Electrocatalysis for the synthesis of chemicals

Marta Costa Figueiredo

NL IL mini symposium on energy conversion and storage , 13/01/2021


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Department of Chemical Engineering & Chemistry | Inorganic Materials & Catalysis

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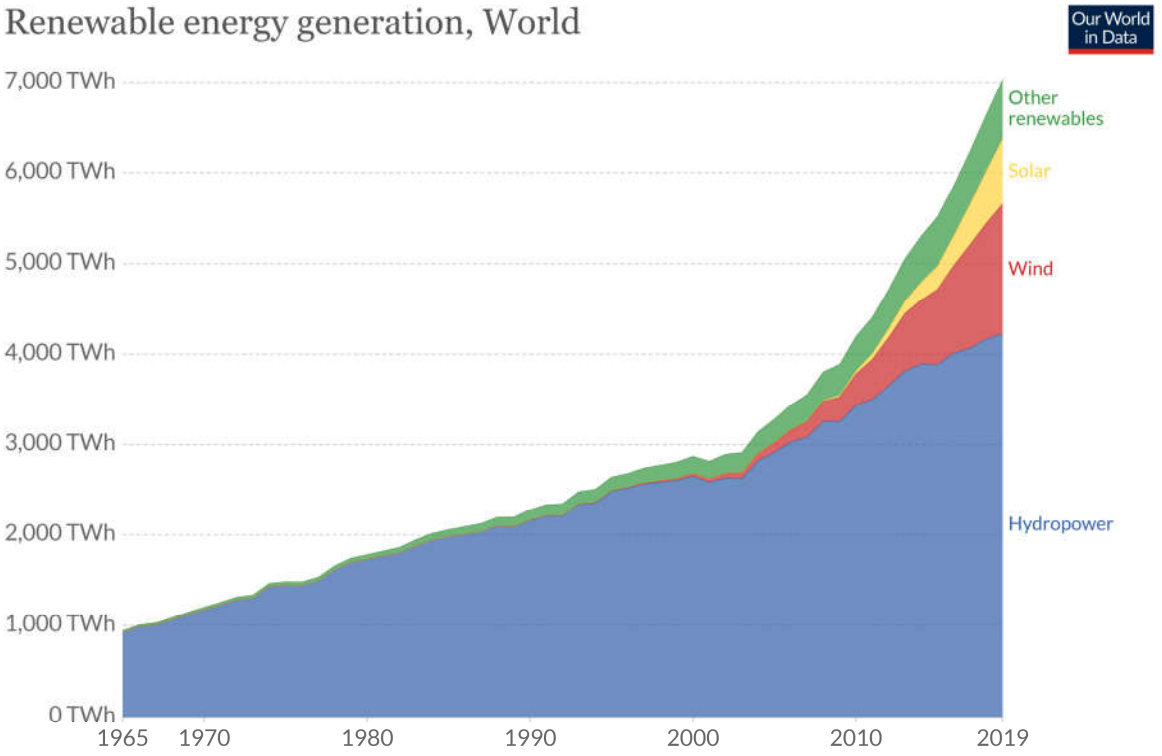
IMC INORGANIC MATERIALS & CATALYSIS

Outline

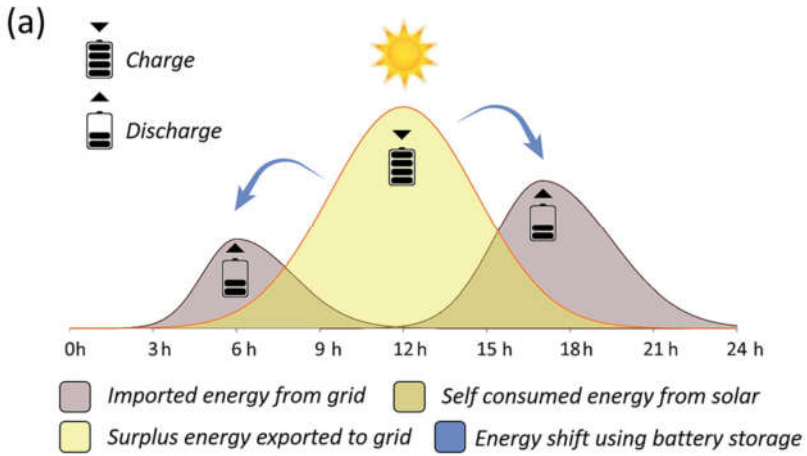
- Introduction
  - Electrocatalysis
  - Electrocatalysis at TU/e
- Electrochemical conversion of CO_2 to formic acid
- Nitrate and Nitrite reduction to ammonia and urea

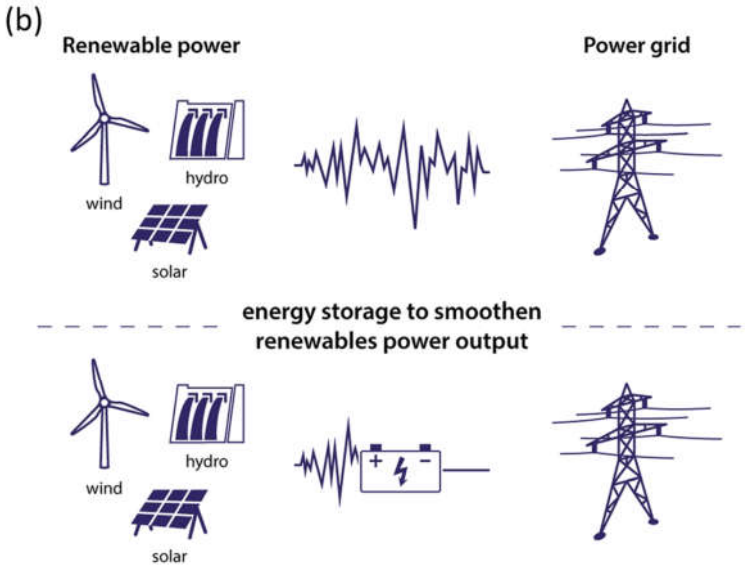
Introduction

Energy storage and conversion



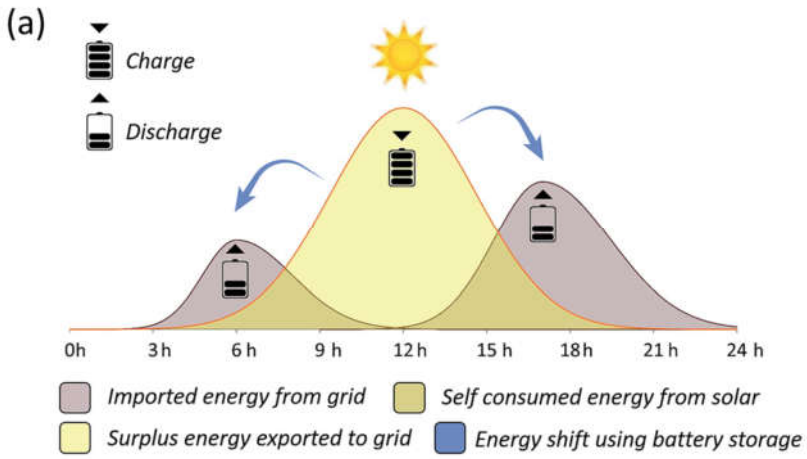
Energy storage and conversion

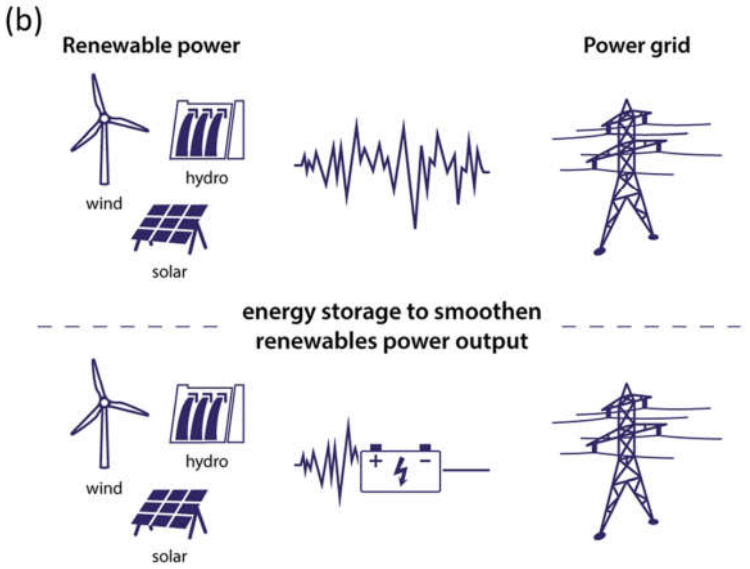




Electrical energy storage systems

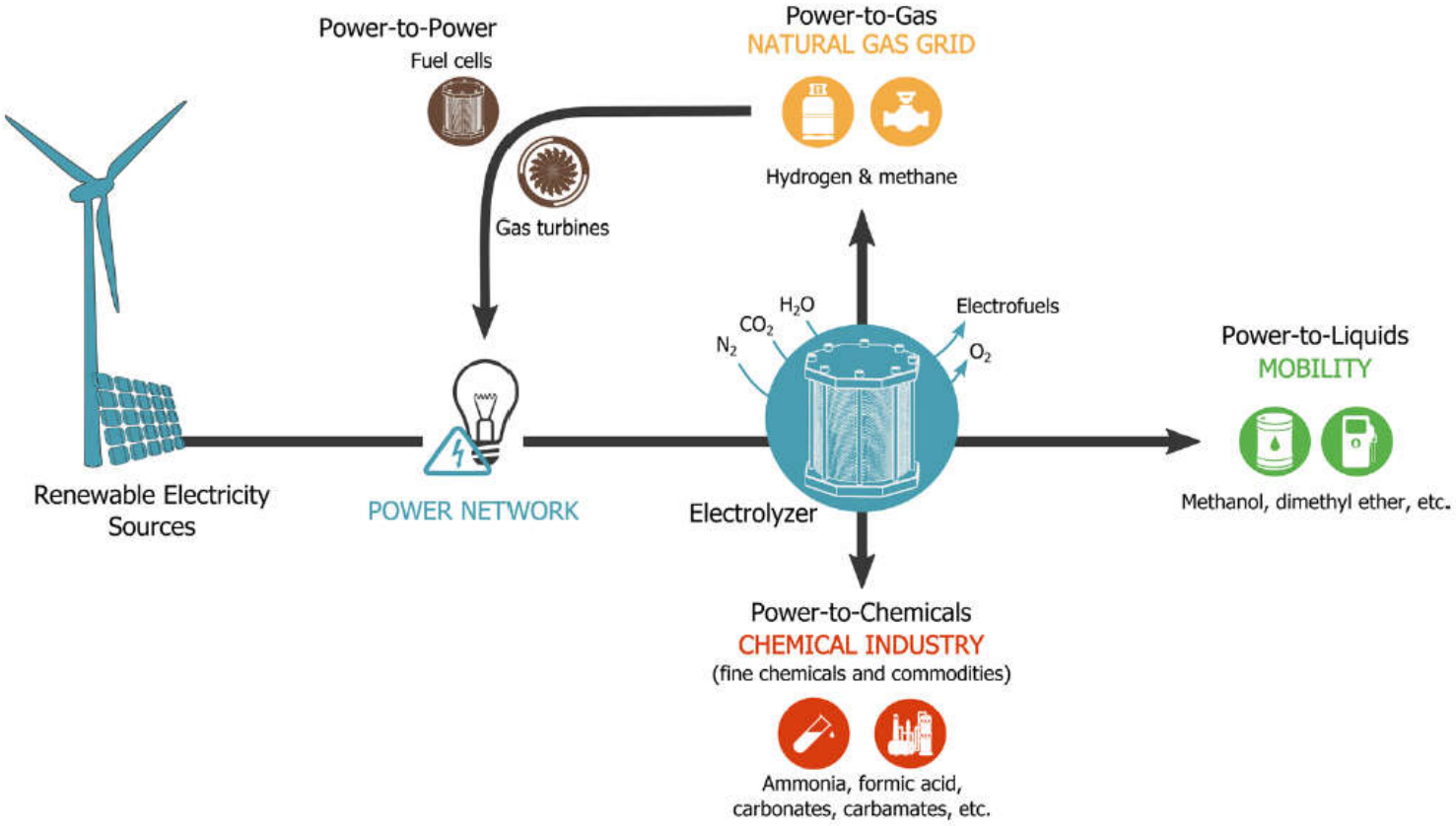
Energy storage and conversion



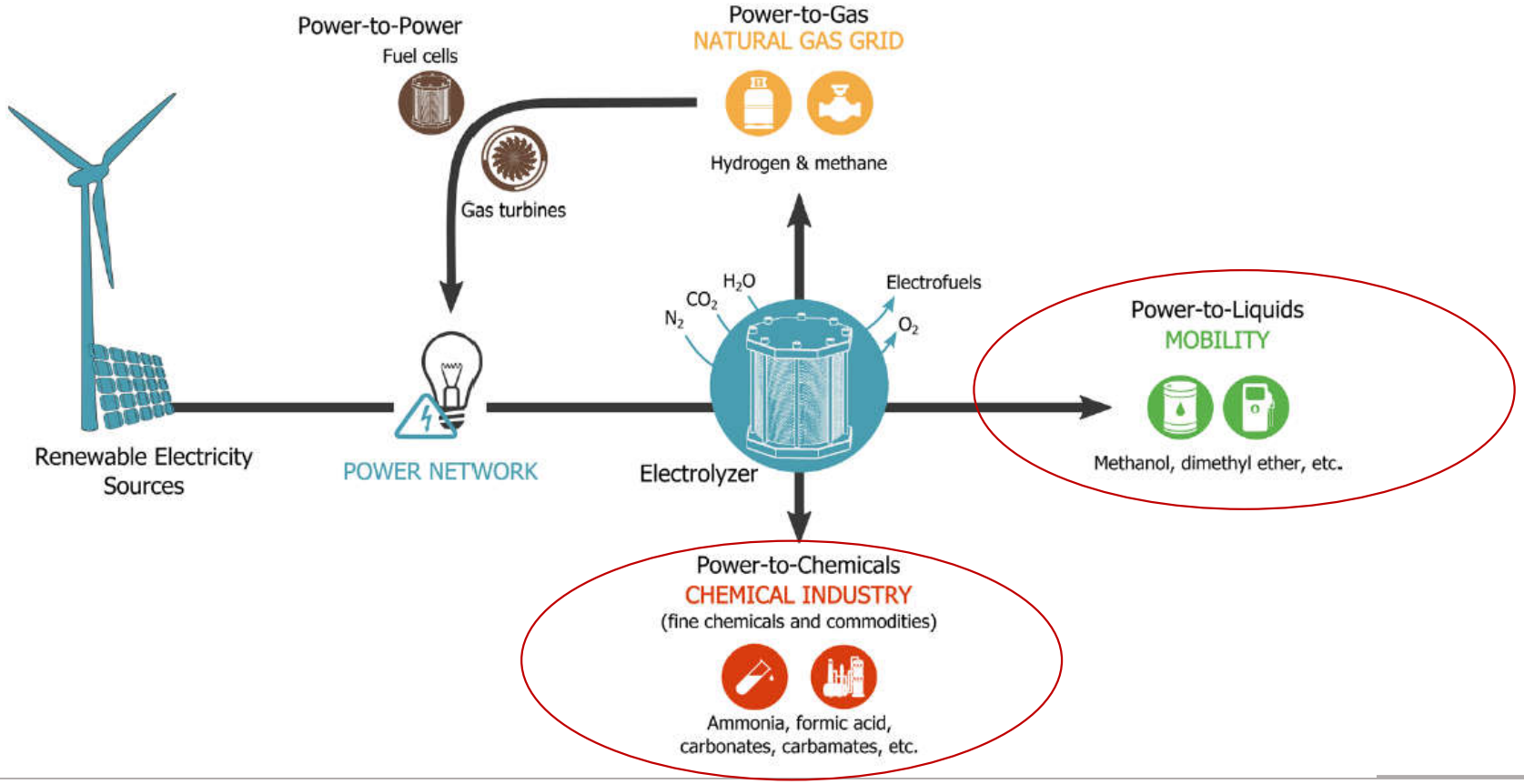


Electrical energy storage systems
Or
Use of energy surplus to produce chemicals

Electrosynthesis of chemicals



Electrosynthesis of chemicals



Electrosynthesis of chemicals

- **Successful examples**

- Chlor alkali (chlorine and caustic soda)

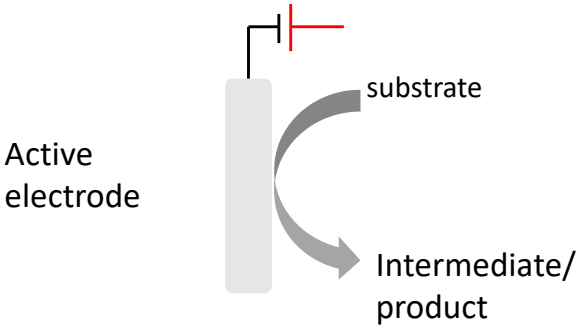
- Aluminum production

(before electrolysis implementation aluminum was as expensive as silver)

Electrocatalysis

Electrocatalytic synthesis

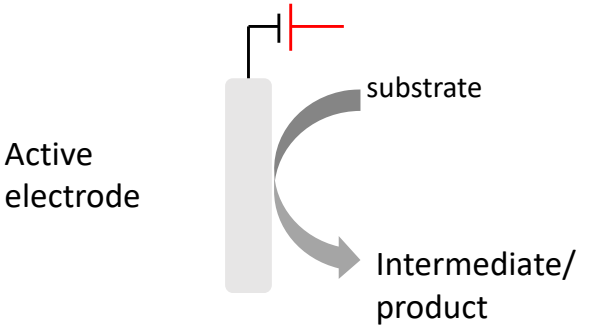
- Electrocatalytic approach of synthesis



Electrocatalysts: electrode material that interacts specifically with some species involved in the reaction and remains unaltered after the reaction.

Electrocatalytic synthesis

- Electrocatalytic approach of synthesis



Properties of the electrode

- Structural effects
- Composition effects

- Interaction of the substrate with the electrode
- Adsorption of intermediates or products

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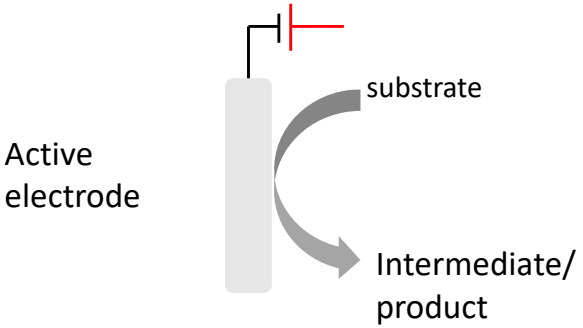

Properties of the electrode

- Structural effects
- Composition effects

- Interaction of the substrate with the electrode
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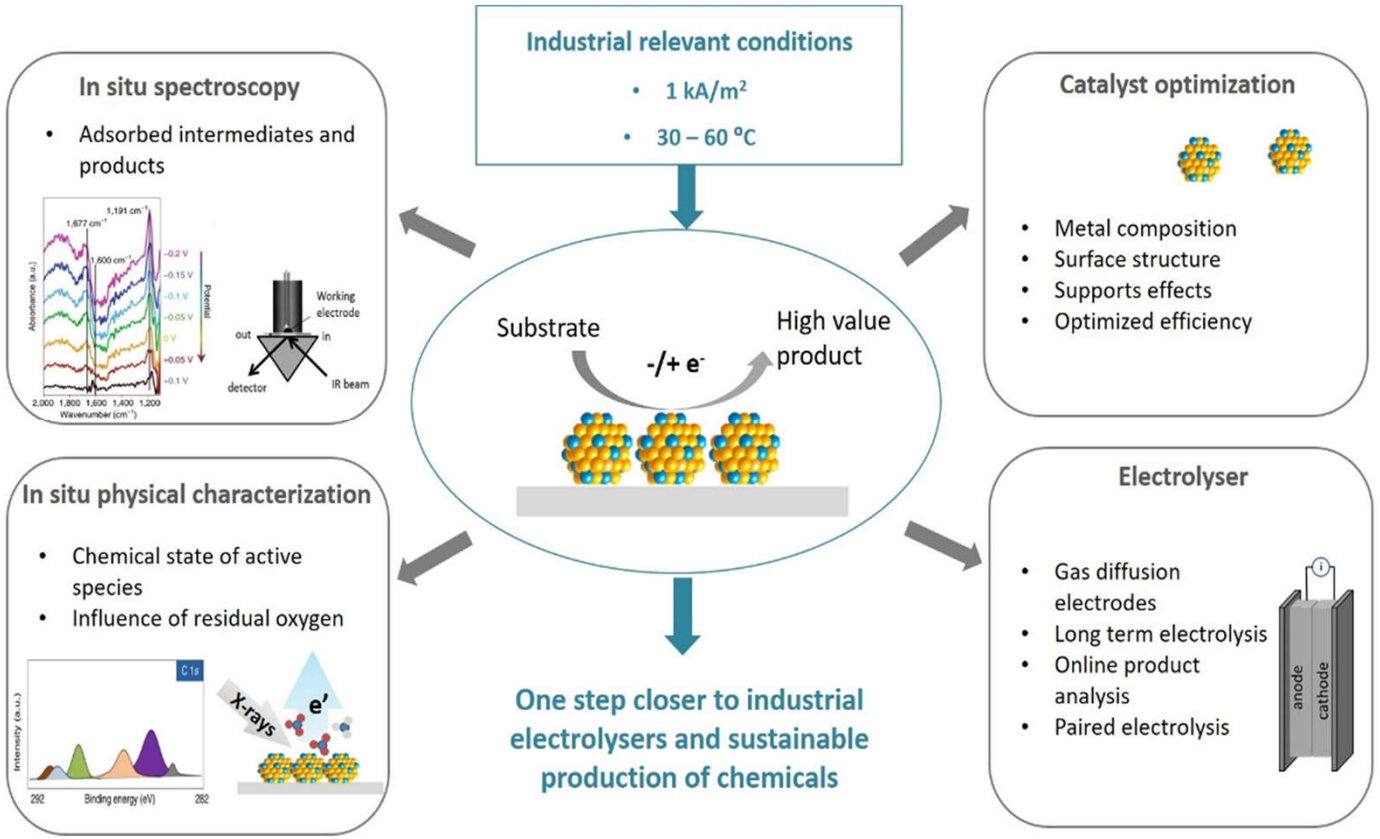
Catalysts development, unravelling reaction mechanism, reaction conditions

High current densities, high faradaic efficiencies, low overpotentials, High selectivity

Electrocatalysis at TU/e - How



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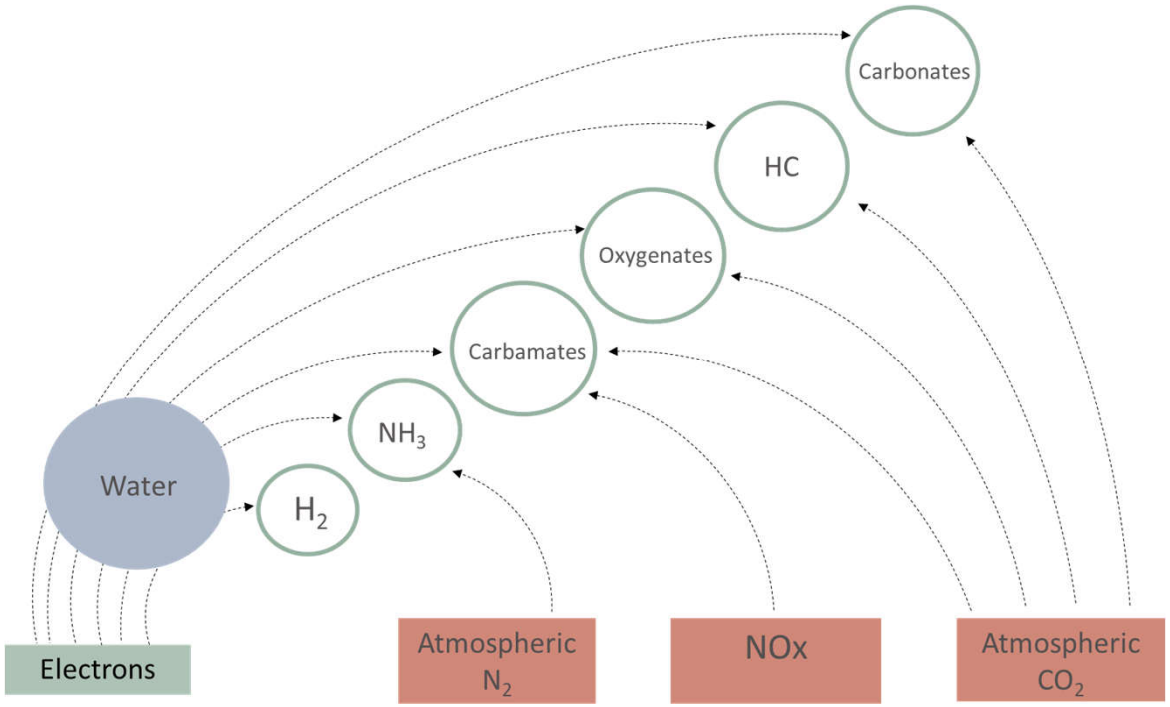
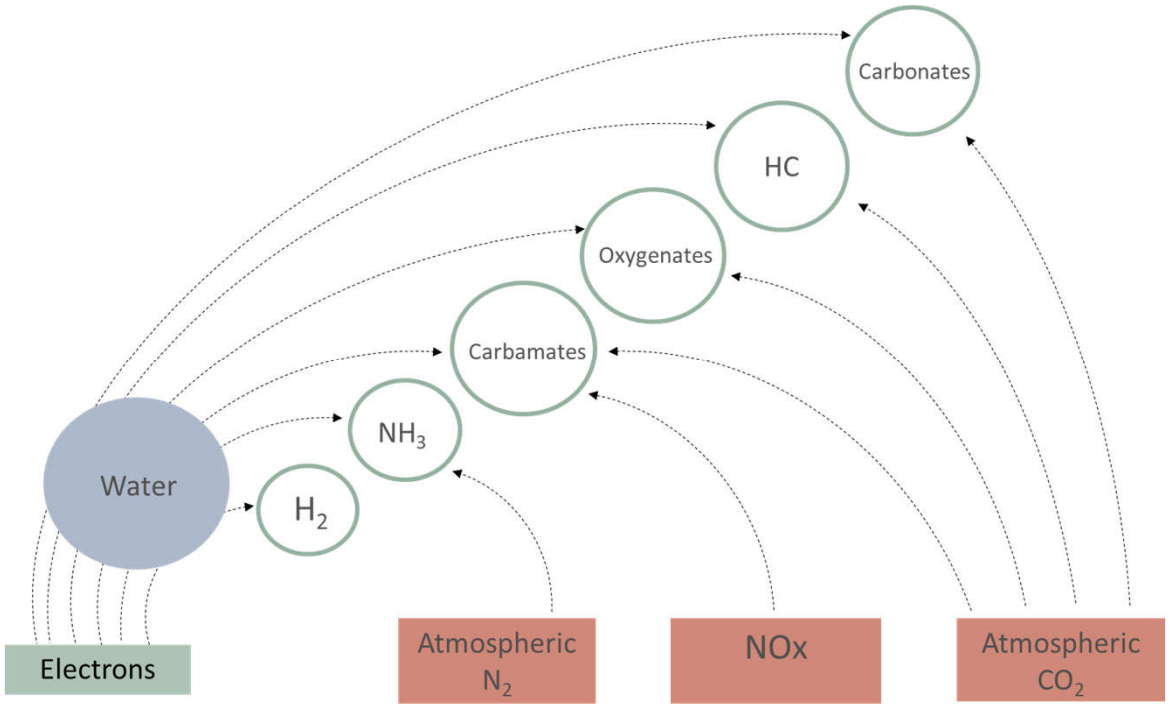
Electrocatalysis at TU/e – What



Credits: Dimitra Anastasiadou

Electrocatalysis at TU/e – What



- CO_2 reduction to formic acid
- Nitrogen containing compounds reduction to ammonia
- Urea electrosynthesis from nitrate and CO_2
- CO_2 reduction to ethanol
- E-Fisher Tropsh (CO conversion to oxygenates and high chain hydrocarbons)
- Synthesis of Dimethyl carbonate from CO_2

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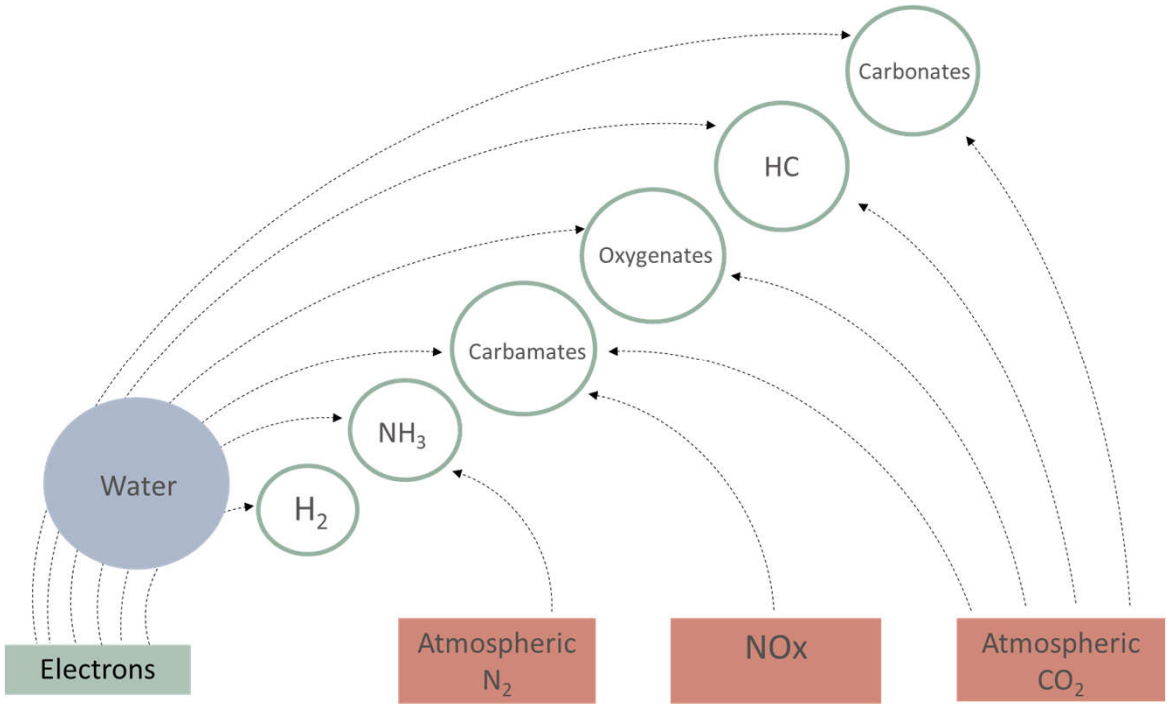

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CO_2 conversion to formic acid

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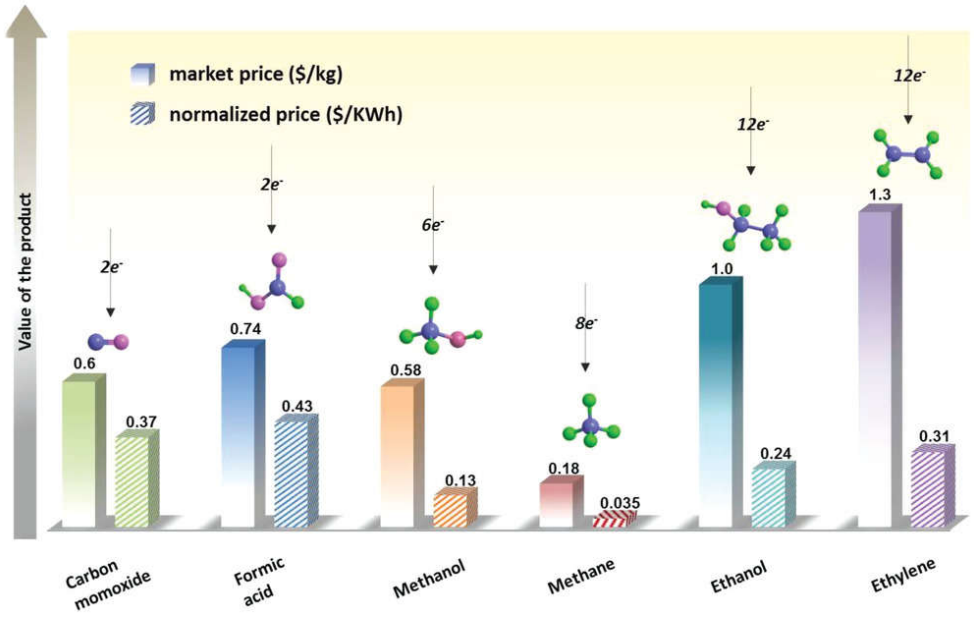


Adv. Energy Mater. 2020, 10, 1902338

$CO_2 + 2H^+ + 2e^- \rightarrow HCOOH$

Catalysts

- Sn
- In
- Bi
- Co, Pb, Pd, Tl, Hg, Cd

Effect of dopants

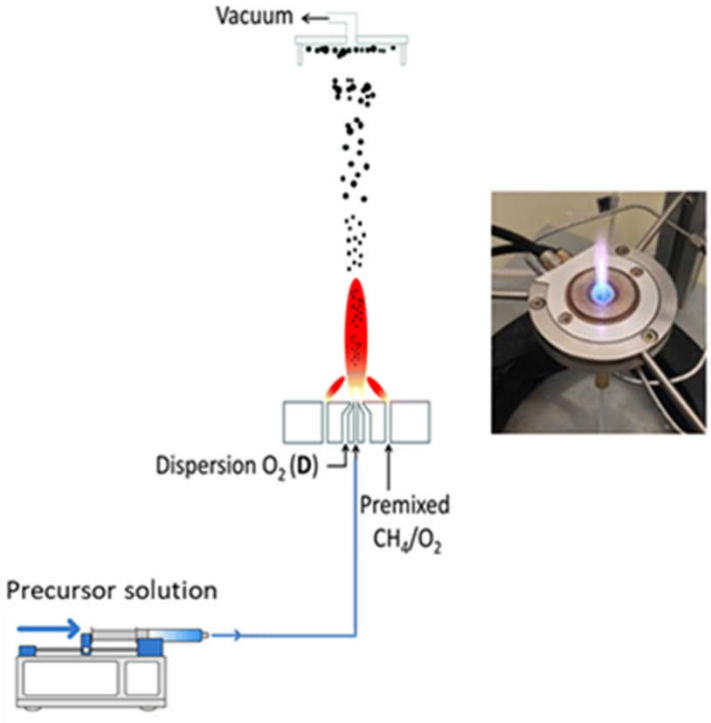
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **No 838014**".

Tim Wissink

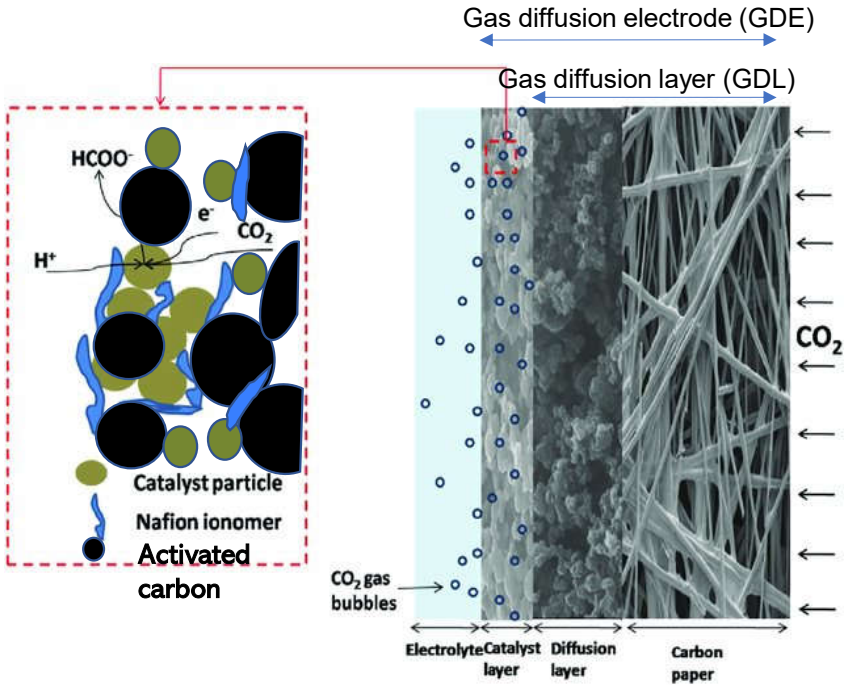
In_2O_3 doped catalysts

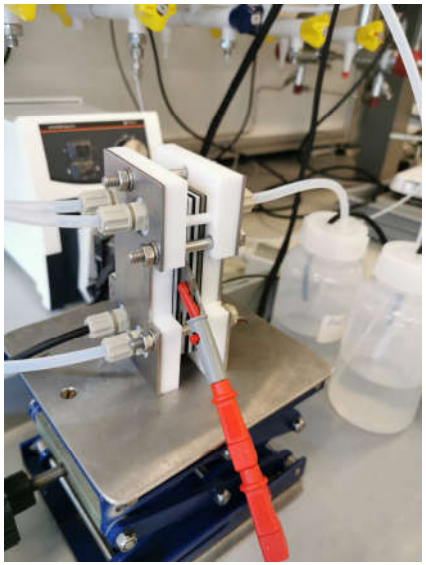
Flame spray pyrolysis (FSP)

- liquid indium nitrite precursor solution adding another metal nitrite for dopants, such as Ce, Co, Ni, Cu or Pd
- Oxygen methane flame
- After ignition the metal nitrites form droplets, combust and subsequently nucleate and condensate into metal oxide particles.
- The size and composition are tuned by the relative concentrations in the precursor and gas flow speed



CO_2 conversion to formic acid

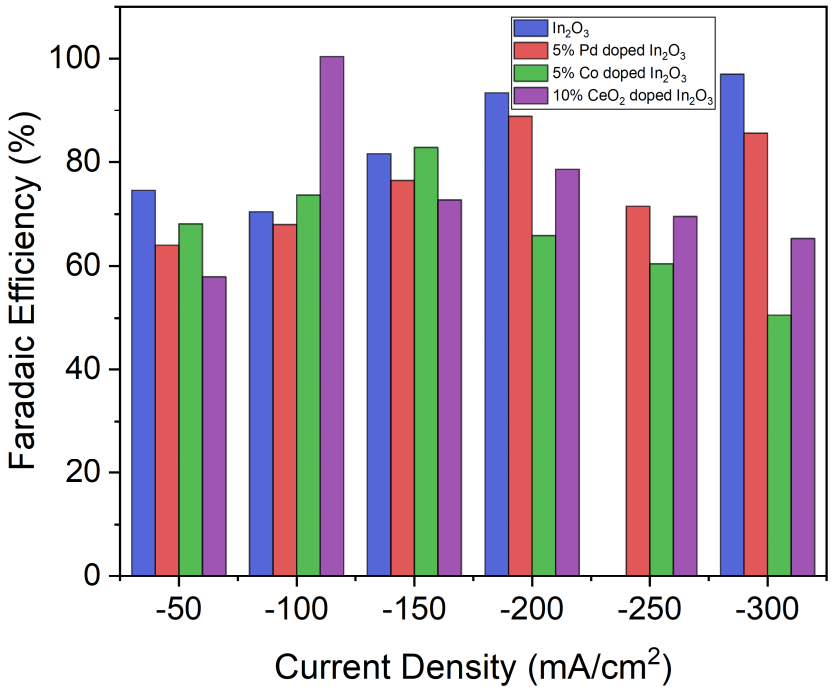




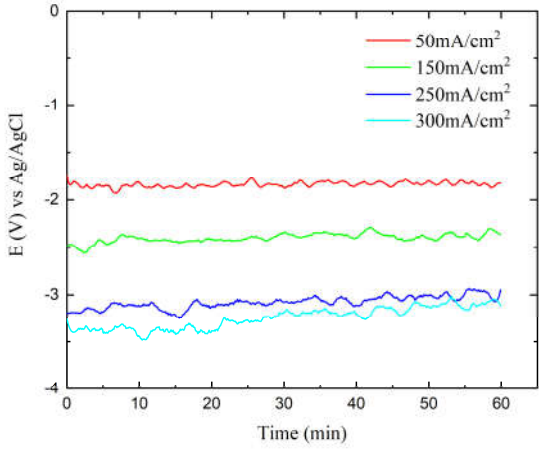
GDE loading: 5:5:3 weight ratio In_2O_3 NP's : Activated Carbon : Nafion ionomer.

In_2O_3 doped catalysts

Catholyte: 0.5M H_2CO_3 (22ml/min), CO_2 saturated (15ml/min)
Anolyte: 0.5M H_2CO_3



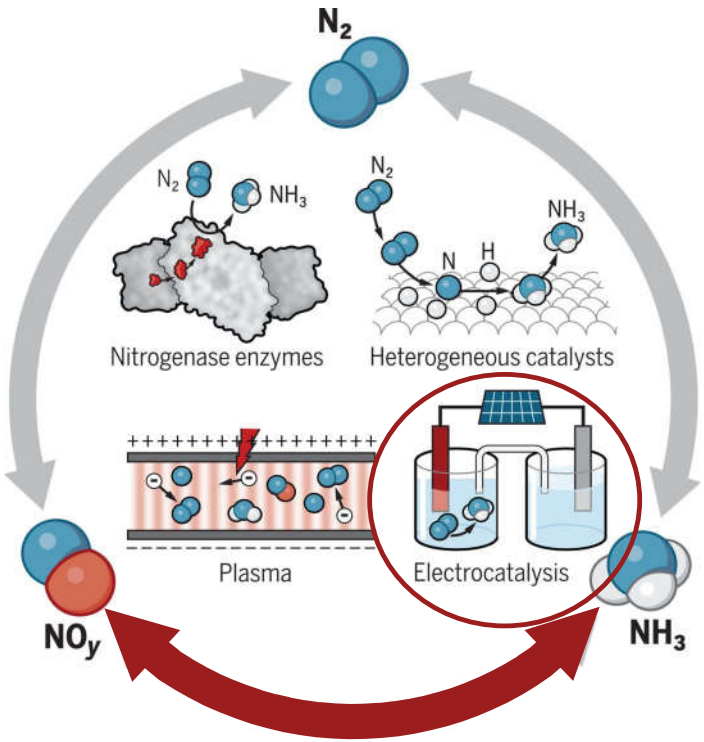
- In_2O_3 doped with Pd, Co, CeO_2
- In_2O_3 performs better at high current densities
- CeO_2 might be a good dopant for lower current densities

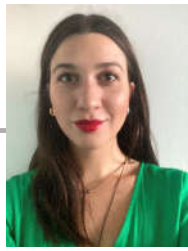


NOx electrochemical reduction

Electrochemical NOx Conversion

Ammonia





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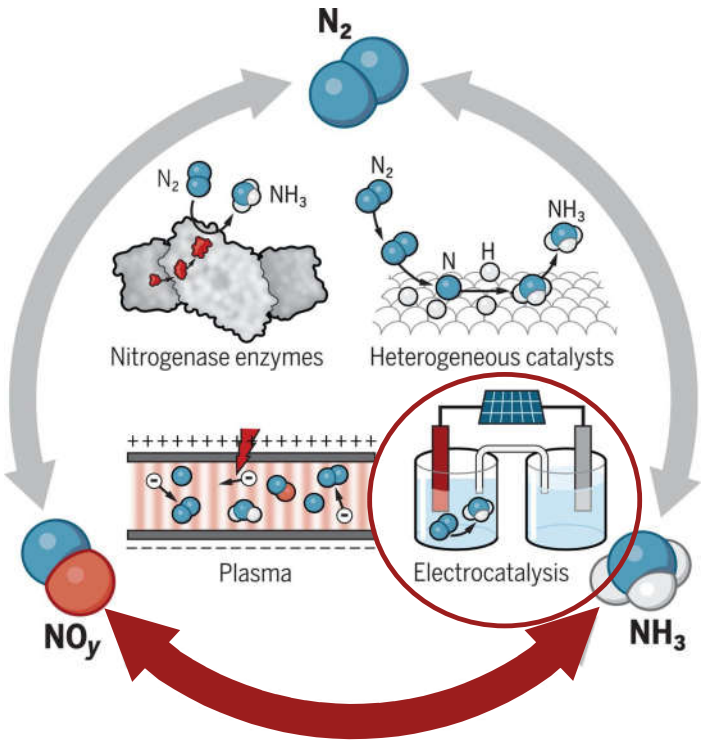
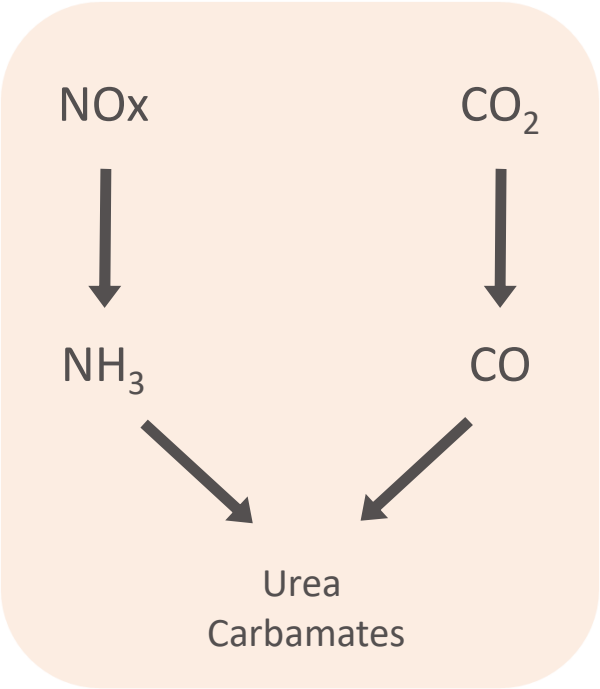
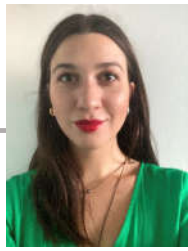
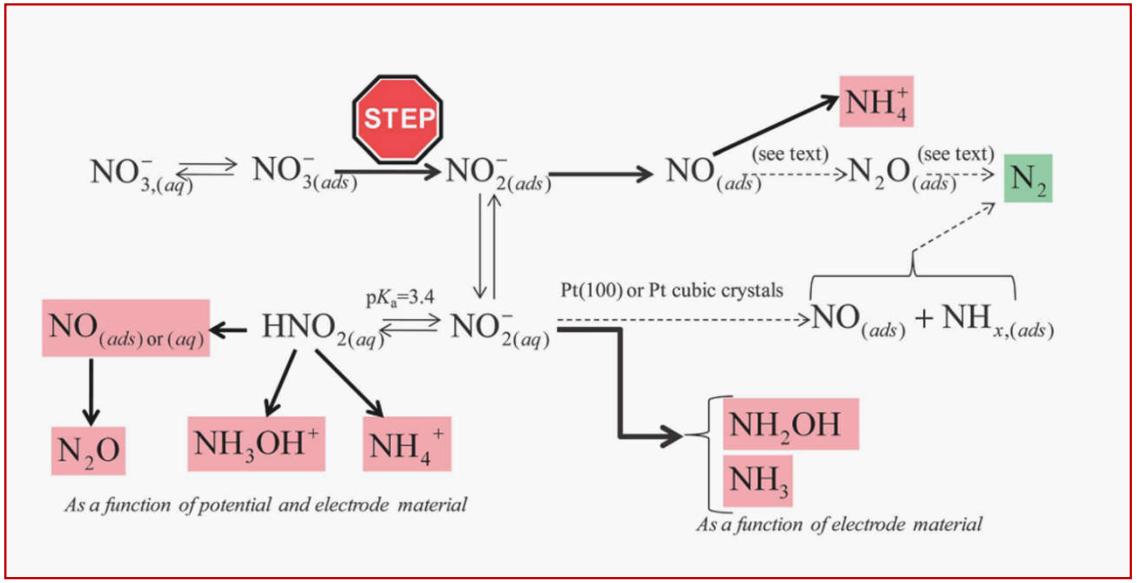


Urea



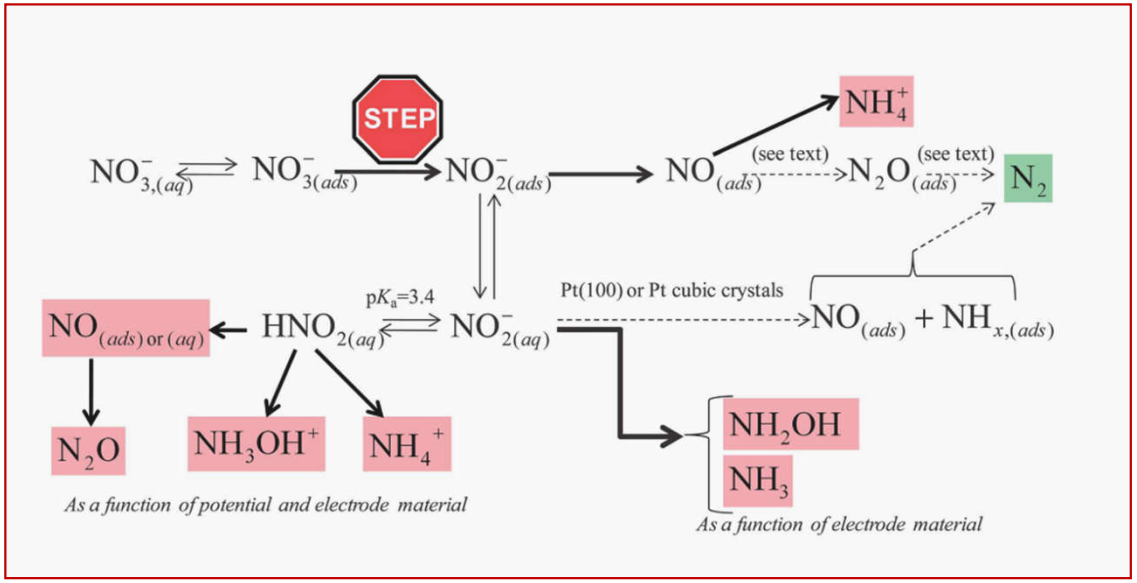


Electrochemical NO_3 reduction pathways

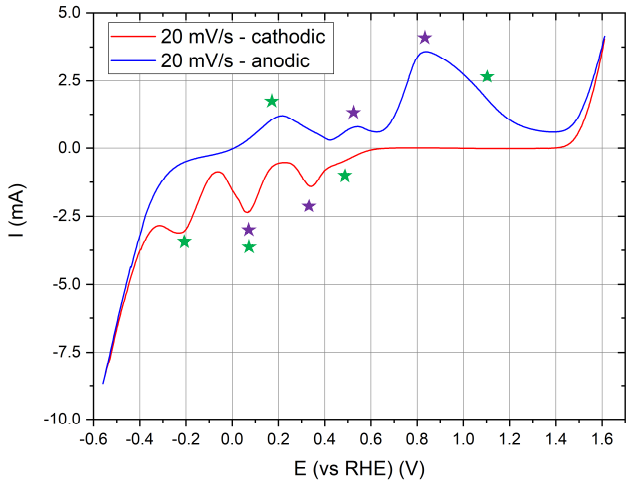


Duca et al., Energy Environ. Sci., 2012,5, 9726

Electrochemical NO_3 reduction pathways



Electrodeposition of CuRu catalysts



★ = Rh feature

★ = Cu feature

Summary

Summary

Electrocatalytic synthesis can help on storing/using the renewable energy

Technologies are still very immature

Further research and developments are required

Thank you for you attention

Prof. Emiel Hensen

Netherlands Organisation for Scientific Research

Advanced Research Center Chemical Building Blocks Consortium

CHEMICAL BUILDING BLOCKS FOR A SUSTAINABLE FUTURE

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Universiteit Leiden The Netherlands

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