TELEGRAM

Toward Efficient Electrochemical Green Ammonia Cycle

Stefania M. S. Privitera, Project Coordinator
Institute for Microelectronic and Microsystems (IMM), Consiglio Nazionale delle Ricerche (CNR), Catania, Italy

Contributors: R. G. Milazzo (IMM-CNR), **M. Leonardi,** (IMM-CNR), **G. Tranchida** (IMM-CNR), **S. Lombardo** (IMM-CNR), **I. Bayrak Pehlivan** (Uppsala University), **T. Edvinsson,** (Uppsala University), **R. Araujo** (Uppsala University), **E. Kemppainen** (HZB), **S. Calnan** (HZB)

TELEGRAM Project

Start: November 2020
Duration: 42 months

Budget: € 3.468 M

Funding

EU
European Climate, Infrastructure and Environment Executive Agency (CINEA)

Partners:

IMM Institute for Microelectronics and Microsystems
Consiglio Nazionale delle Ricerche

HZB Helmholtz Zentrum Berlin

JÜLICH FORSCHUNGSZENTRUM

Coordination

UPPSALA UNIVERSITET

Background

Ammonia is largely used as fertilizer and chemical feedstock

Industrial ammonia production, through the Haber-Bosch process, is responsible for about 1-2% of total CO_2 emissions worldwide every year.

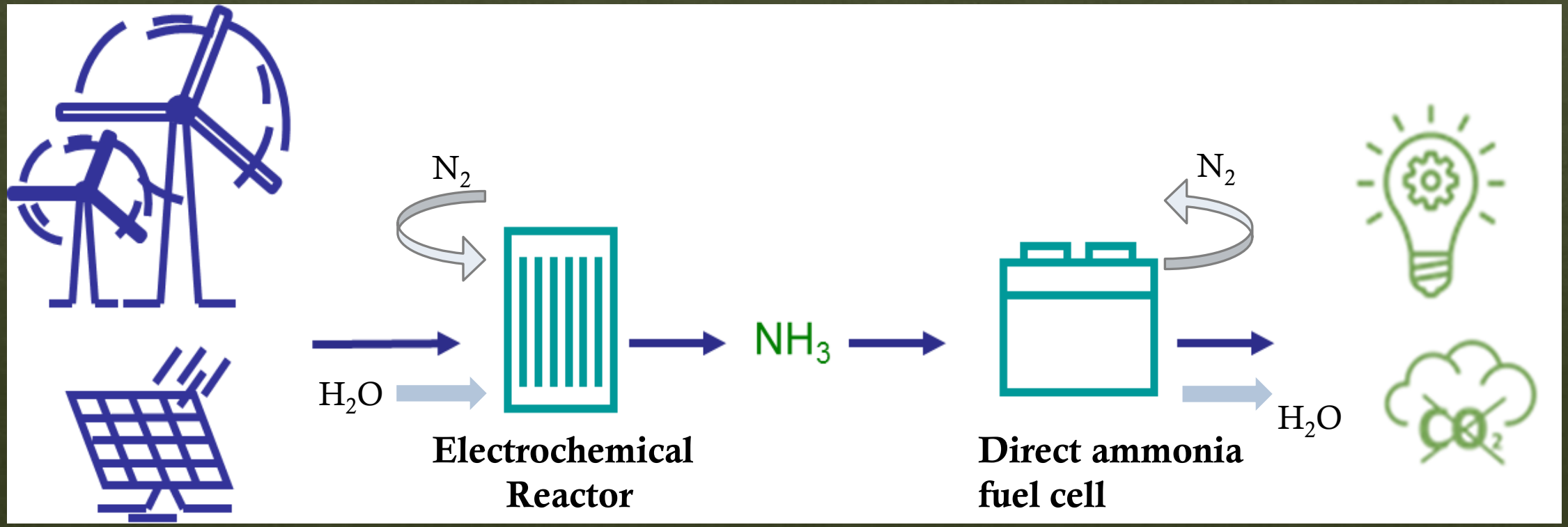
Ammonia is also potentially a formidable energy vector

- Large hydrogen content
- High volumetric energy density
- Easy of liquefaction

It can be used for energy storage to mitigate renewable sources intrinsic fluctuations

Goal

Demonstrate at the laboratory scale a complete green ammonia carbon-neutral energy cycle

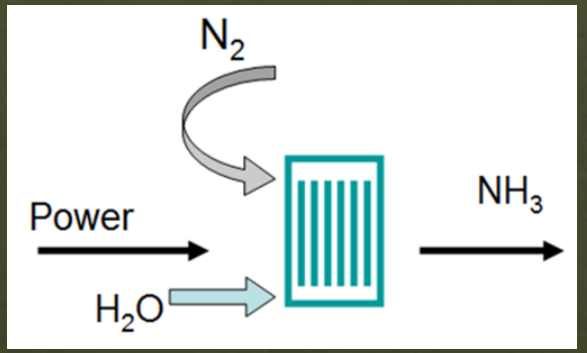


TELEGRAM Project

Development of two key enabling technologies.

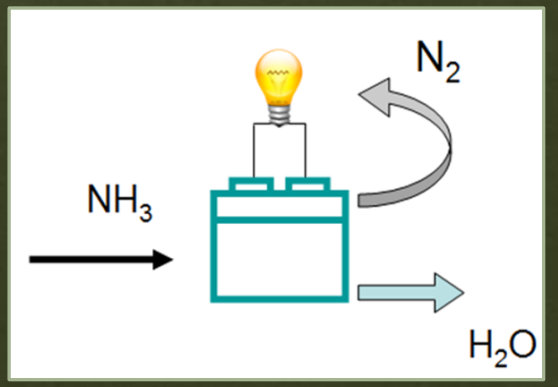
1. Electrochemical ammonia synthesis

A multi-stage membrane reactor which, starting from air and water will produce ammonia at temperature <100°C.



2. Direct Ammonia Fuel cell

A fuel cell which will produce electricity starting from ammonia



TELEGRAM Technical Challenges

Novel catalysts to be developed

Nitrogen reduction from N_2 to NH_3 is difficult
- requires dissociating the N_2 triple bond
- competes with Hydrogen evolution reaction

NRR

$$N_2 + 6H^+ + 6\ e^- \rightarrow 2NH_3$$

Low faradaic efficiency and/or low yield

Low-cost sustainable catalysts

Reduced noble metals amount and use earth abundant materials

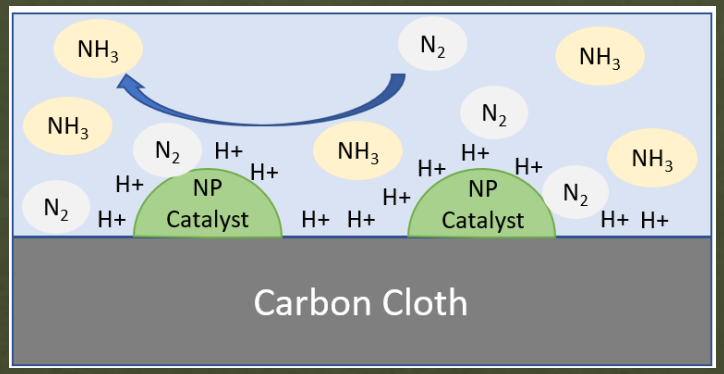
Ammonia Oxidation

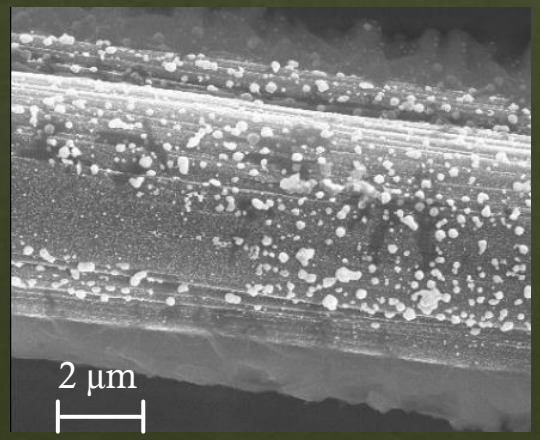
$$2NH_3 + 6OH^- \rightarrow N_2 + 6H_2O + 6\ e^-$$

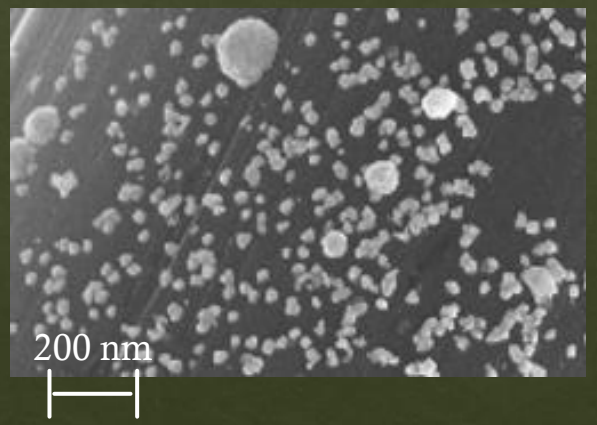
Catalyst approaches for Nitrogen Reduction

1. Nanoparticles

Au-Mo on Carbon cloth

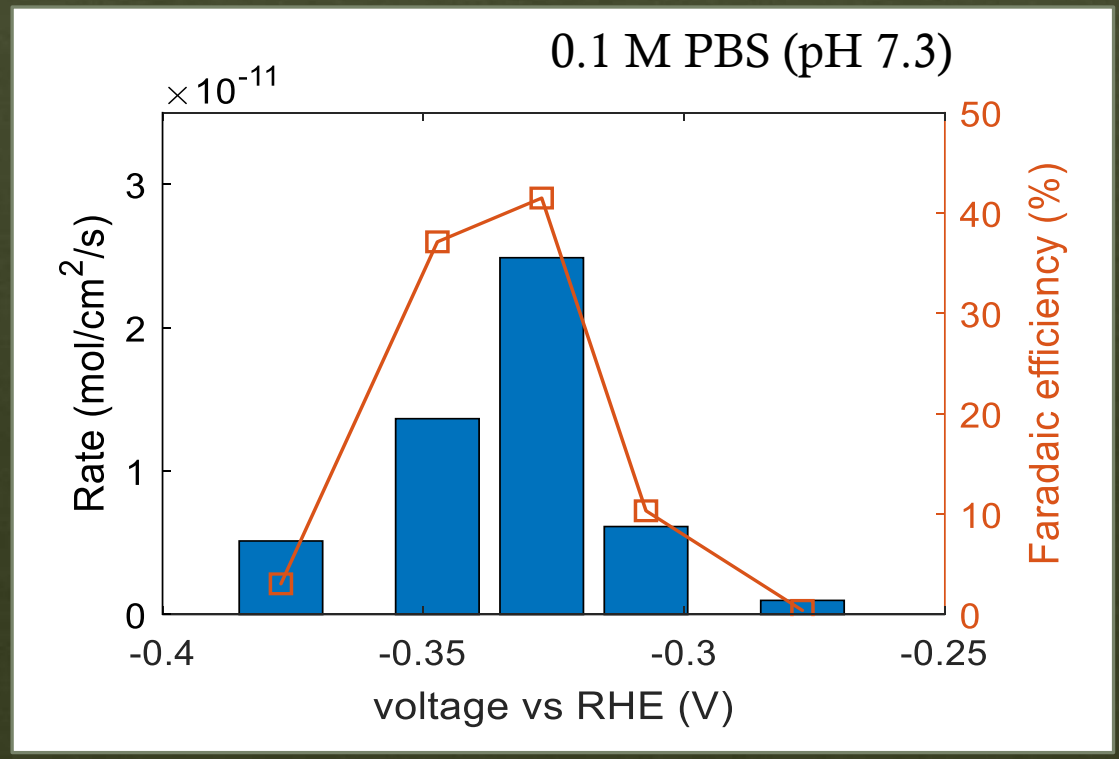






Low Au loading: < 0.01 mg/cm^2

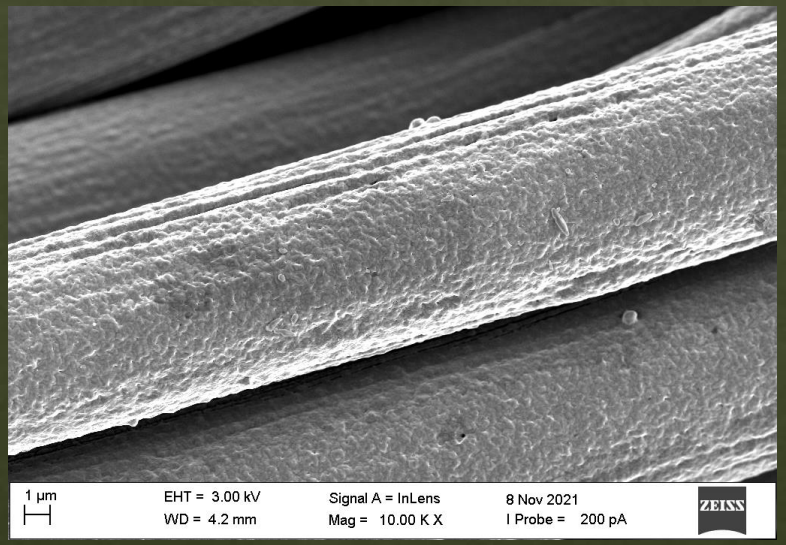
Target: 50%

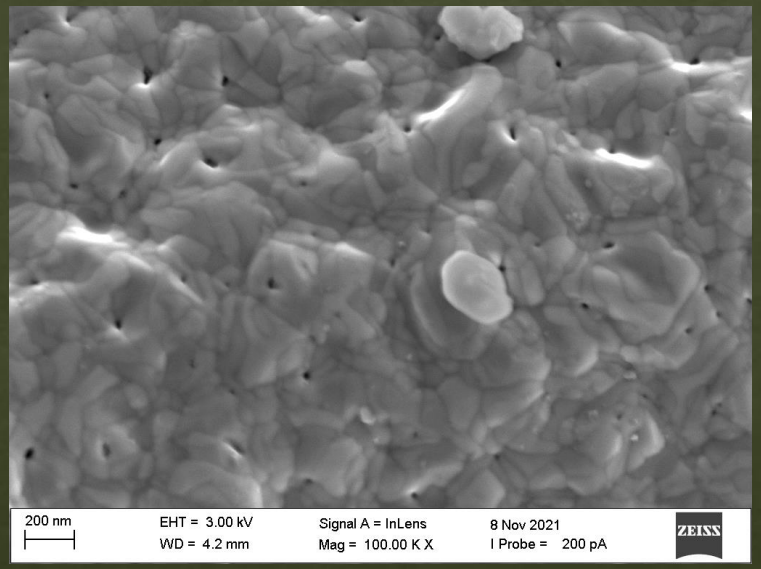


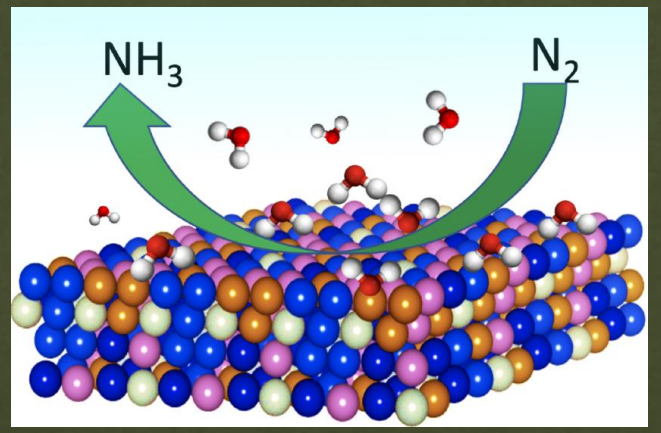
Catalyst approaches for Nitrogen Reduction

2. High entropy alloys (Uppsala University)

CoCrFeMnNi on carbon cloth







KOH concentration (M)	Ammonia rate (mol cm^{-2} s^{-1})	FE%
0.1	1.76×10^{-11}	0.2
1	6.87×10^{-11}	20
5	**1.64×10^{-10}**	**11**

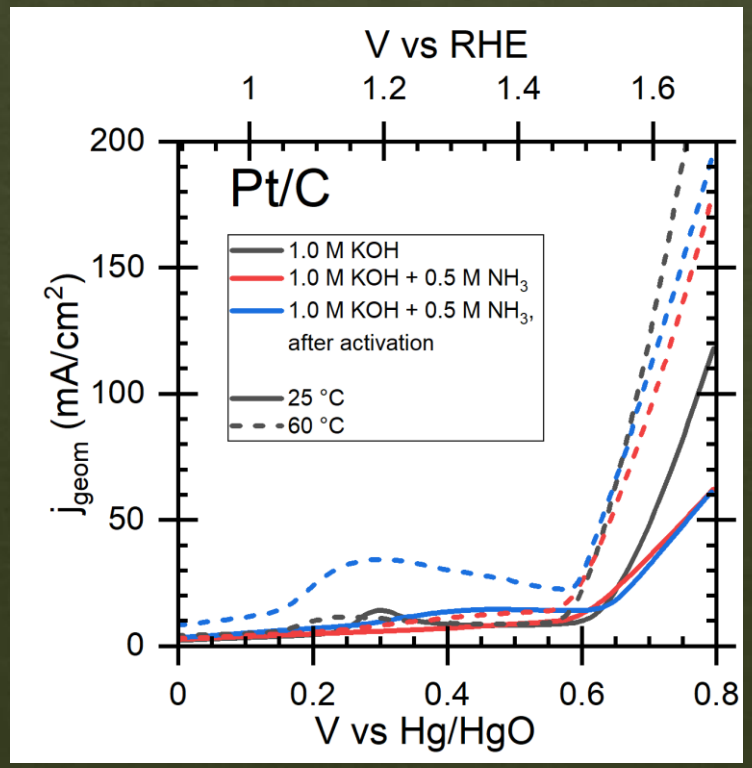
Alloy composition selected through atomistic simulations among 3000 HEAs

Presented at 5th International Conference on Applied Surface Science, 25 -28 April 2022, Palma, Mallorca, Spain, **Title:** High-entropic alloys for electrochemical ammonia synthesis in alkaline electrolytes, **Contributors:** Ilknur Bayrak Pehlivan, León Zendejas Medina, Rafael B. Araujo, and Tomas Edvinsson

Catalyst approaches for Ammonia Oxidation

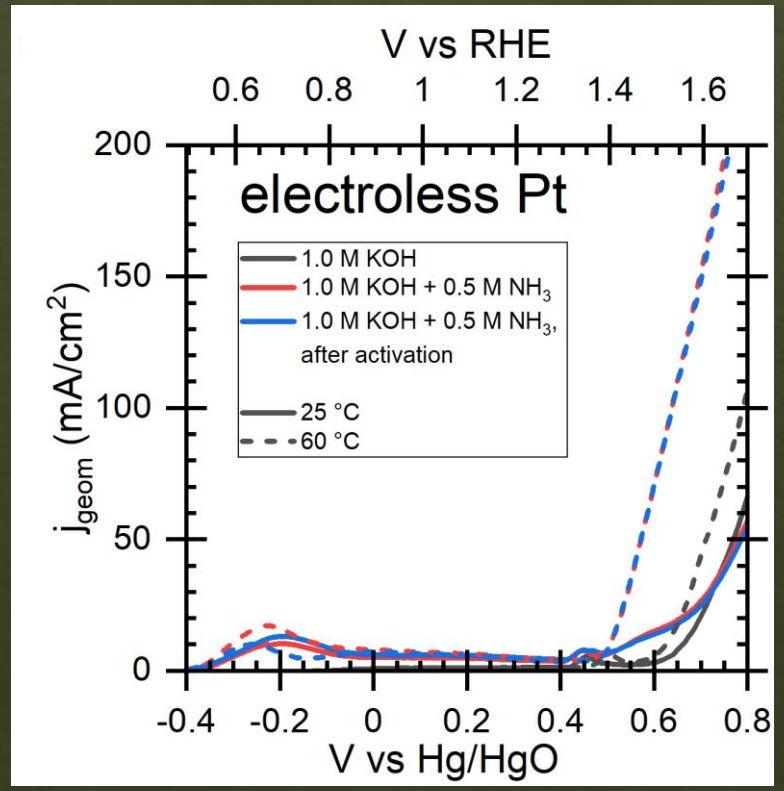
From noble metals to earth abundant catalysts (HZB)

1 mg/cm² of Pt on carbon



Onset 0.2 V

0.01 mg/cm² of Pt on Ni foam (synthesised at CNR, tested at HZB)

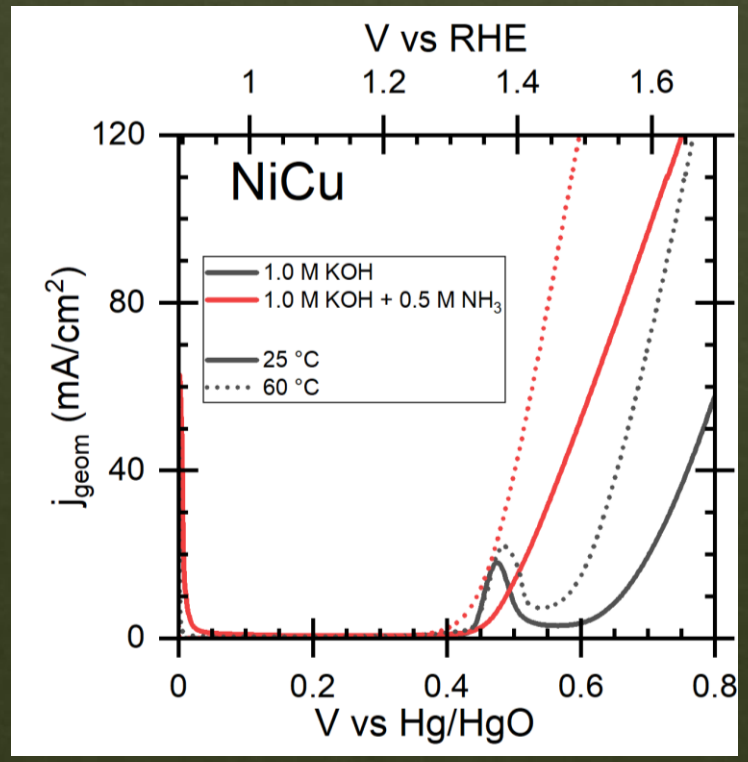


Onset 0.3 V

Catalyst approaches for Ammonia Oxidation

From noble metals to earth abundant catalysts (HZB)

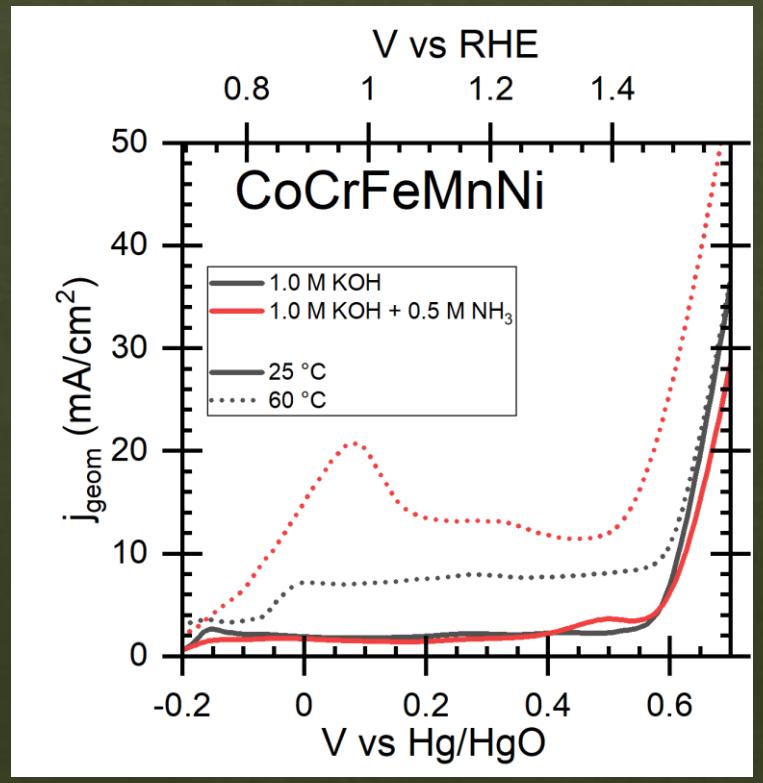
NiCu
(synthesised and tested at HZB)



Current comparable with Pt
Stability needs improvement

No noble Metals
Onset 0.4 V

High entropy alloy
(synthesised at UU, tested at HZB)



Good stability
Lower current compared with Pt

Stefania M. S. Privitera

Summary and Upcoming activities

- Development of novel catalyst is a crucial issue for the development of a green ammonia cycle
- Catalysts developed in TELEGRAM are promising but needs optimization
- A trade-off has to be found between reduced amount of noble metals and performance
- Testing of developed catalysts in the prototype devices is ongoing. The reactor will be powered by renewable energy sources and will be coupled to the fuel cell to demonstrate the complete ammonia energy cycle

Thank You !

For more information and news please visit our website:

https://www.telegram-project.eu/

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101006941. The project started on the 1st of November 2020 with a duration of 42 months.