Department of Chemistry & Chemical Biology
Waksman Institute of Microbiology

Charles Dismukes
Chemical & Biochemical Catalysis
2024-2025

Mahak Dhiman
Postdoc

Hengfei Gu
Postdoc

Henry Jin
PhD Candidate

Yifei Li
PhD Candidate

Shubham Gupta
PhD Candidate

Chris Turner
PhD Candidate

Former PhD and Postdoc Alumni

Shinjae Hwang
Applied Materials
Semi-conductor Industry

Karin Calvinho
CTO RenewCO$_2$

Anders Laursen
CEO RenewCO$_2$

Apostolos Zournas
LBNL Postdoc
Biocatalysis

Recent Collaborators

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Todd Deutsch
Yingying Chen
Ashlee Vise
Kai Zhu

Boulder

Charles Musgrave
Aziz Alherz
Aaron Holder
Zack Bare

PENN

Andrew Rappe
Rob Wexler
Tian Qui

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

MENTORING IMPRESSIONABLE MINDS

Rutgers Undergraduate trainees (next steps after RU)

Alexander Kim

Sofia (Max) Dvinskikh
Yale

Ajay Kashi
Opus12

Edward Izett
Opus12

Kyra Yap
Stanford

Sunjay Melkote
Stanford National Lab

Devan Solanki
Yale

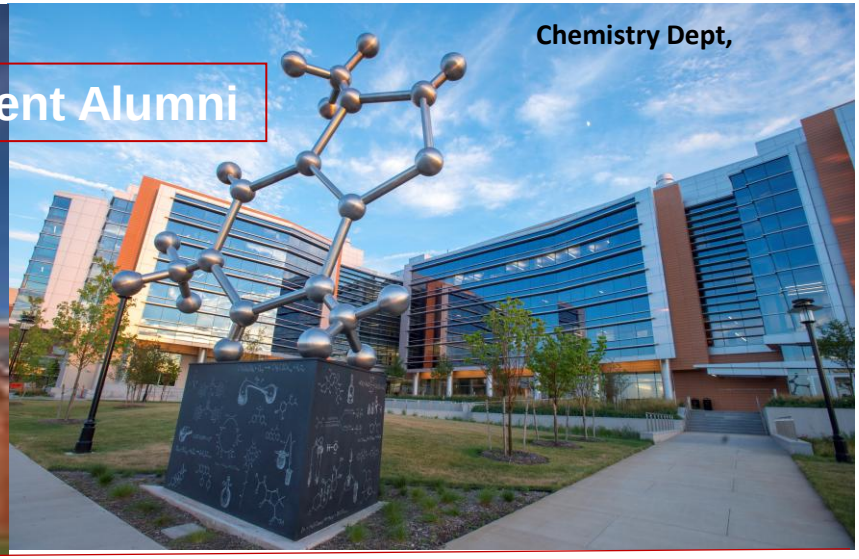
Lauren Ostopowickz
Arizona State

Anika Jalil
UC Santa Barbara

Tim Goetjen
Northwestern

Jonah Williams
McDermott

Jack Weber
Columbia



McKinsey &

LSU faculty

Loyola faculty

S.V. Start up

ABT Analytics

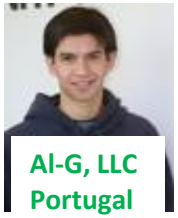
JBI-LBNL

RenewCO2 startup

RenewCO2 startup

Semiconductor Industry

Princeton U. Postdoc



Al-G, LLC Portugal

Petrochem Industry

Semiconductor Industry

RU Startup

Faculty Valparaiso Univ

Opus 12 Start up

Our Recent Funding Agencies

Lubrizol

DOE-BES
DOE-EERE
DOE-AMO

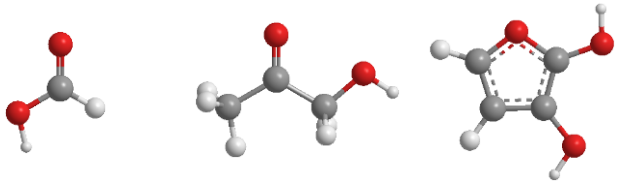
NSF-STTR

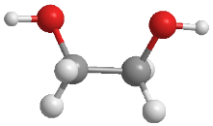
Energy for an overcrowded planet

Department of Chemistry & Chem Biology

Electro-Catalysts for Water Oxidation
-H^+ & e^- from water

Carbon-Negative Synthesis from Scratch Electro-Catalysts for CO_2 Conversion

-2018 

-2023 

-2024 C-negative polymers from CO_2

Food for an overcrowded planet

Waksman Institute of Microbiology

Improving Photosynthesis in Vivo:
-Eliminating flux chokepoints

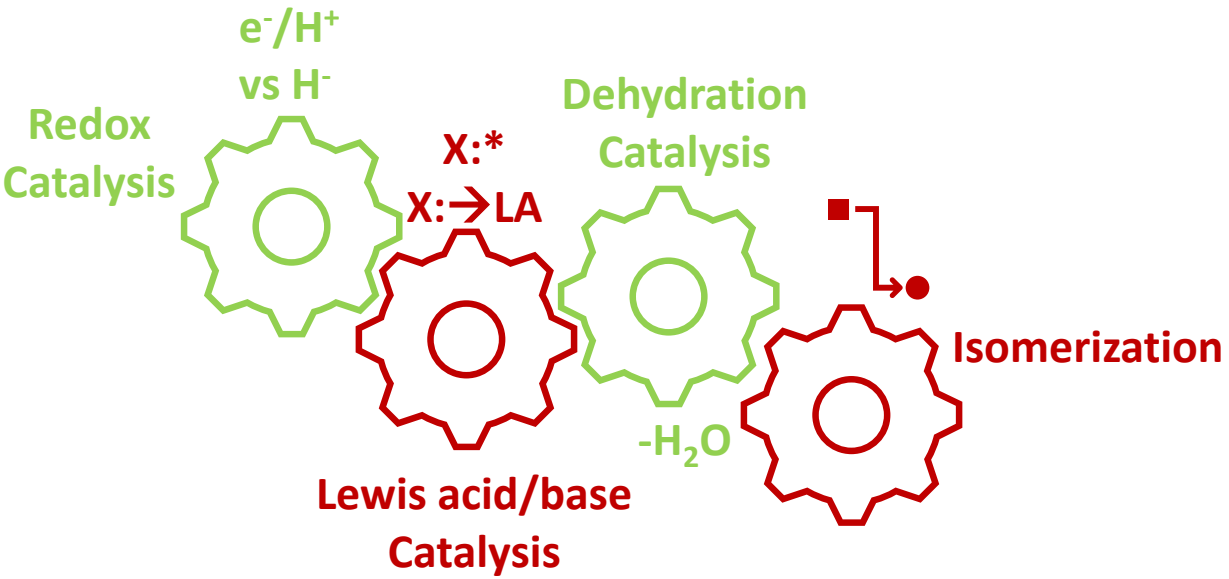
Chokepoints in CO_2 Carboxylation:
-RuBisCO/ Calvin-Benson Cycle

Catalysis by Photosynthetic Enzymes:
-Photosystem II/Water Oxidation

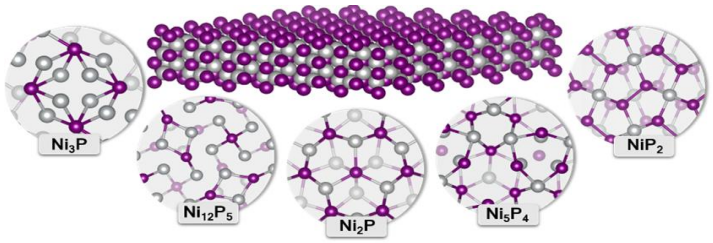
Rutgers Startup
from 5 RU patents

RENEW CO_2

Achieving Product Selectivity in Multi-electron Redox Catalysis Requires Activating Different Types of Chemical Reactions in Sequence

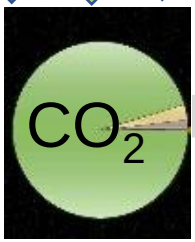


Carbon Negative Chemicals & Fuels from Scratch



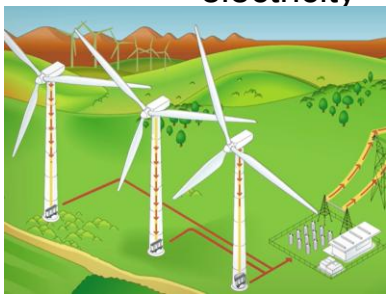
Rutgers CO_2-Negative Electrocatalysts

Fossil
Biomass
DAC



water

electricity



Transition Metal Phosphides

Electrolyzer #1

co-catalyst

Ni_xP_y

Ni_xP_y + LA

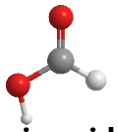
TMP-2

Ni_xP_y facet

Ni_xP_y + heat

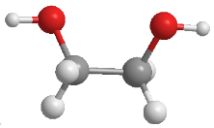
TMP-1

C1



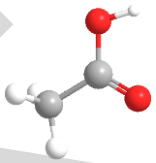
Formic acid

C2



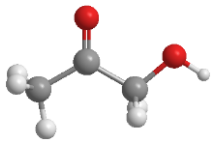
Ethylene glycol

Ethylene oxide



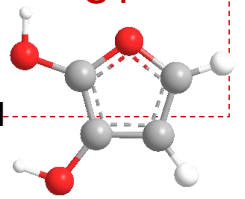
Acetic acid

C3

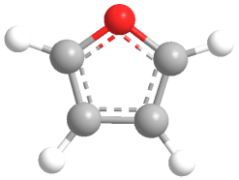


Methylglyoxal

C4



Furandiol

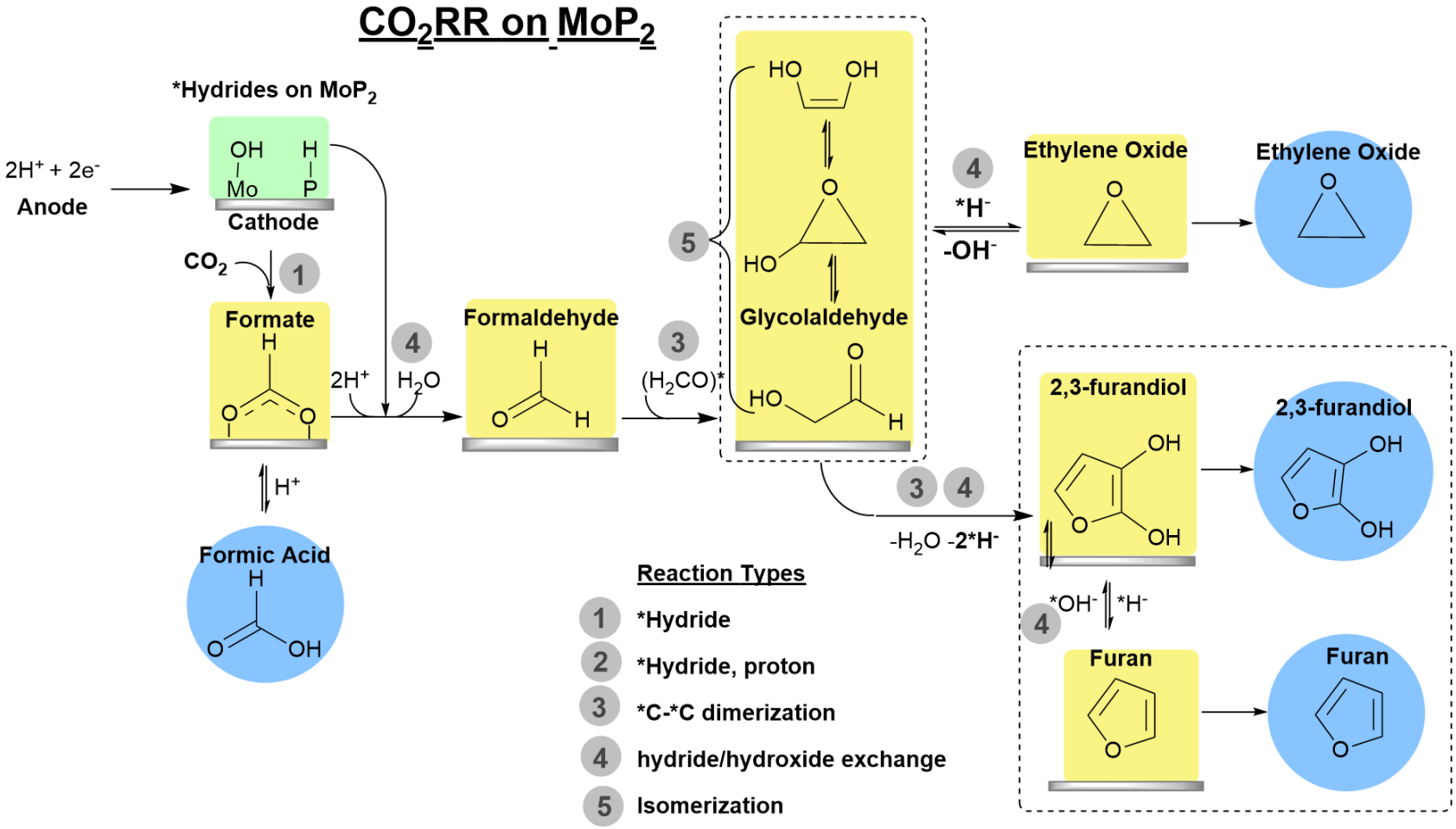


Furan

Future Targets

- -ethanol
- -propanol
- -C_4 butanol
- -C_6 & diesel

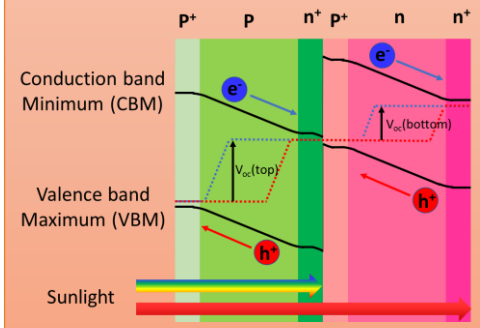
Carbon-Negative Synthesis of Ethylene Oxide from Scratch: Monomer Precursor to Polyethylene Plastic



NREL-Rutgers Collaborations on Photoelectrochemical Cells for Splitting Water

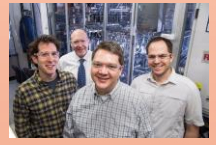
Platinum group metal-free (PGM-free) integrated tandem junction photoelectrochemical (PEC) water splitting devices

High performance solar cells

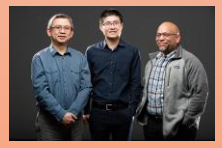


Choices:

1. $GaInP_2$/GaAs III-V tandem
2. Hybrid organic-inorganic perovskite (HOIP)/Si tandem



Dr.Todd Deutsch's team



Dr. Kai Zhu's team

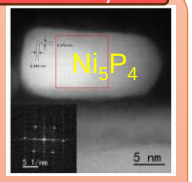
Interfacial connection layers

- Anti-corrosion protection layer: Titanium dioxide (TiO_2)
- Diffusion barrier: Titanium nitride (TiN)

▪ Pulsed laser deposition
▪ Thermal evaporation of Ti in O_2 or N_2

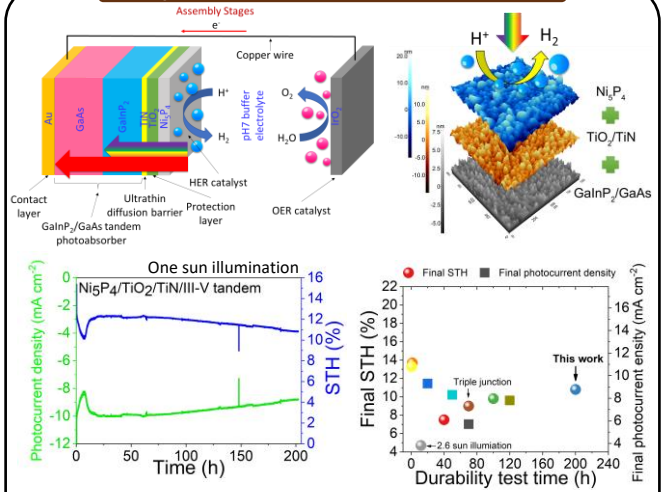
Hydrogen evolution catalysts

- Catalysts : Ni_5P_4 or Ni_3P



▪ Phosphidation
▪ Electrodeposition of Ni-P

$Ni_5P_4/TiO_2/TiN/III$-V tandem photocathode

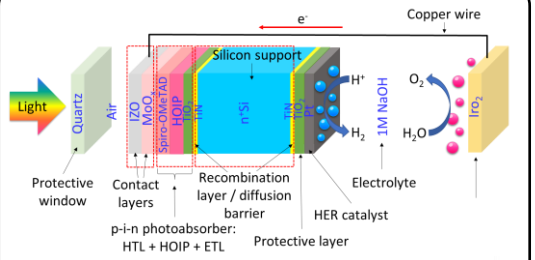


- Initial solar to hydrogen (STH) efficiency in pH 7 sodium phosphate electrolyte: 11.4%–13.2%
- Durability: Over 200 h without failure above 10% STH efficiency, exceeding all previous benchmarks

ACS Energy Letters 9(3), 789-797 (2024)

https://doi.org/10.1021/acsenergylett.3c02606

HOIP/n^+Si/Pt single junction photocathode

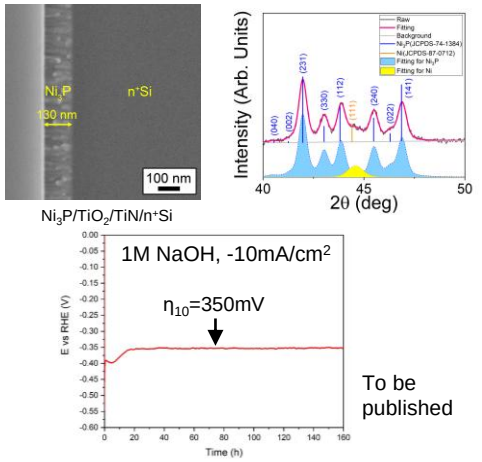


- Achieved a high photocurrent density of −15.9 mA cm−2 (at 0 V vs reversible hydrogen electrode) in 1 M NaOH

Adv. Funct. Mater. 33(25), 2301196 (2023)

https://doi.org/10.1002/adfm.202301196

Electrodeposition-assisted synthesis of Ni_3P film

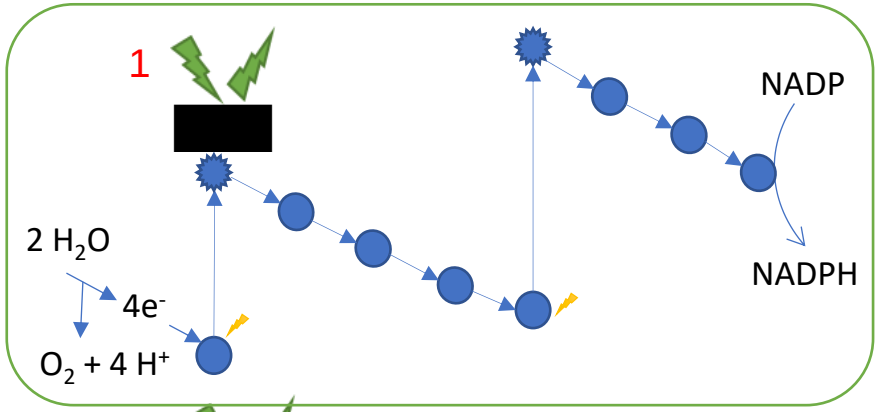


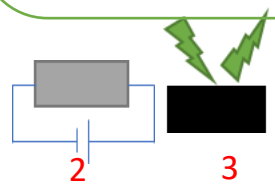
To be published

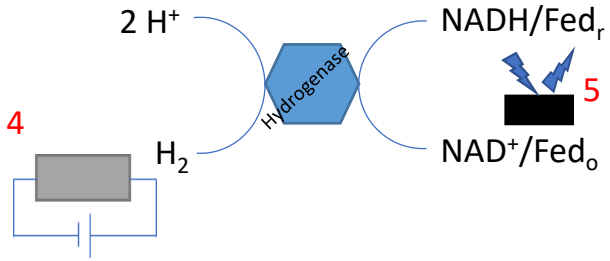
- Operated continuously for over 160 h at -10 mA/cm² for the hydrogen evolution reaction without any degradation
- Can be synthesized in a large scale

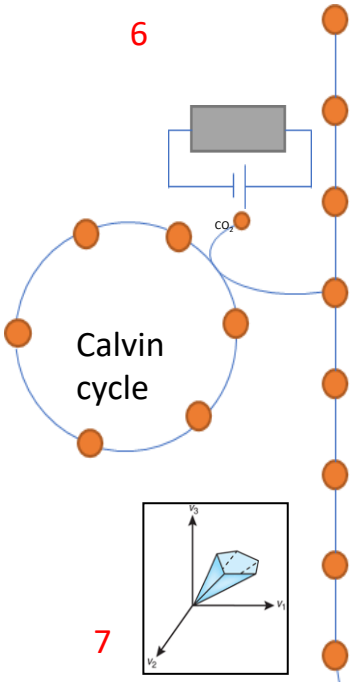
Rutgers team:
Eric Garfunkel
Charles Dismukes
Martha Greenblatt
Anders Laursen
Shinjae Huang
Hengfei Gu
Spencer Porter

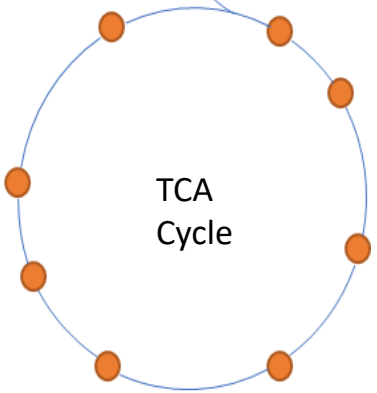
Dismukes Waksman lab analytical toolbox

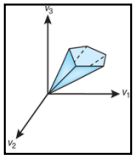






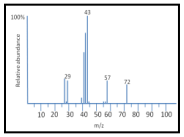




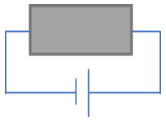


Computational Techniques

Fluorometry



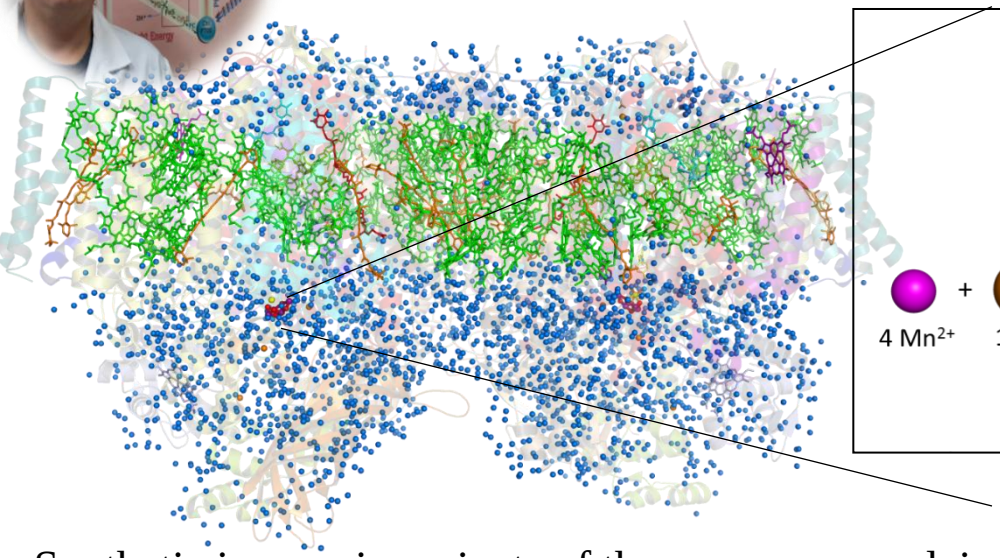
Mass Spectrometry

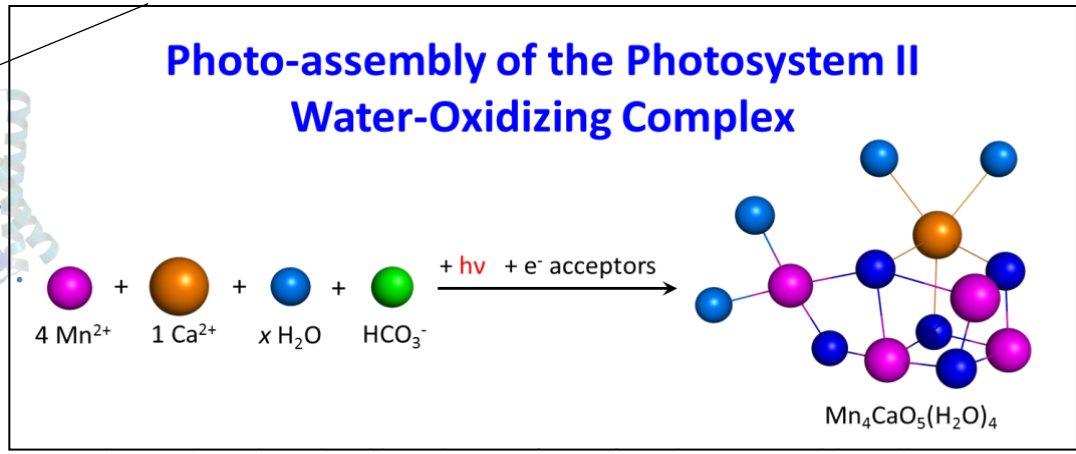


Electro-chemistry

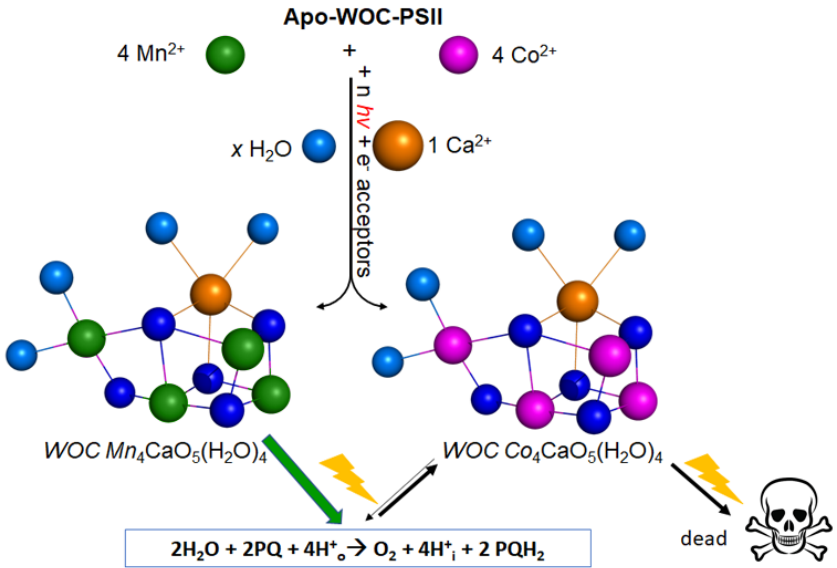
Powerful tools developed in our laboratory offer unique insights into biology

Inorganic Mutants of Photosynthetic Water Oxidases



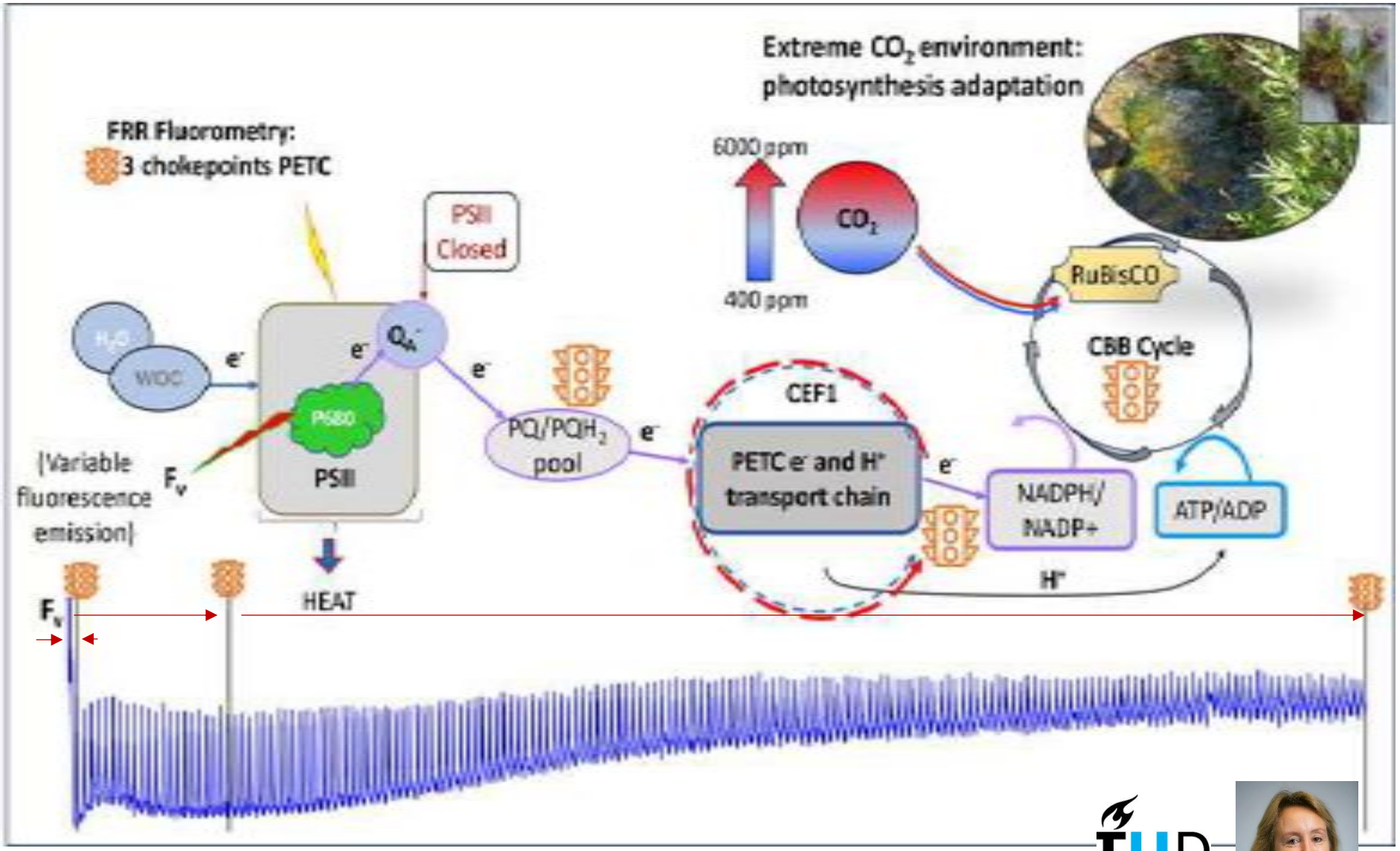


Synthetic inorganic variants of the manganese-calcium cofactor of the water oxidation complex (WOC) of PSII have revealed the intrinsic trade-offs between increasing the thermodynamic driving force for water oxidation, photodamage to the reaction center, and photoprotection by acceleration of charge recombination.



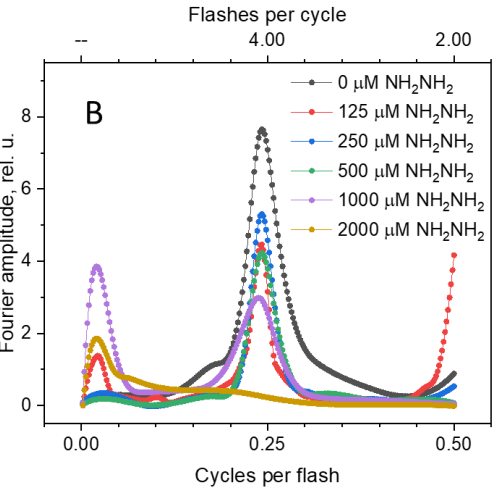
Collaborator:
Prof Petra Fromme &
research group

Observing & Eliminating Bottlenecks in the PET Chain to Improve Photosynthesis

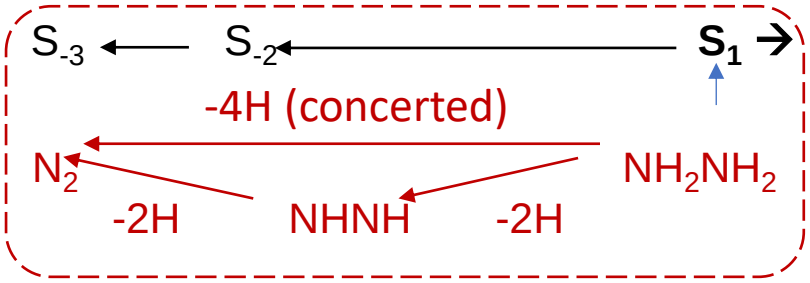


ten Veldhuis, M.-C., G. Ananyev and G.C. Dismukes, 2024. **in review**

Adding a Co-Catalyst to PSIIX Converts the 4 Flash Photocycle to a 2 Flash Photocycle



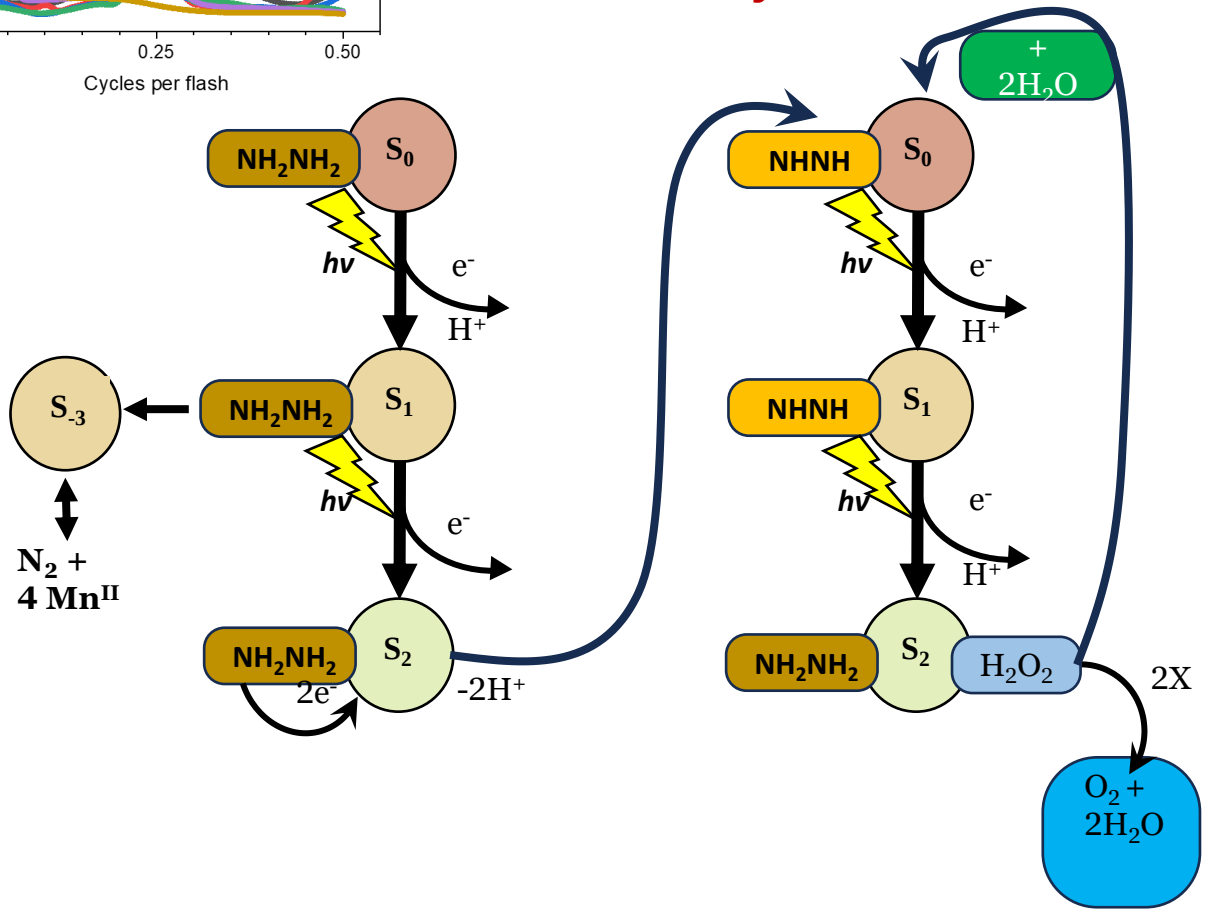
Reduced states



Joliot-Kok Cycle

$S_2 \rightarrow S_3 \rightarrow S_4 \rightarrow O_2$

Reactions of Hydrazine with PSIIX



Collaborator:
Prof Petra Fromme &
research group