Writing' (HRSMC) also several courses from Leiden University were completed (PhD Introductory Meeting, Speed Reading, Manage your Brain, Basic Project Management, Negotiating, Storytelling Lab, Scientific Conduct). Additionally, he presented his work at several national and international conferences and summer schools, both via poster presentations (ECCM graduate school in 2021, HRSMC symposium in 2021, 2022 and 2023, Surfcat summer school in 2022, ISE topical meeting in 2022, NCCC in 2022, Amcel symposium in 2023, ISE 74<sup>th</sup> Annual Meeting in 2023, the M2I conference from 2020 till 2023) and via oral presentations (NCCC in 2023 in Noordwijkerhout, CHAINS-IUPAC in Den Haag in 2023, M2I conference in Apeldoorn in 2023, NanoGE in Keele in 2023, National Symposium on Electrochemical Conversion in Den Haag in 2024, ISE 75<sup>th</sup> Annual Conference in Montreal in 2024). Rafaël was also member of the PhD platform of the Holland Research School for Molecular Chemistry (HRSMC) and the PhD representative during the CASC staff meetings.

# Acknowledgements

With the end of my PhD also my time at Leiden University comes to an end after a decade long journey. This journey formed me both as a researcher and as a person, and I would like to take this opportunity to express my gratitude to the people who joined me on this journey and contributed to the realization of this thesis, may it be directly or indirectly.

First I would like to thank prof. dr. Marc Koper for his supervision during all these years. We first met in my first year as a bachelor student and during this interview my passion for electrochemistry was ignited. I want to thank Marc for providing me the opportunity to join the Catalysis and Surface Chemistry (CASC) group not once, but three times during all these years. Thank you for the freedom to explore my own ideas, for the impactful advises, for all the feedback on my work, for the opportunities to go on conferences both in the Netherlands and abroad, for providing an excellent work environment and creating such an amazing research group full of wonderful people.

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A PhD is not a journey you should do on your own and I'm grateful for all the wonderful people in the CASC research group that joined me on this journey, not only in the lab but also as wonderful friends outside of the university. Sergi, I'm grateful and happy I can call you my good friend. Even though in the lab we did not spend much time together, the more time we spend at the lunch table and outside of university. Thank you for all the laughter, stories, food and good times. Alisson, you have been the closest colleague I worked with. Thank you for all the wonderful scientific discussion we had, for the amazing collaboration and for all the fun, also outside of the lab. With Cássia, Marleen and Francesc, we had a lot of fun times. Thank you for the wonderful dinners, the great parties and your amazing friendship.

I'm thankful to all the other people I closely work with in our project. You were amazing colleagues in and outside of the lab; Xuan, Zhiqin and Quentin. I also want to express my gratitude to our collaborators from Utrecht. Angela, Joyce and Thimo, we had a great time during all the meetings and conferences we were together.



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