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PECSYS

5th November 2020

An introduction

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Institute of Chemical Research
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nº 732840

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Artificial photosynthesis

Storage →

FUELS

Highest energy density
Easy to transport
Most industries depend on fossil fuels → Renewable

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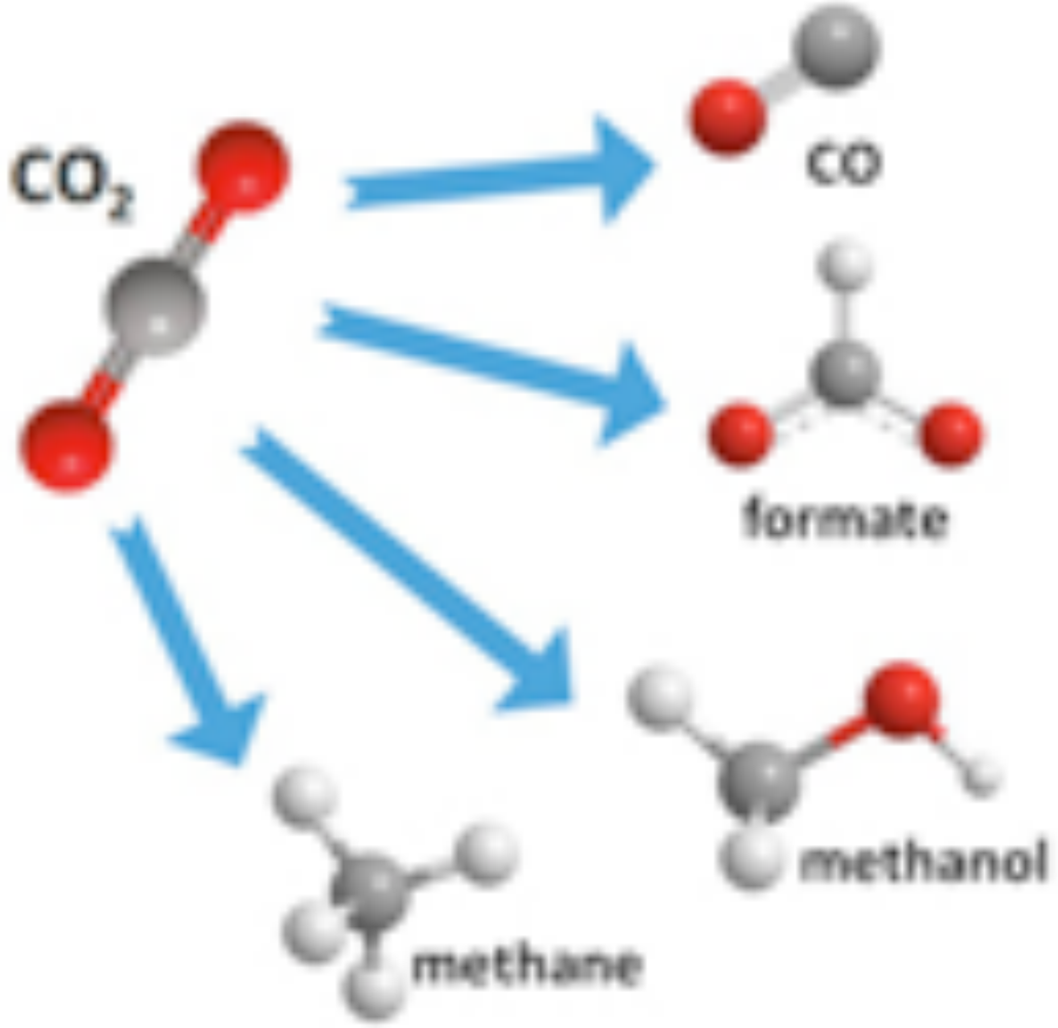
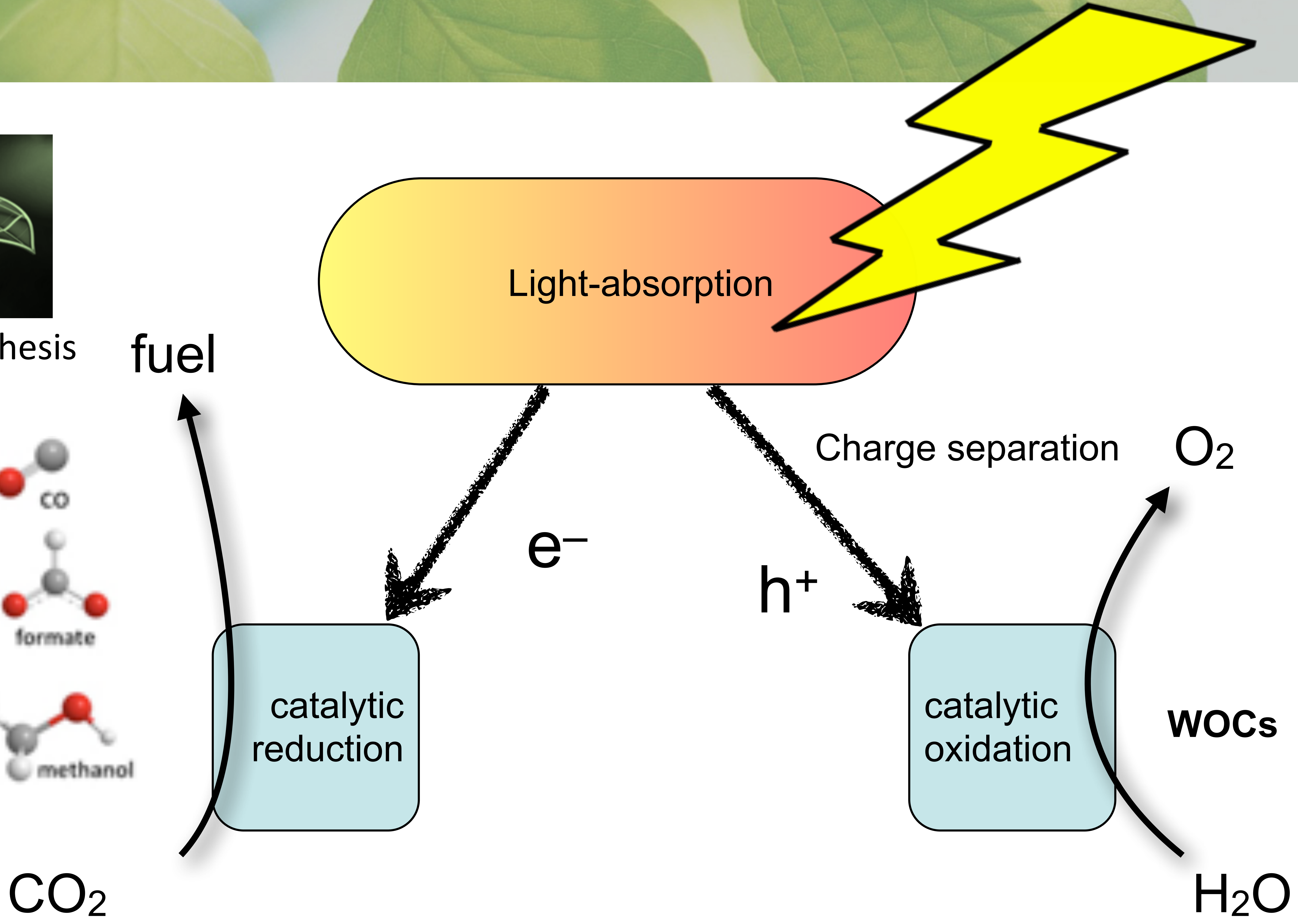
Advantages of fuels

- High energy density
- Easy to transport
- Completely stable
- Reliable, easy set-up

	MJ/L	MJ/Kg
Uranium	$>10^9$	$>10^8$
Gasoline	34	46
Coal	≈38	≈30
Methane (liquified)	22	55
Wood	≈13	≈16
H_2 (700 bar)	9	142
Li battery	<2.6	<0.9
Alkaline	<1.3	<0.6
Lead_acid battery	0.56	0.17

Artificial photosynthesis





$E\ (V) = 1.23 - 0.059\ pH$

THE ADVERSARY

Fossil fuels (again)

Massive production scale! (5000 m^3 methane / hour)🤪

- Minimum price! 1-3$/Kg (500 L)🤐
- Well-established and reliable industry
- Profitable industry

$60.91/barrel of oil (by March 14th 2018))

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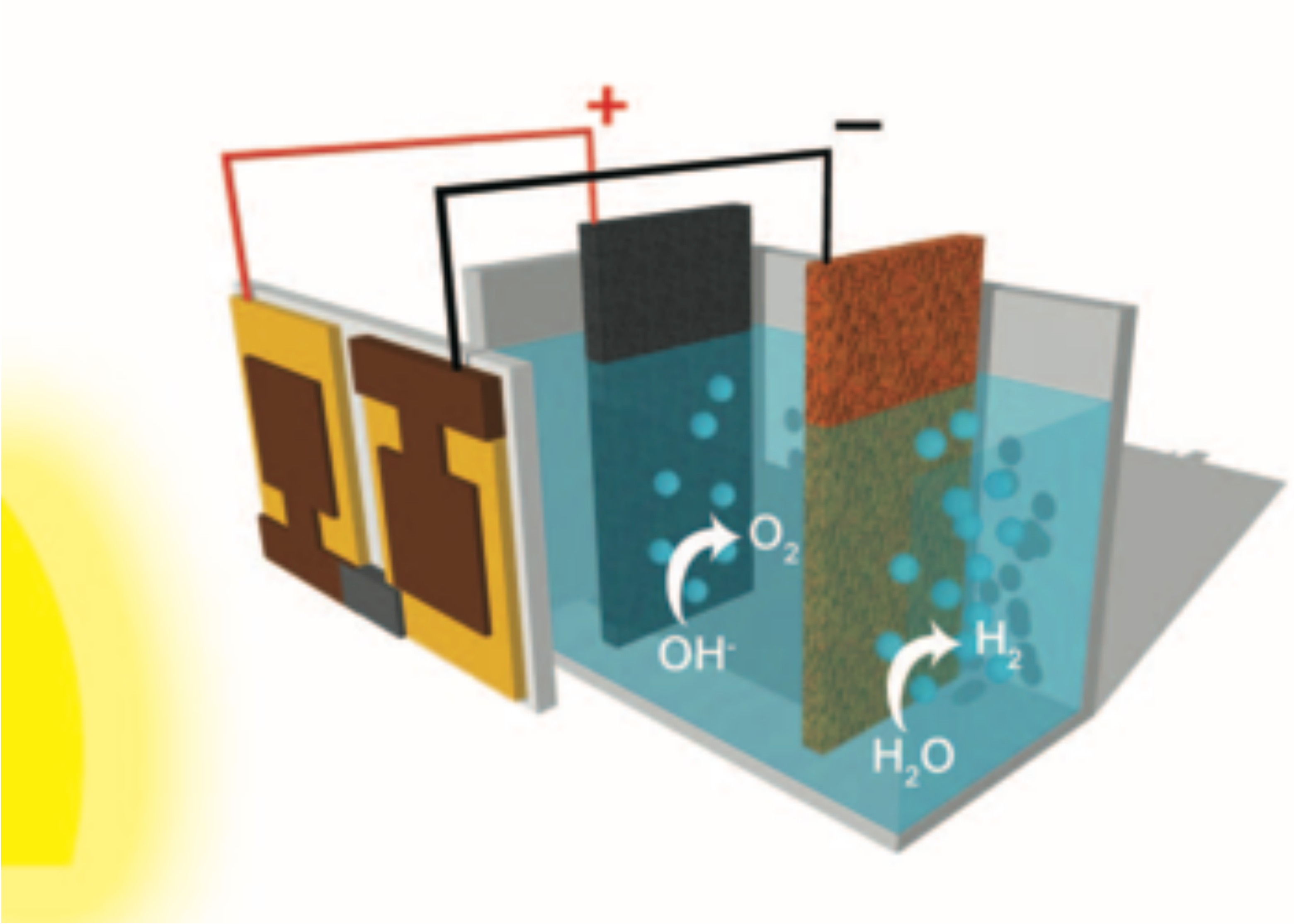
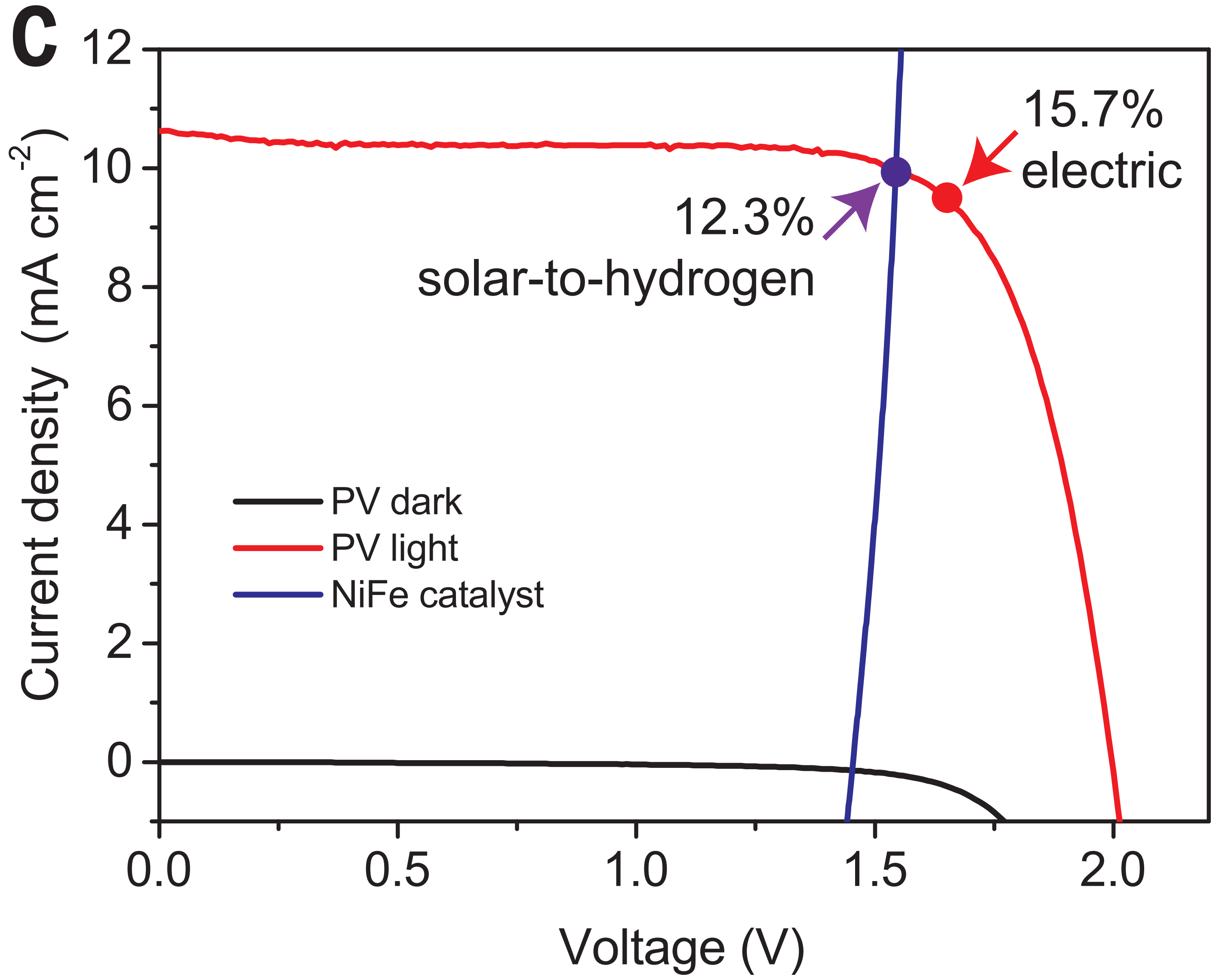
Artificial photosynthesis (1)

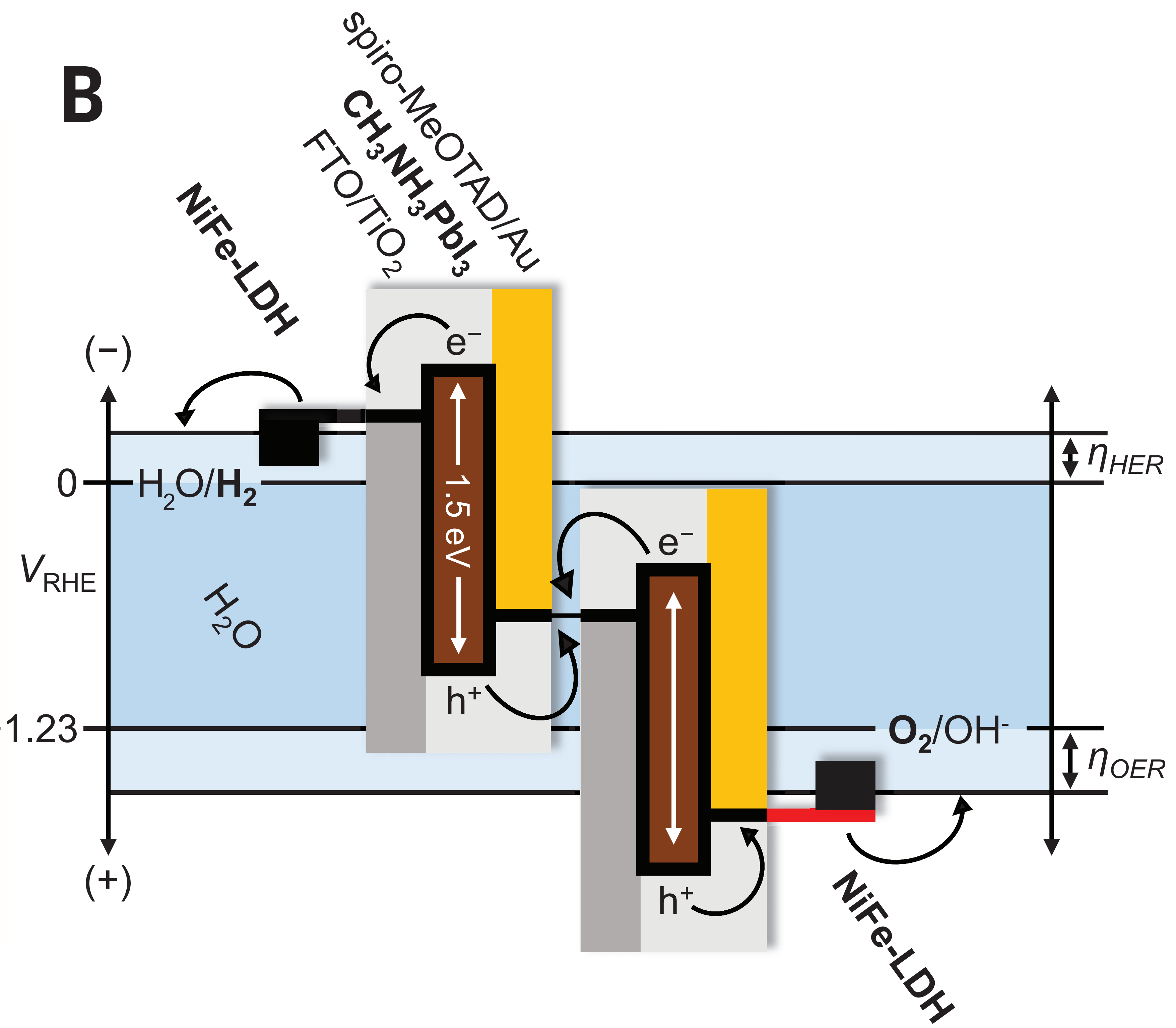
A



C



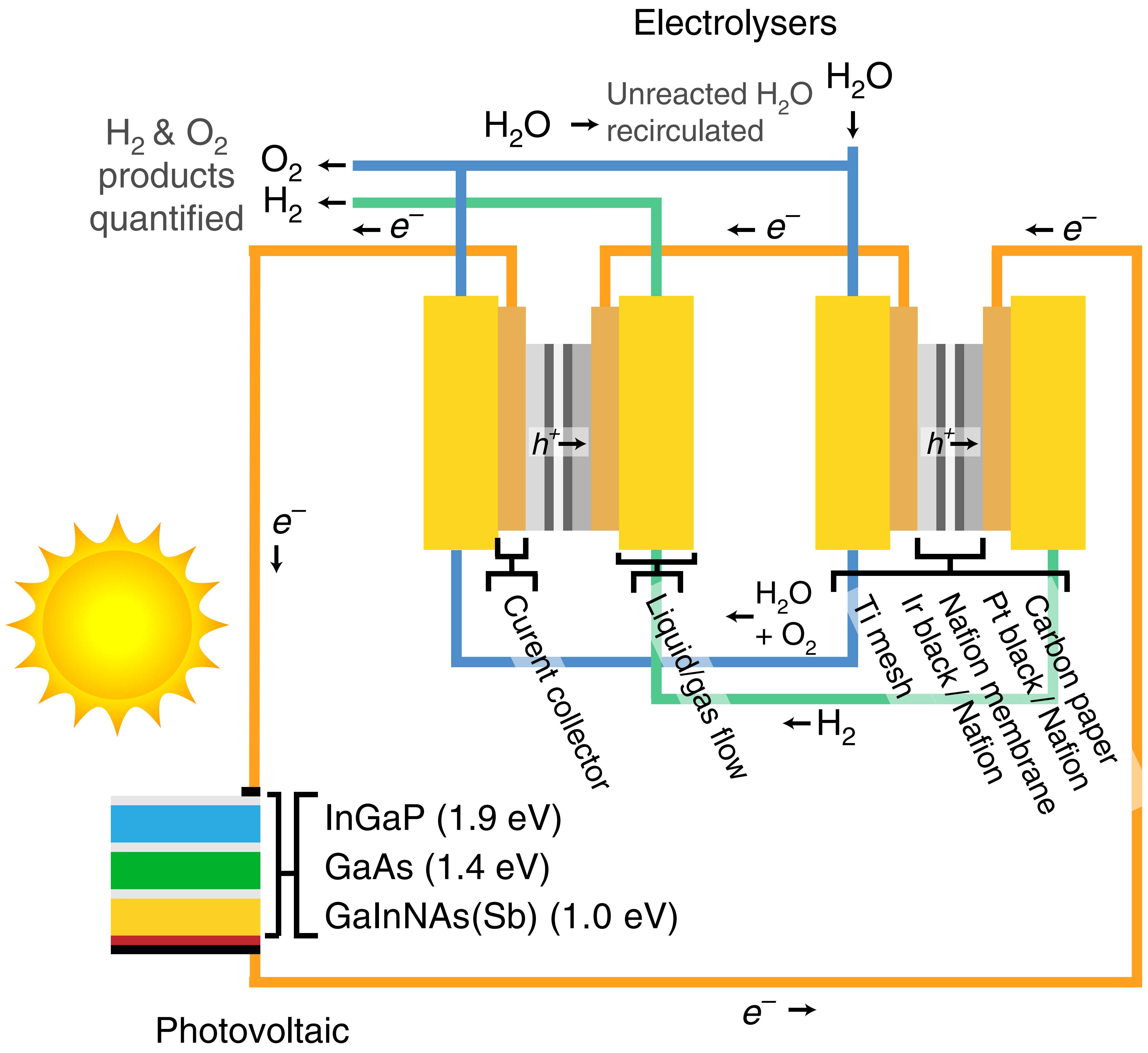
B



area. The overall decrease in current on longer time scales is mainly due to the instability of the perovskite solar cell, a challenge that could be addressed by proper passivation and encapsulation techniques. A second representative device,

Grätzel, M. *et al. Science* **2014**, *345*, 1593.

Artificial photosynthesis (2)



This is the highest STH efficiency reported to date and the first solar water splitting system that demonstrates a STH efficiency reaching 30% or higher.

STH efficiency through the 48 h experiment. The operating current decreased by only 10% over this period

Jaramillo, T. F. *et al. Nat. Commun.* **2016**, *7*, 13237.

Artificial photosynthesis (technological requirements)

- Efficient
- Fast
- Robust (10 years)
- Abundant materials
- Scalable processes
- **Economically profitable (?)**

The objective

Use-inspired
Basic research
UNDERSTANDING

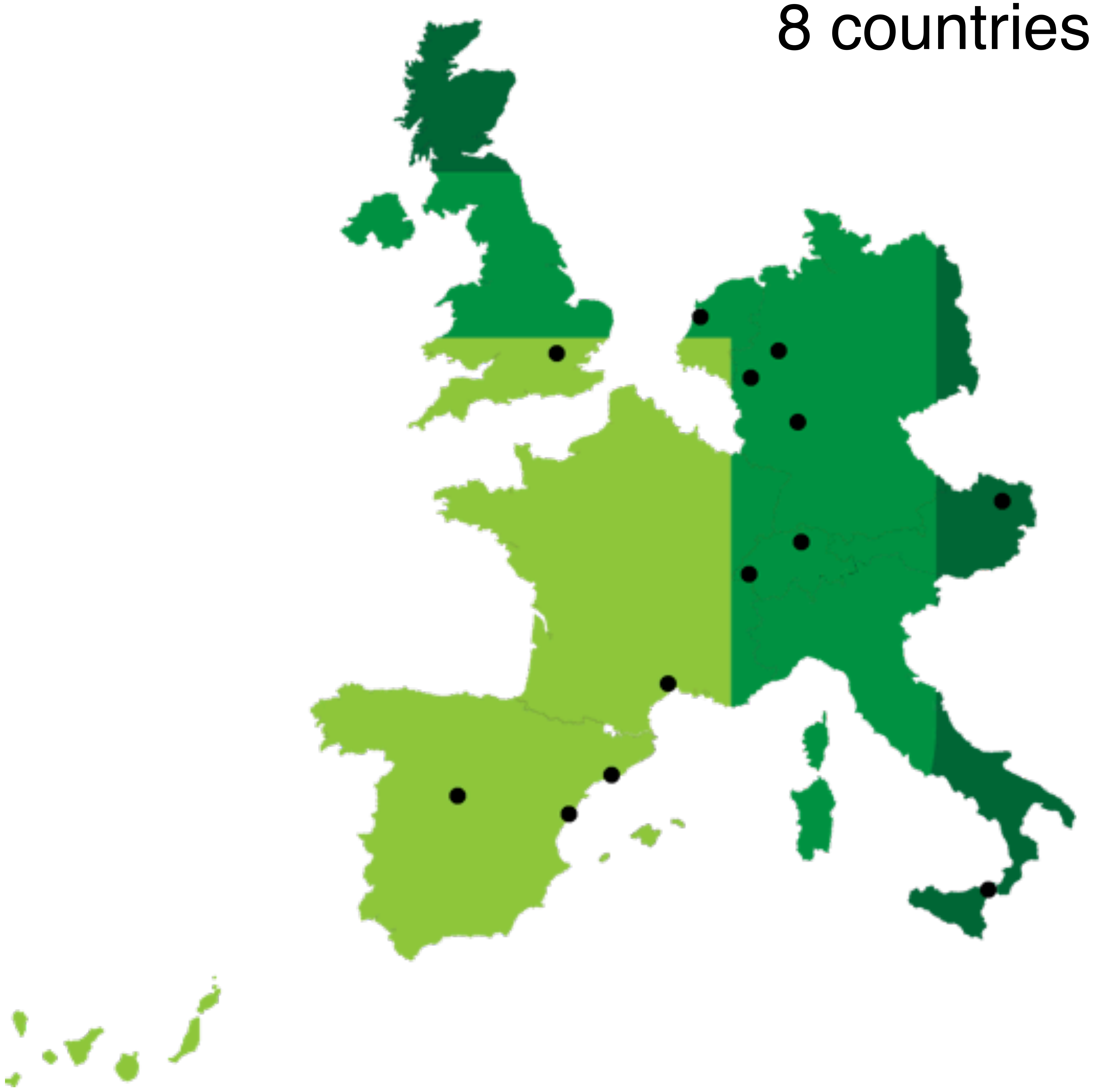
Applied research
TECHNOLOGY

- Surface science
- Modeling
- Mechanisms
- Interfaces

- Efficient and fast
- Robust (10 years?)
- Earth abundant materials
- Scalable processes
- Economically **competitive** (with fossil fuels!)

A-LEAF: Collaborative project

8 countries



A-LEAF: Collaborative project

13 partners

9 Universities
3 Research Institutions
1 Industrial partner

8 countries

ICIQ Institut Català d'Investigació Química | ETH Zürich | Universiteit Leiden | instituto imdea nanociencia | EPFL École Polytechnique Fédérale de Lausanne | TU WIEN | Universitat Jaume·I | Imperial College London | Technische Universität Darmstadt | JÜLICH Forschungszentrum | Université de Montpellier | INSTM | covestro

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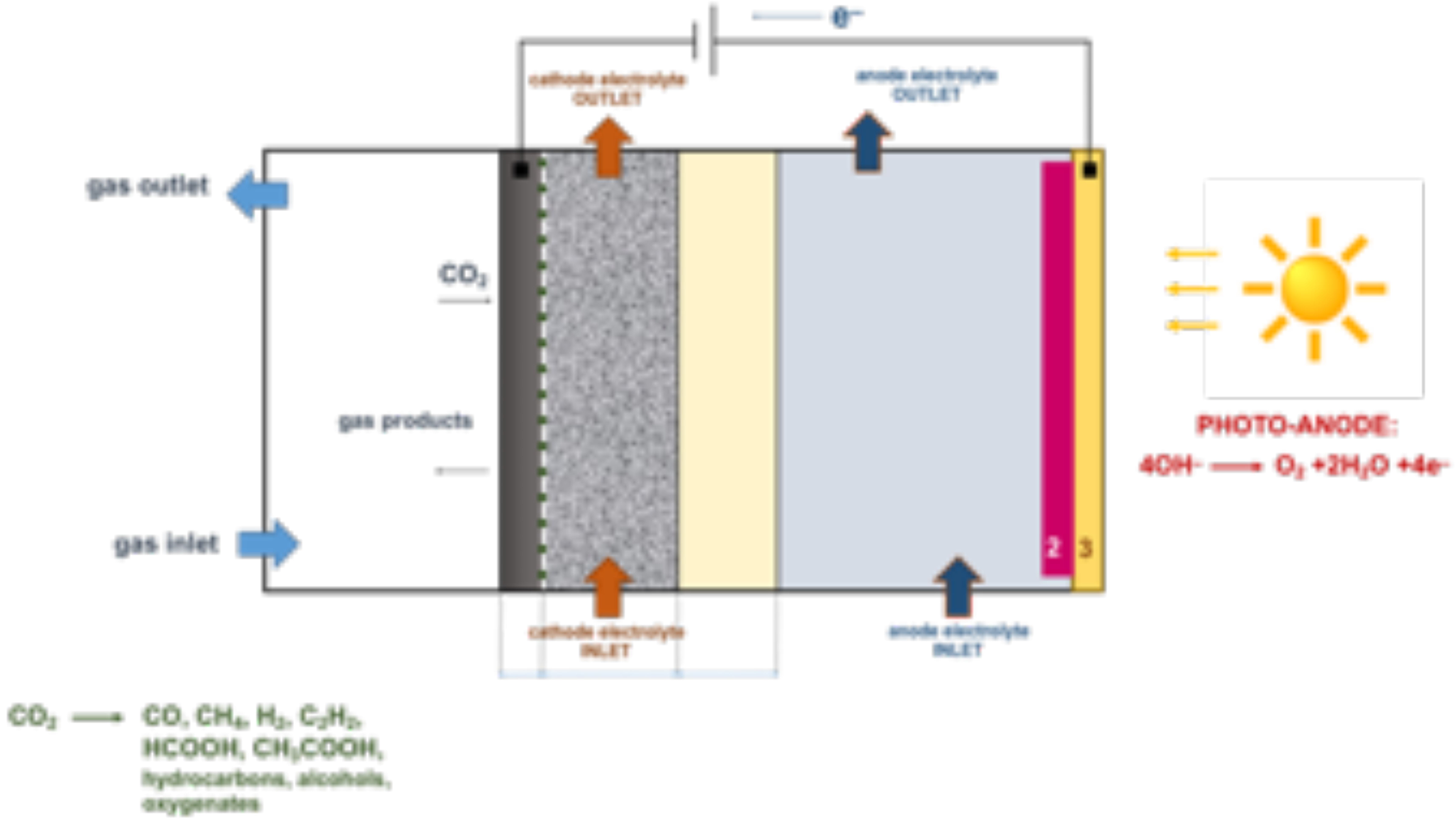
11

A-LEAF: Target integrated prototype



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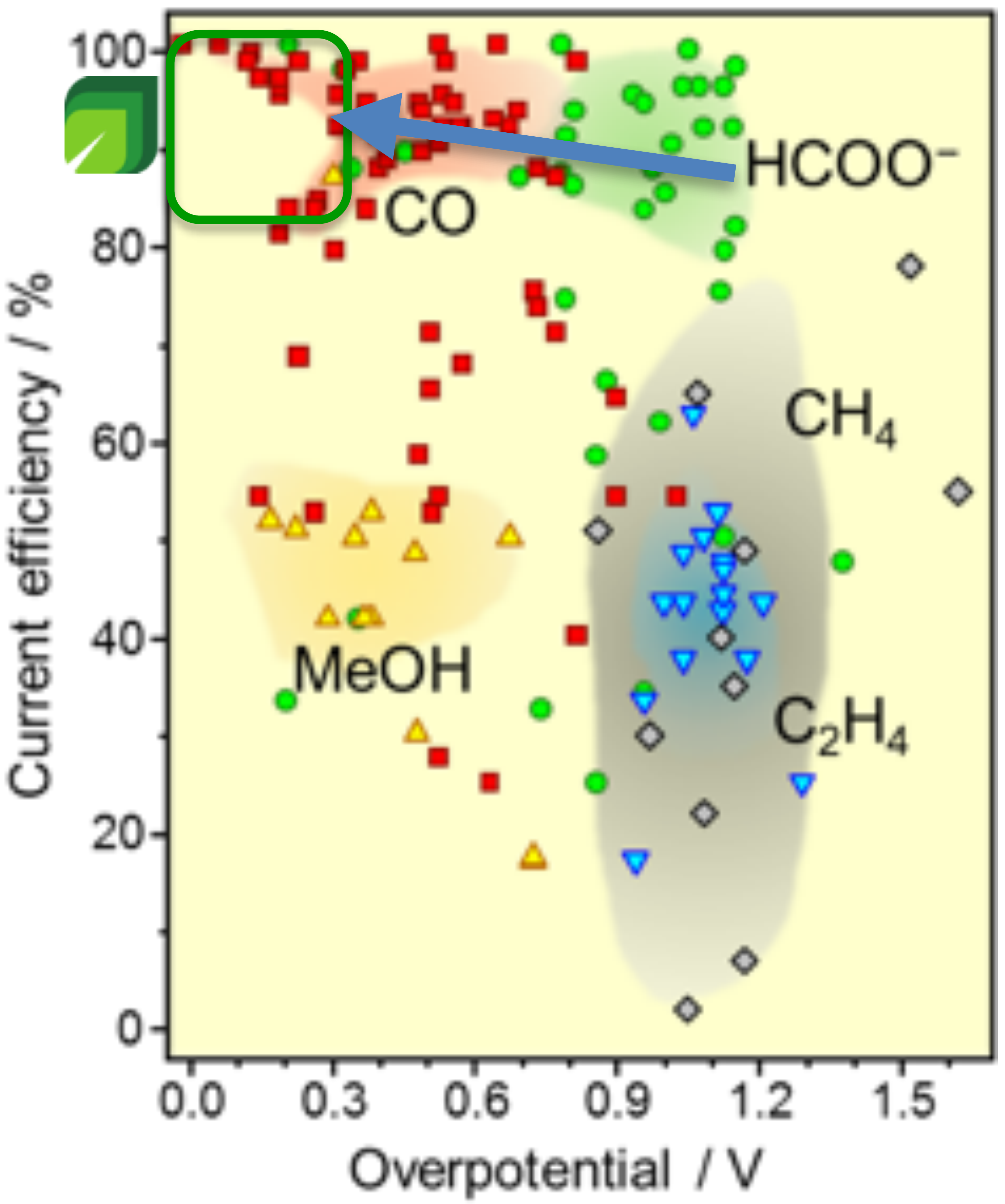
1+: Optimizing CRC catalysts

Dr. A. Martín-Fernández

Raw material: ***Cu***

Target product: ***formate***



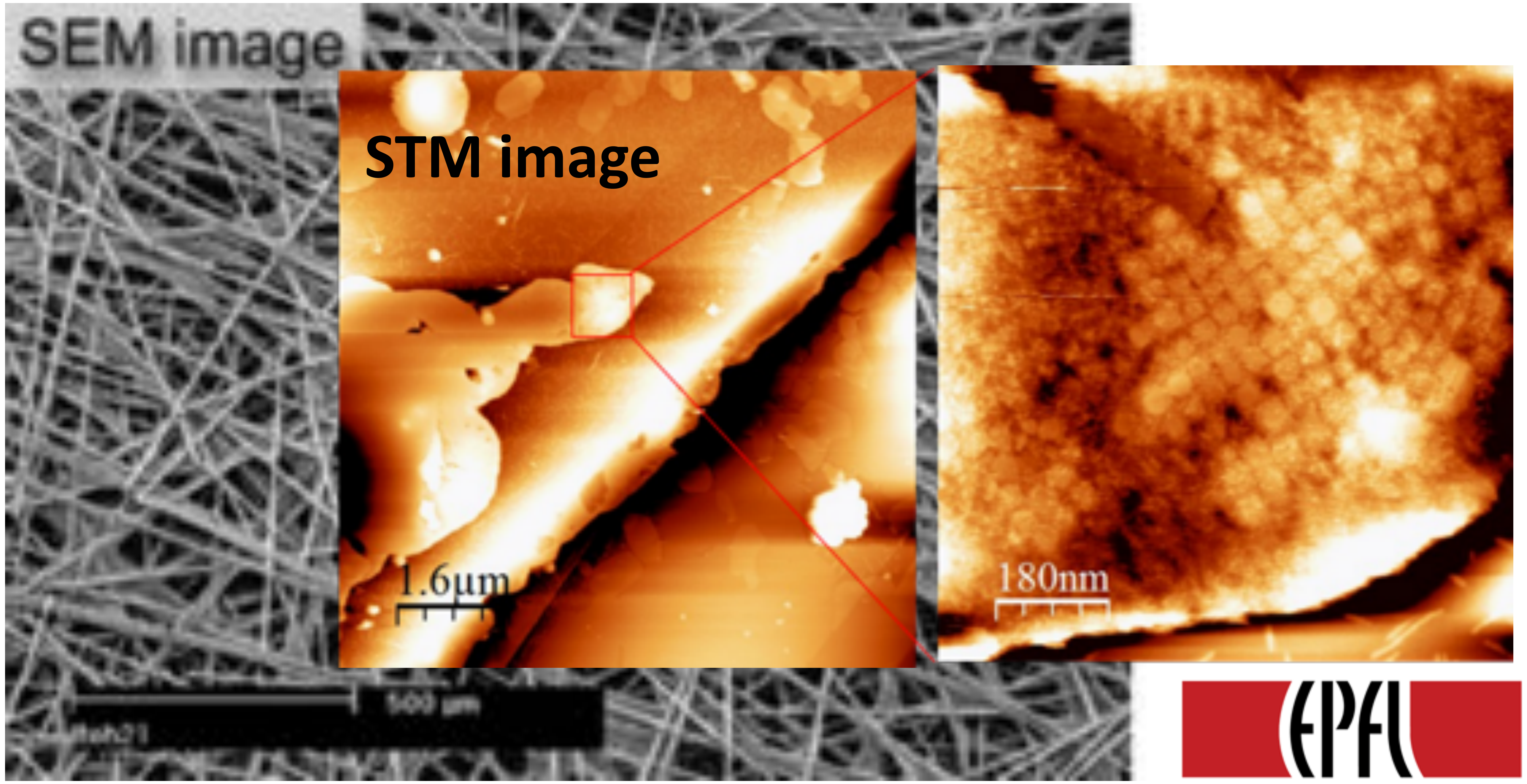
Prof. J. Pérez-Ramírez

ETH Zürich

a-leaf *ChemSusChem.* **2019**, 12, 3501; *Nat. Commun.* **2018**, 9, 1477; *ACS Catal*. **2018**, 8, 837.

1: Characterising CRC catalysts

Gas diffusion layers are a porous material composed of a dense array of **carbon** fibers, which also provides an electrically conductive pathway for current collection.



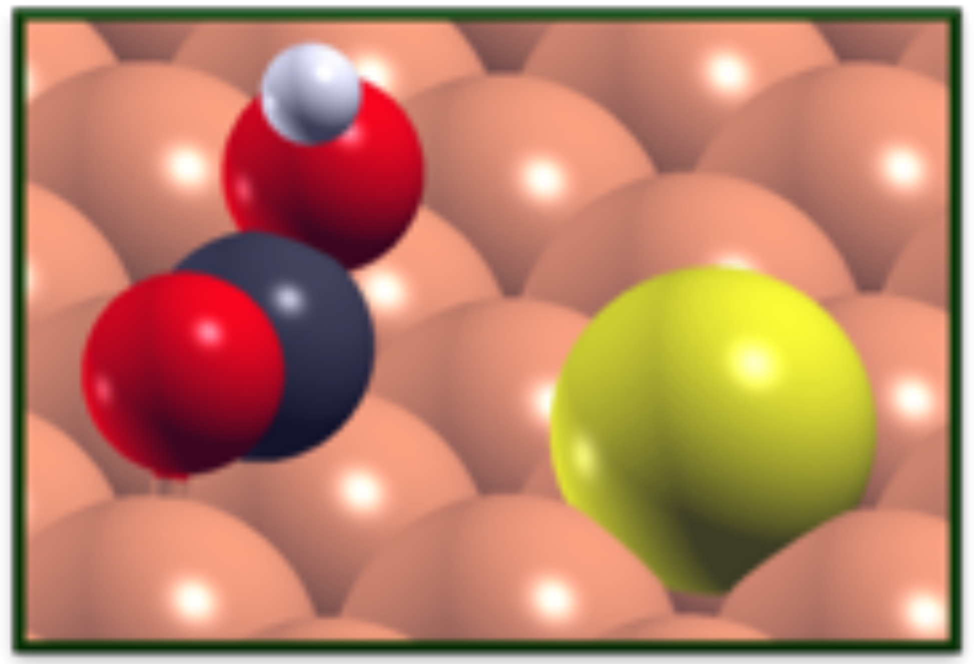
Prof. M. Lingenfelder

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

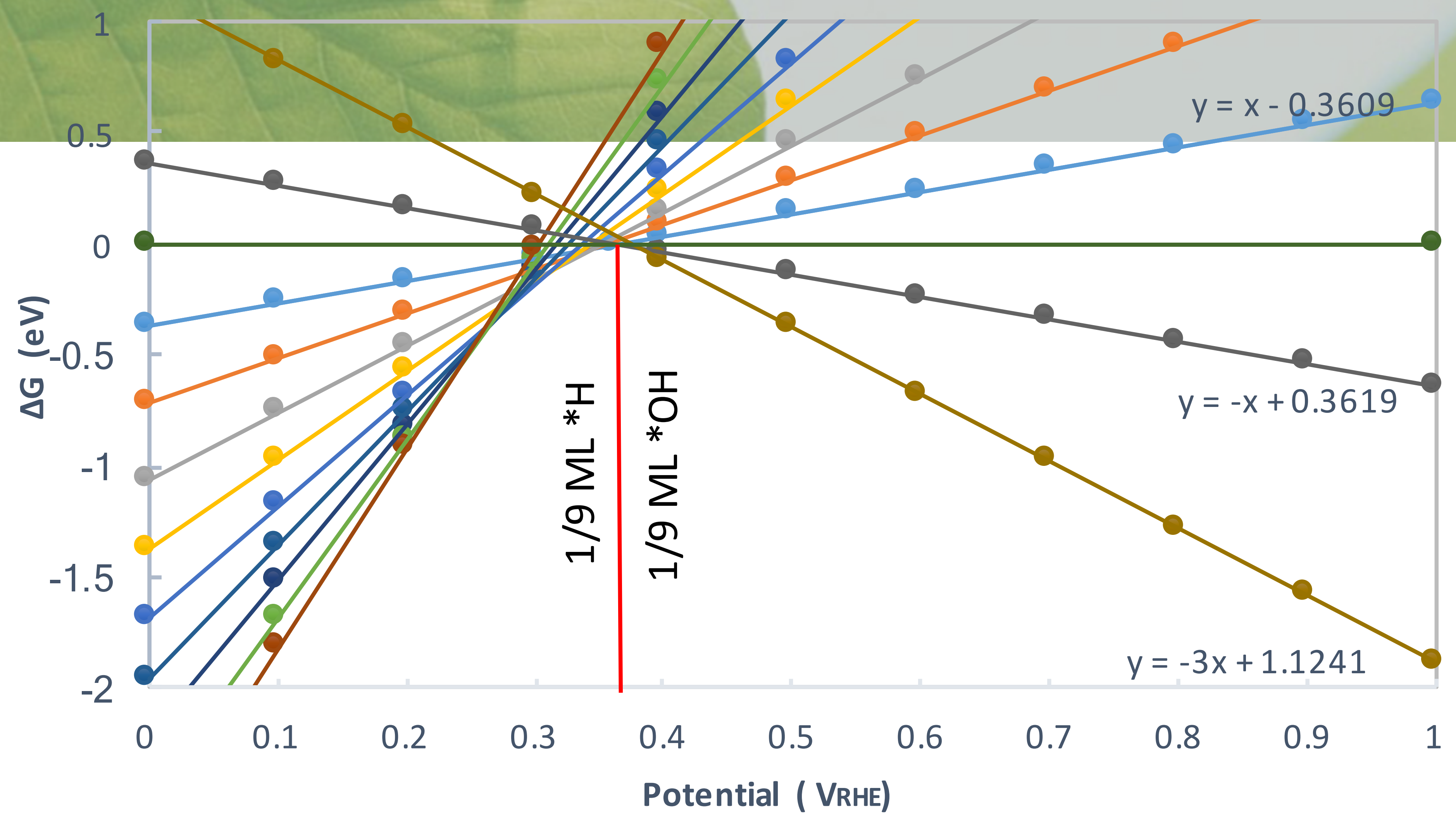
CRC catalysts: Copper-based **nanostructures** which provide high activity although medium selectivity.

Angew. Chem. Int. Ed. **2019**, 58, 10295

1++: Understanding CRC catalysts

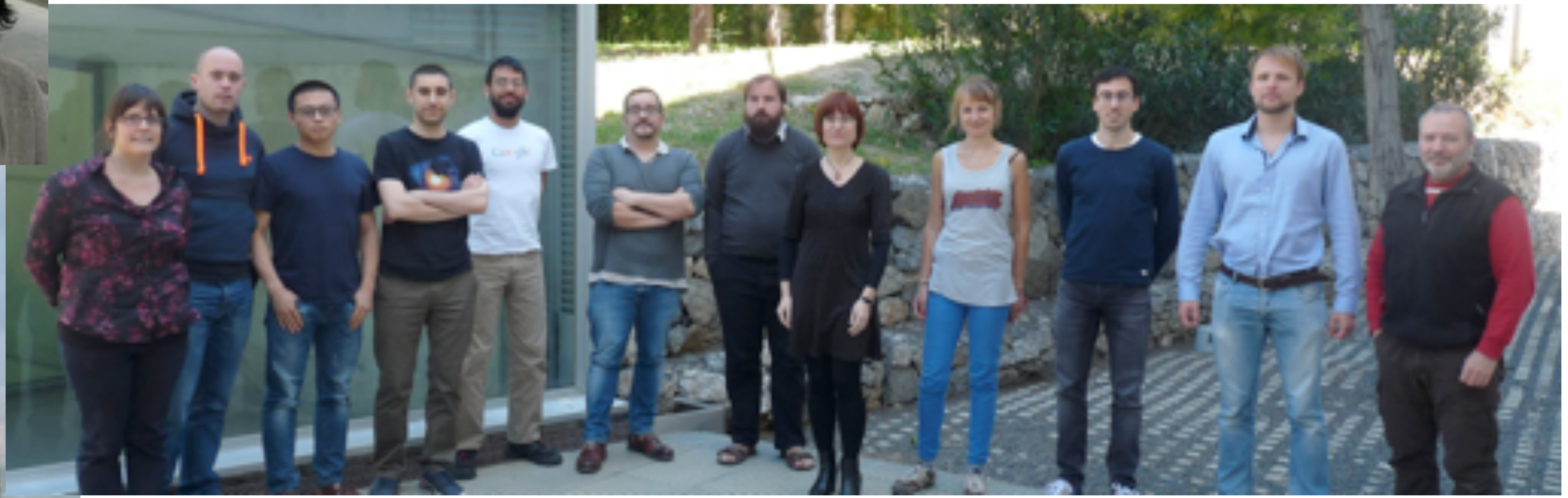


experimental/computational methods



Mechanism

Prof. M. Koper



Prof. N. López

ICIQ Institute of Chemical Research of Catalonia

Universiteit Leiden

ACS Energy Lett. **2020**, 5, 3176 ;*ACS Catal.* **2018**, 8, 9359tt

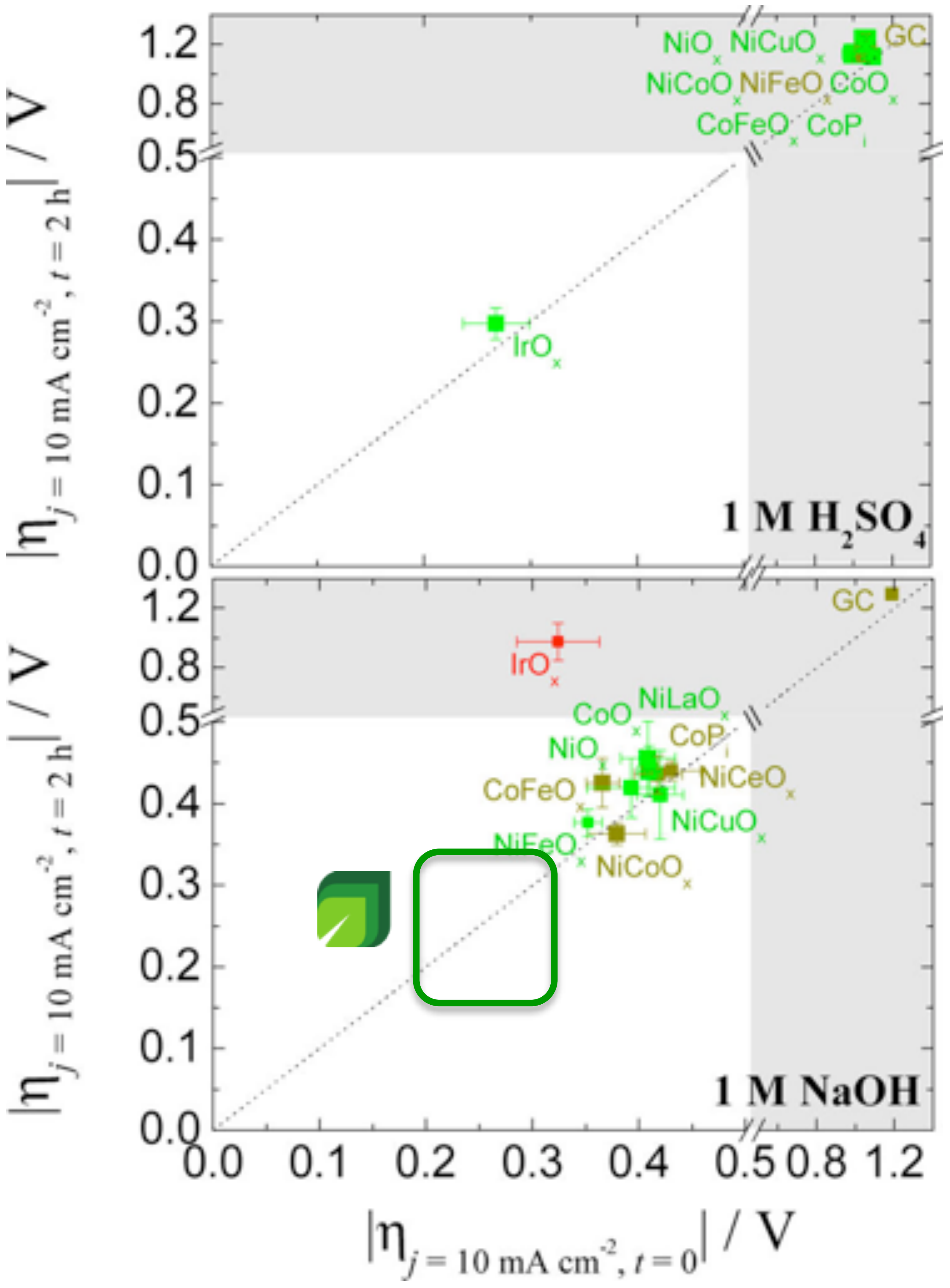
2: OER catalysts

Prof. J. Lloret-Fillol & JR

Raw materials:

Fe, Ni, Zn

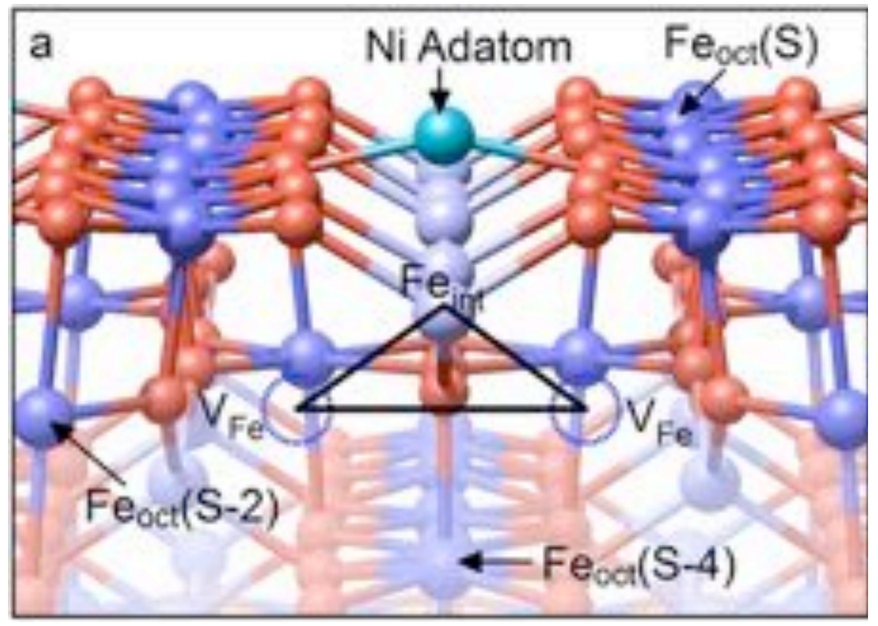
McCrory, C. C. L. *et al.* J. Am. Chem. Soc, **2013**, *135*, 16977–16987

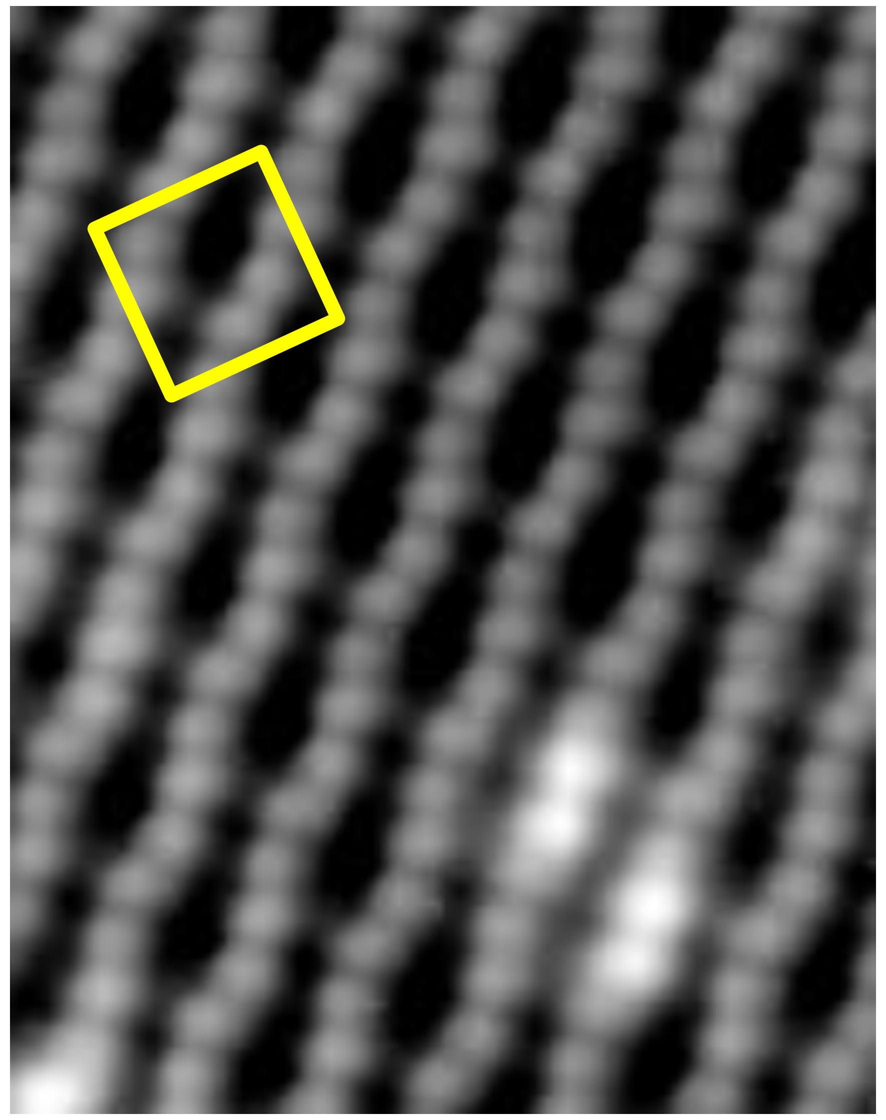


ACS Appl. Energy Mater. **2019**, 2, 8930

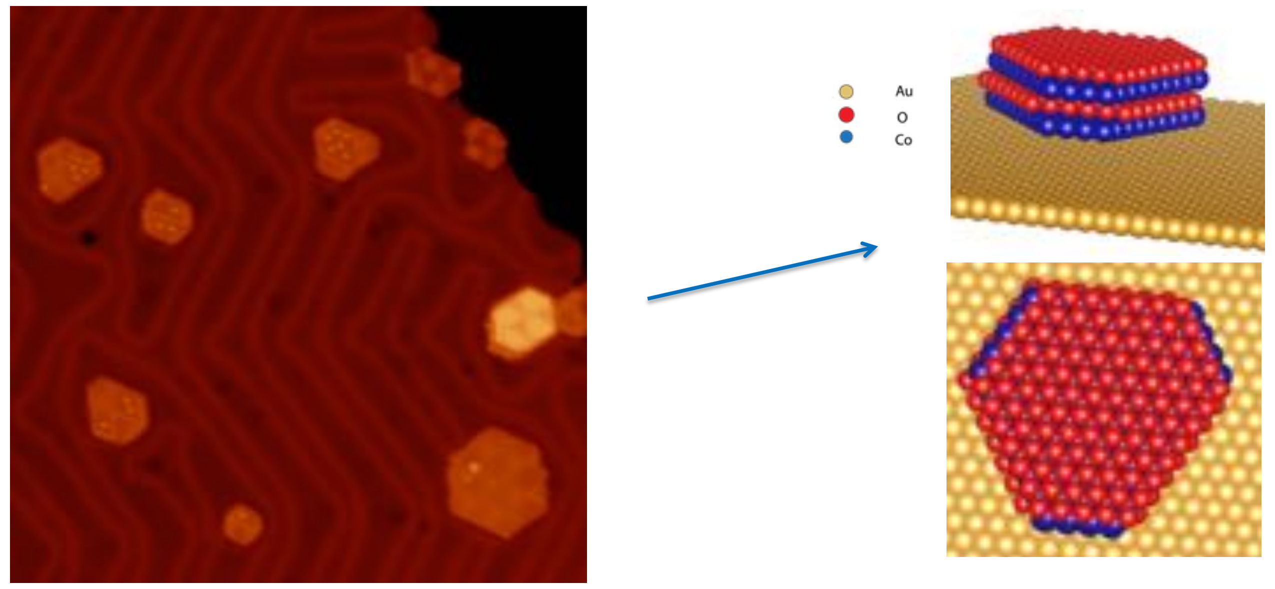
2+: Characterising OER catalysts

Surface doping

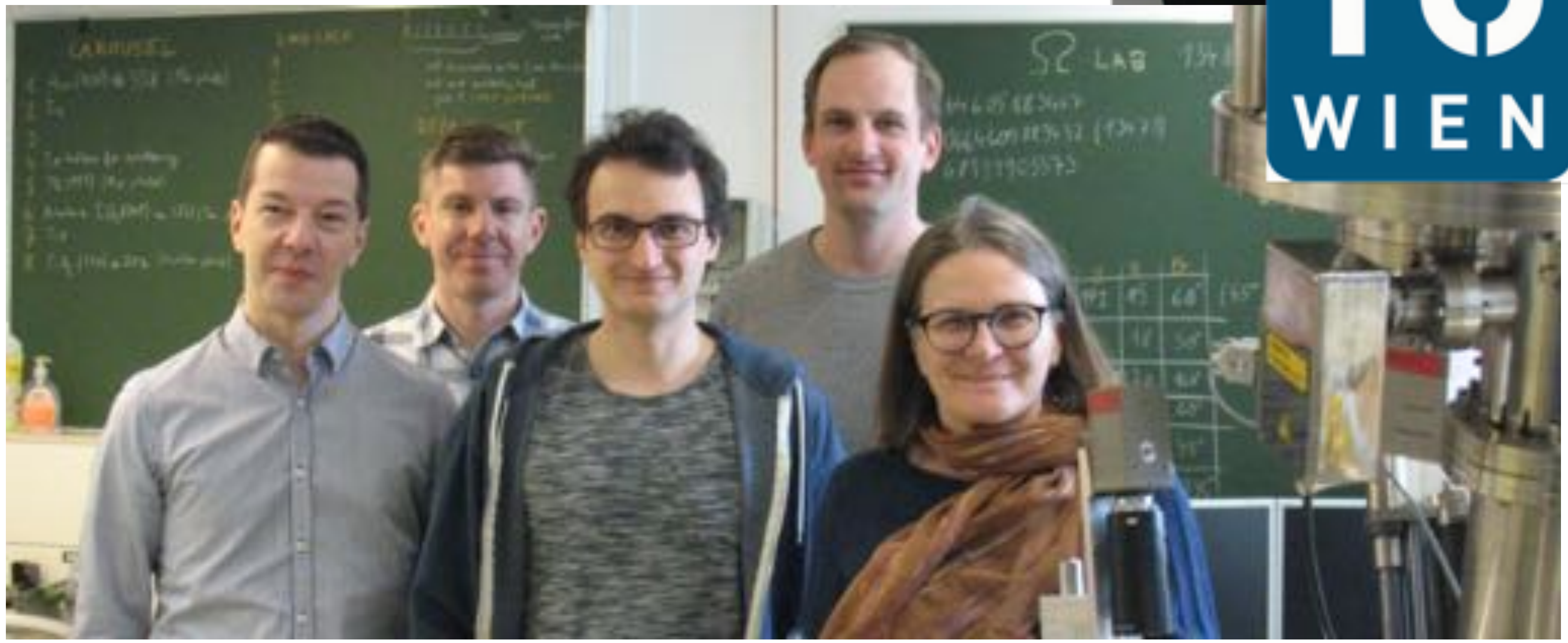




Nanostructuration



Prof. U. Diebold



Prof. D. Écija

J. Chem. Phys. **2019**, 151, 154702

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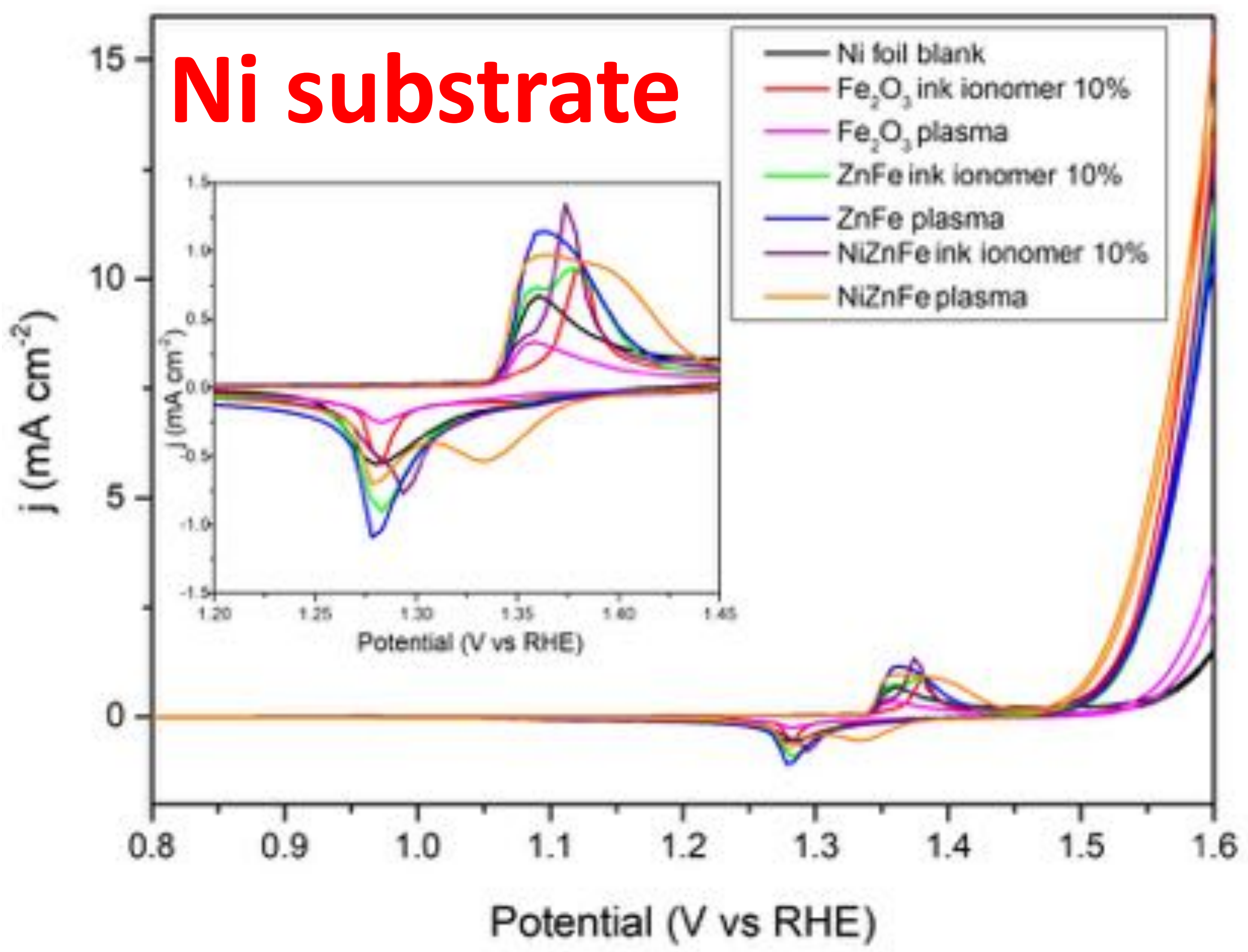
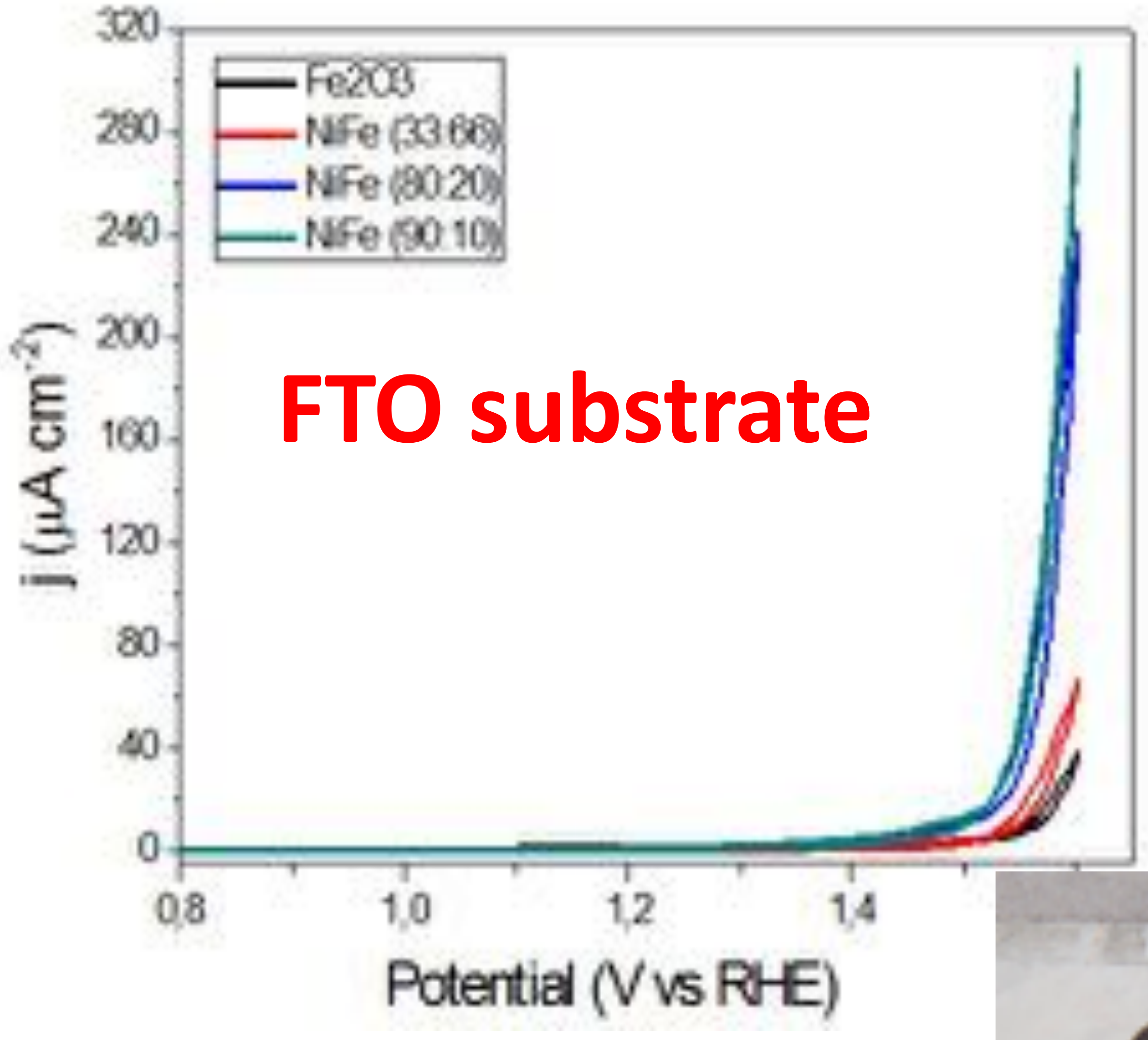
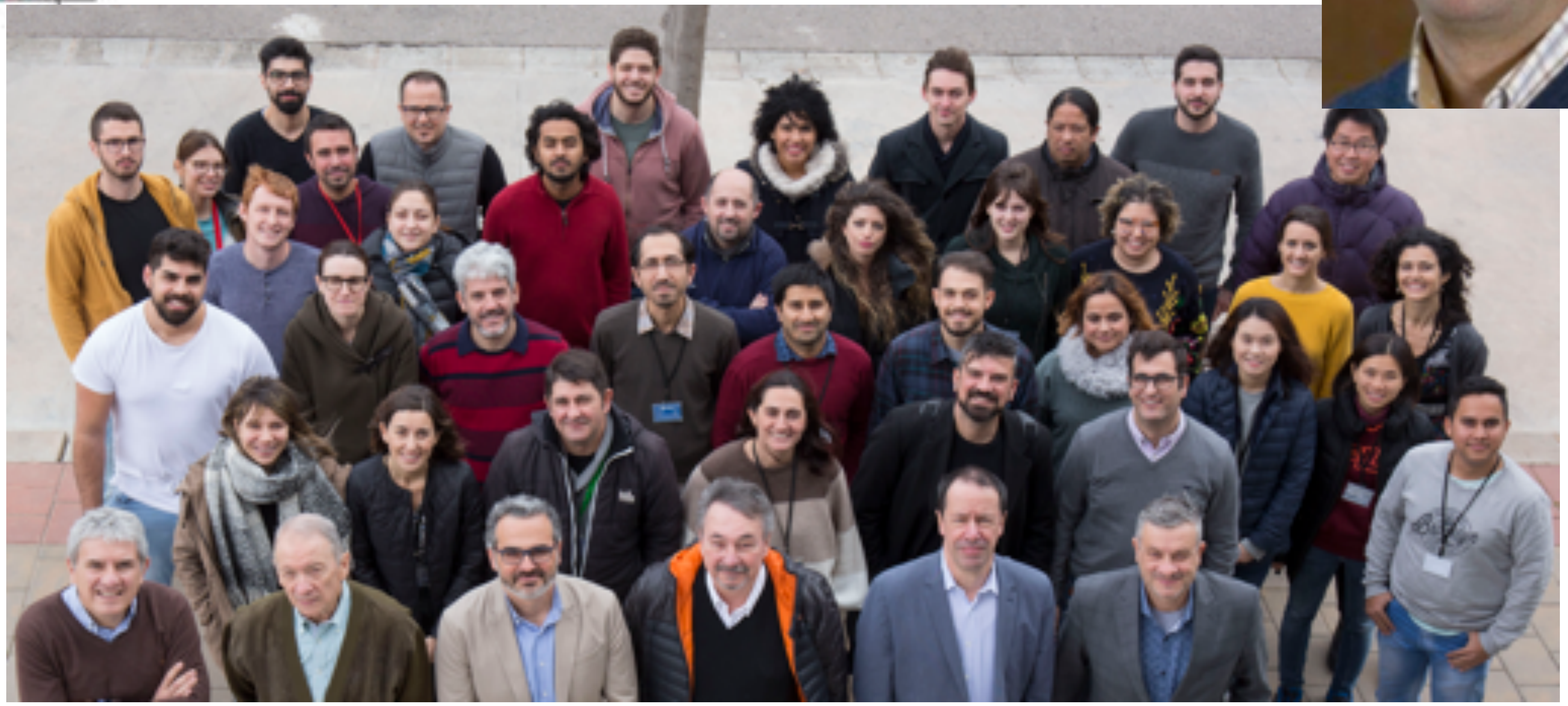
2++: Characterising OER catalysts





UNIVERSITAT JAUME•I

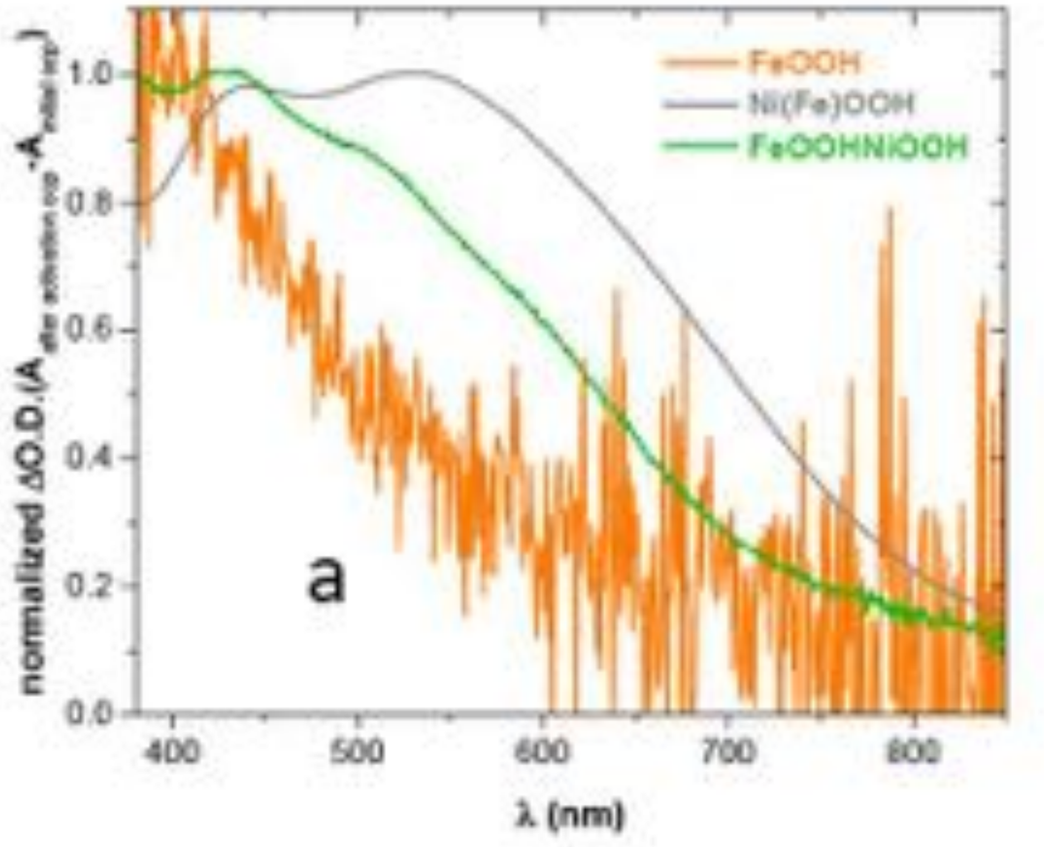
Prof. S. Giménez

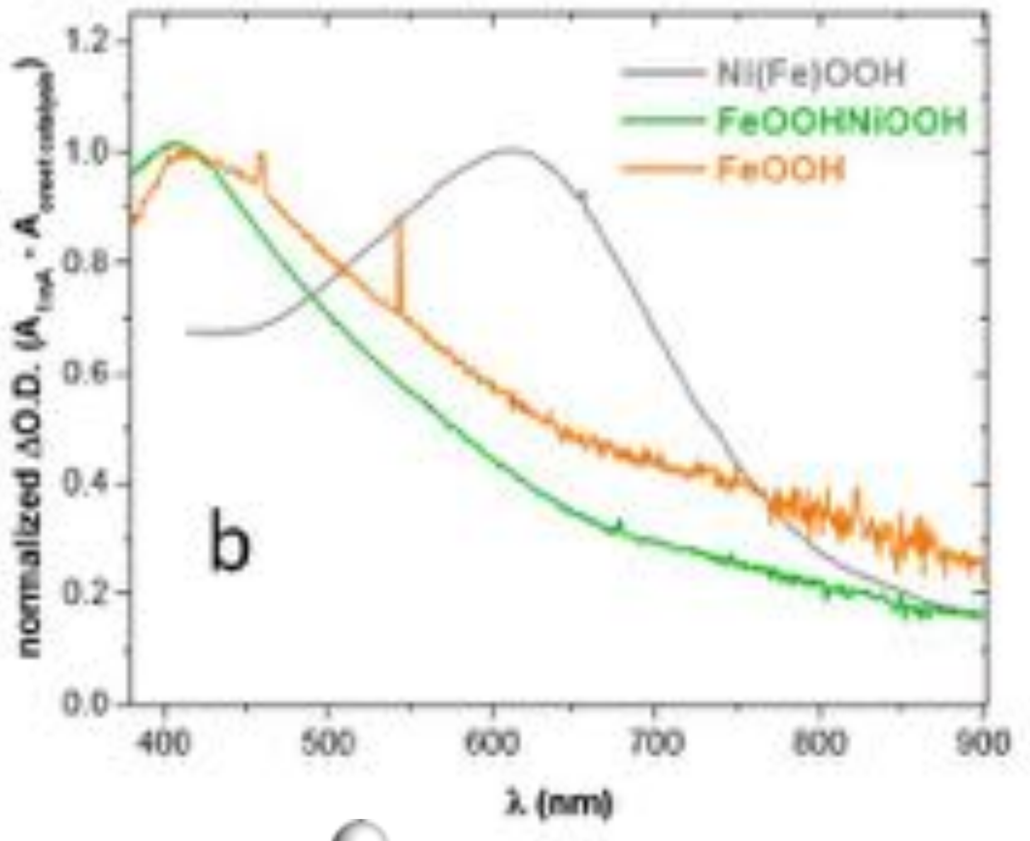


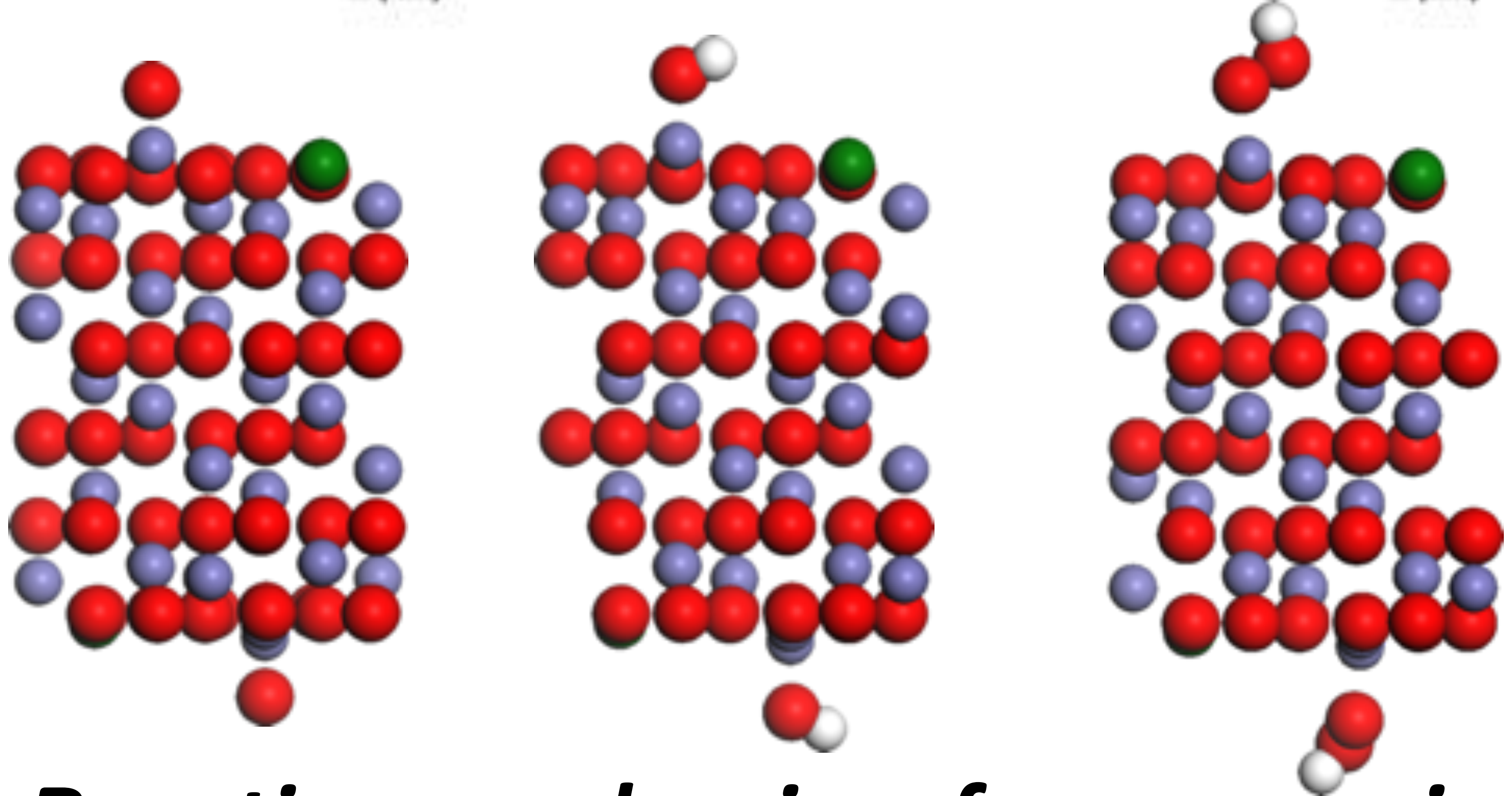
Electrochemical correlations

a-leaf *Mater. Adv.* **2020**, 1, 1202; *ACS Energy Lett.* **2019**, 4, 337

2++++: Understanding OER catalysts



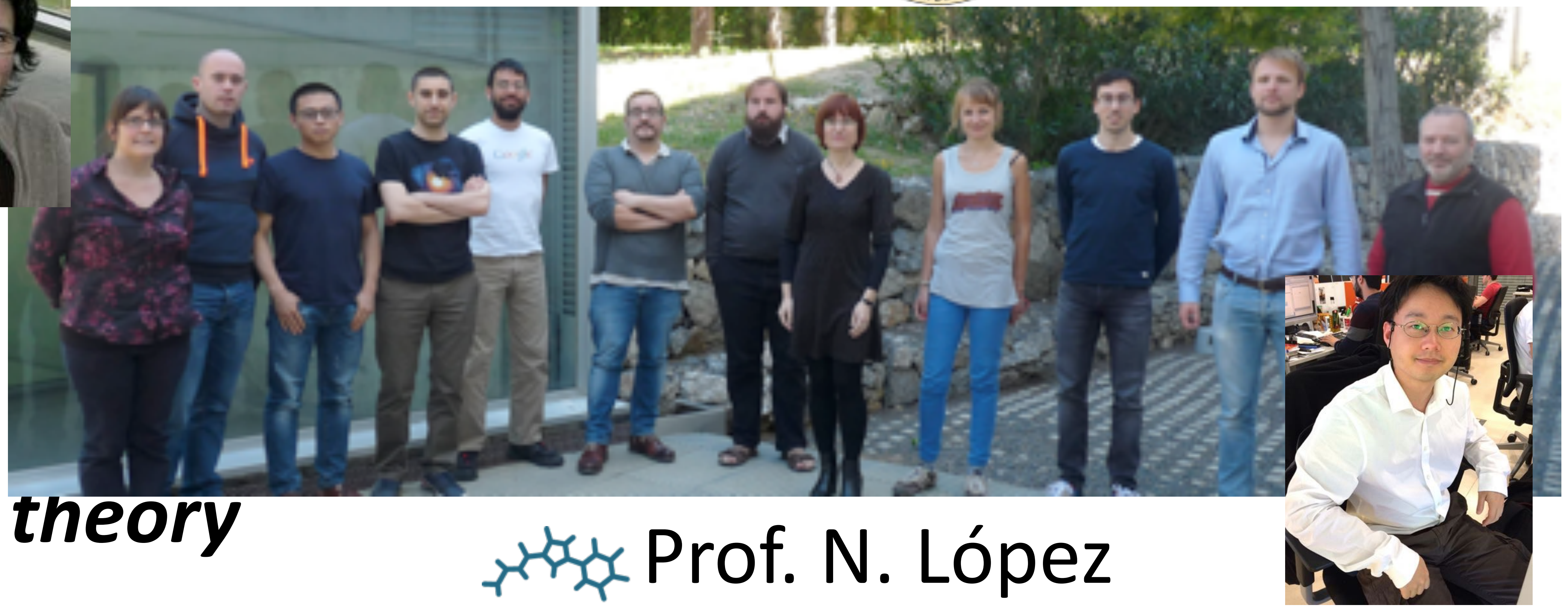




Reaction mechanism from experiment AND theory

Prof. J. Durrant

Imperial College London



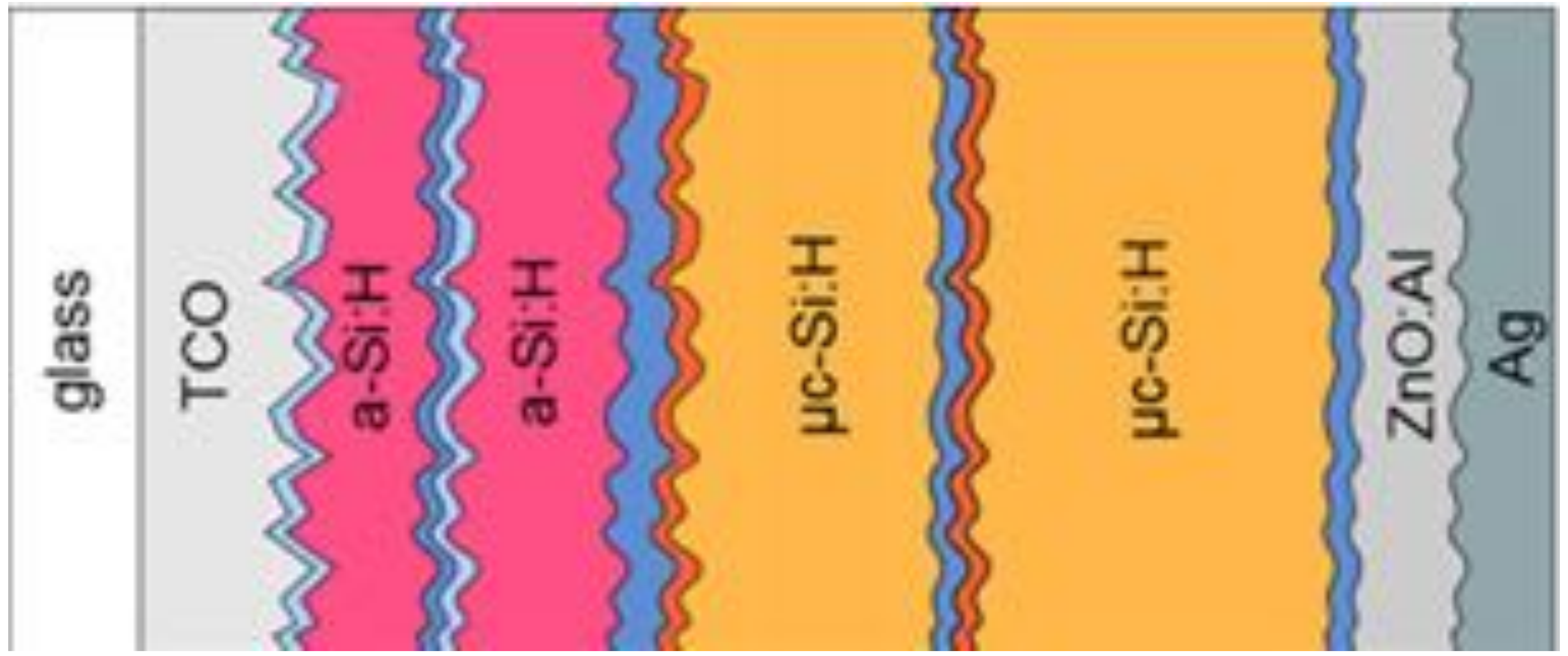
Prof. N. López

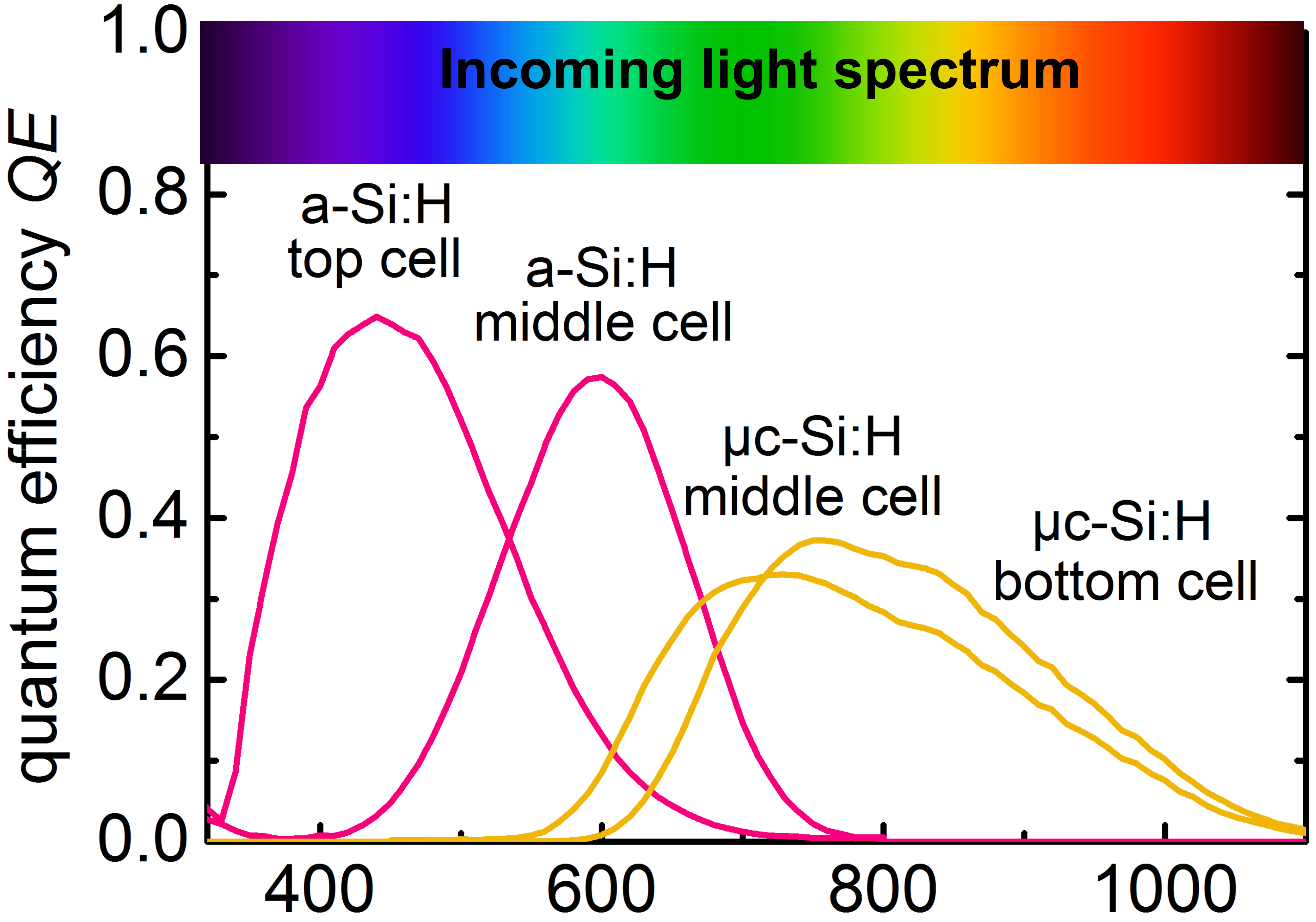
ICIQ Institute of Chemical Research of Catalonia

Chem. Sci., **2020**, 11, 2464; *J. Phys. Chem. Lett.*, **2018**, 9, 7153

3: Photovoltaics

*Raw material: **Si***





Dr. T. Merdzhanova & Dr. V. Smirnov

JÜLICH FORSCHUNGSZENTRUM

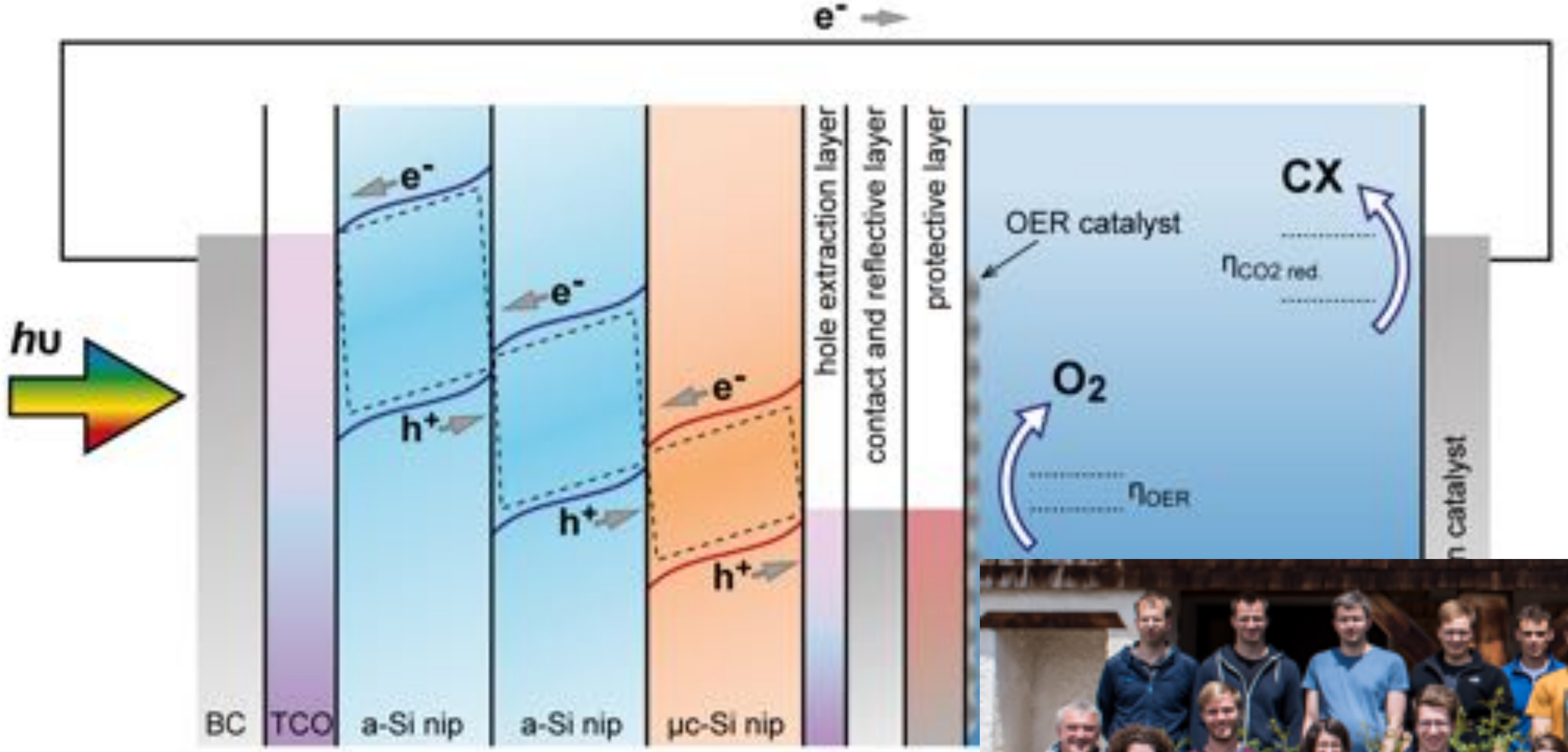
Prof. F. Finger

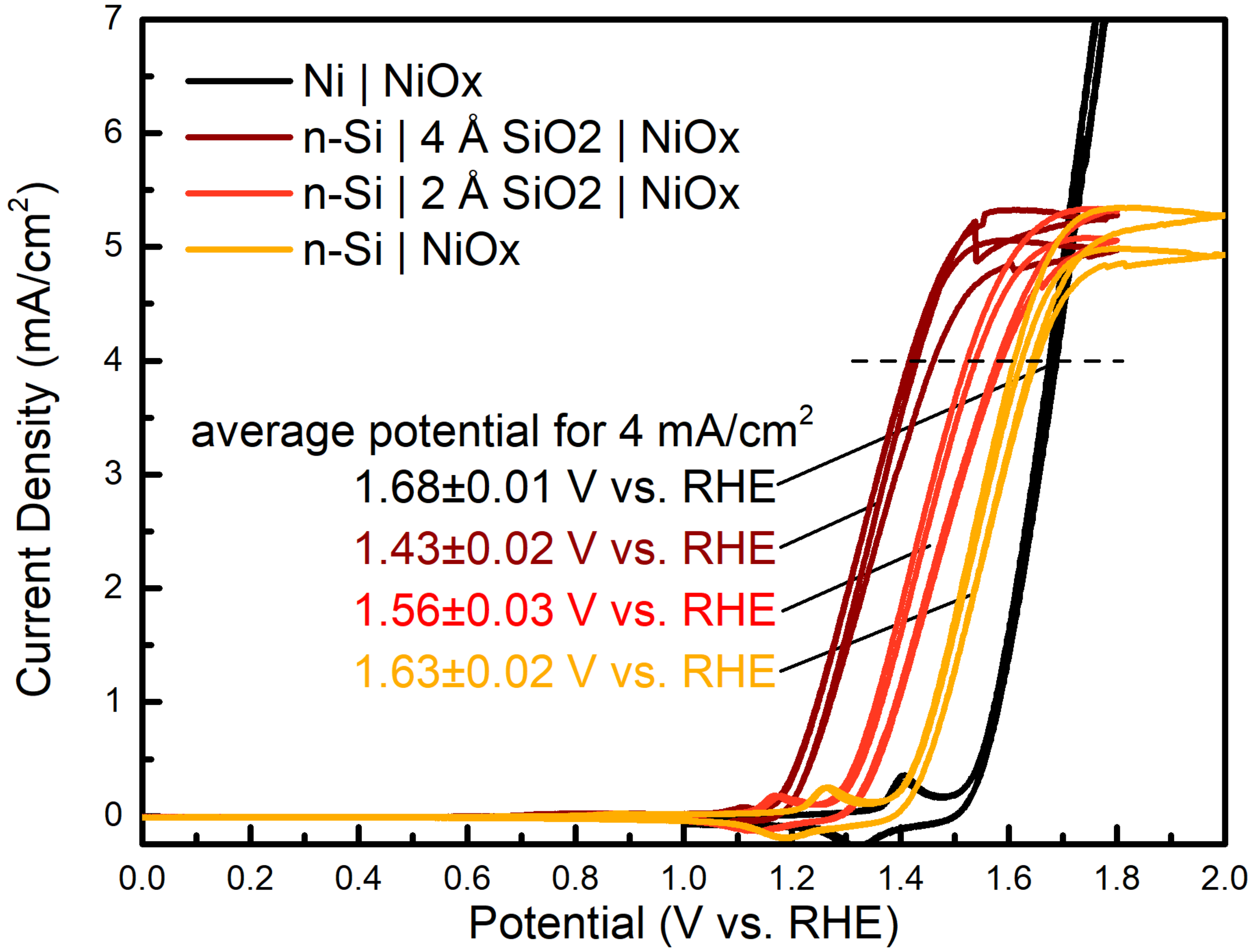
>15% sun to power conversion

Mater. Adv. **2020**, 1, 1202;

3+: Photovoltaics

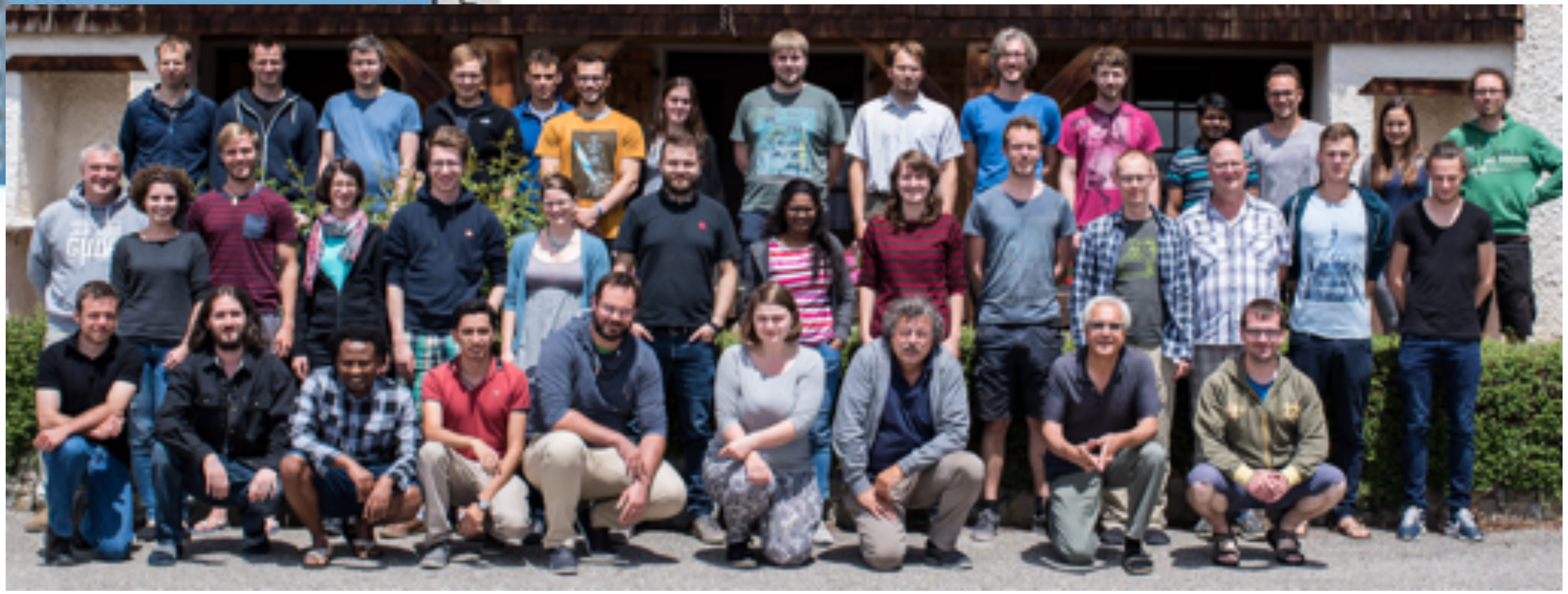
Interfaces





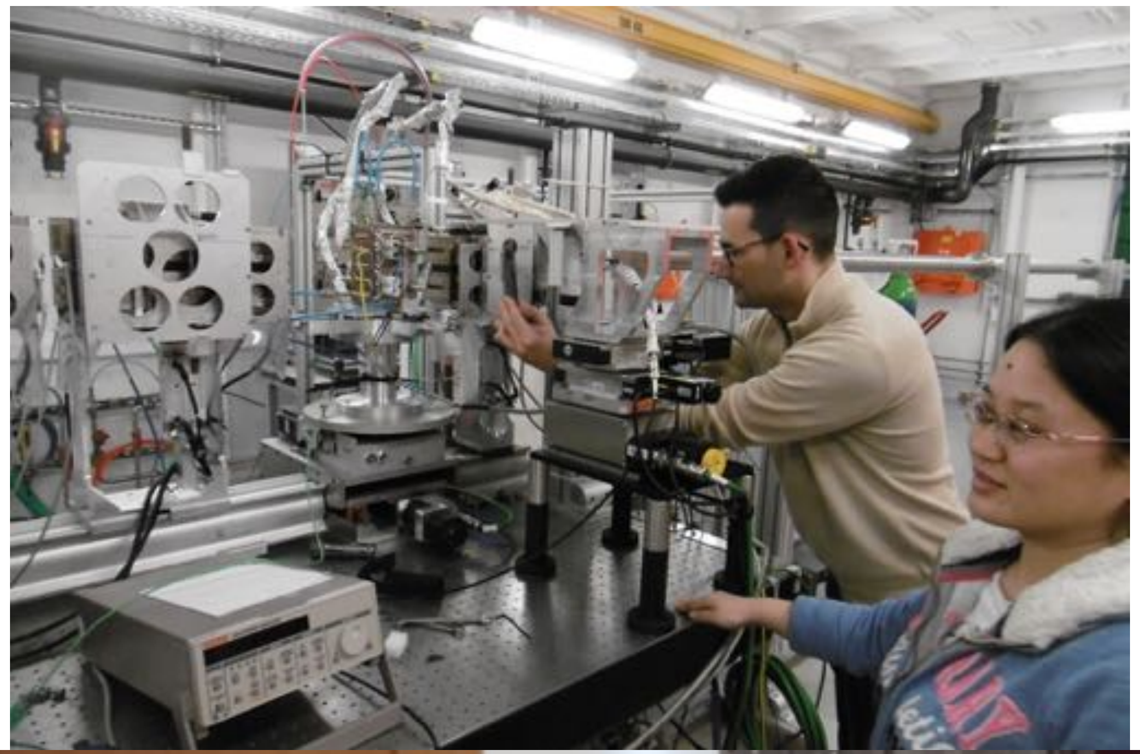
TECHNISCHE UNIVERSITÄT DARMSTADT

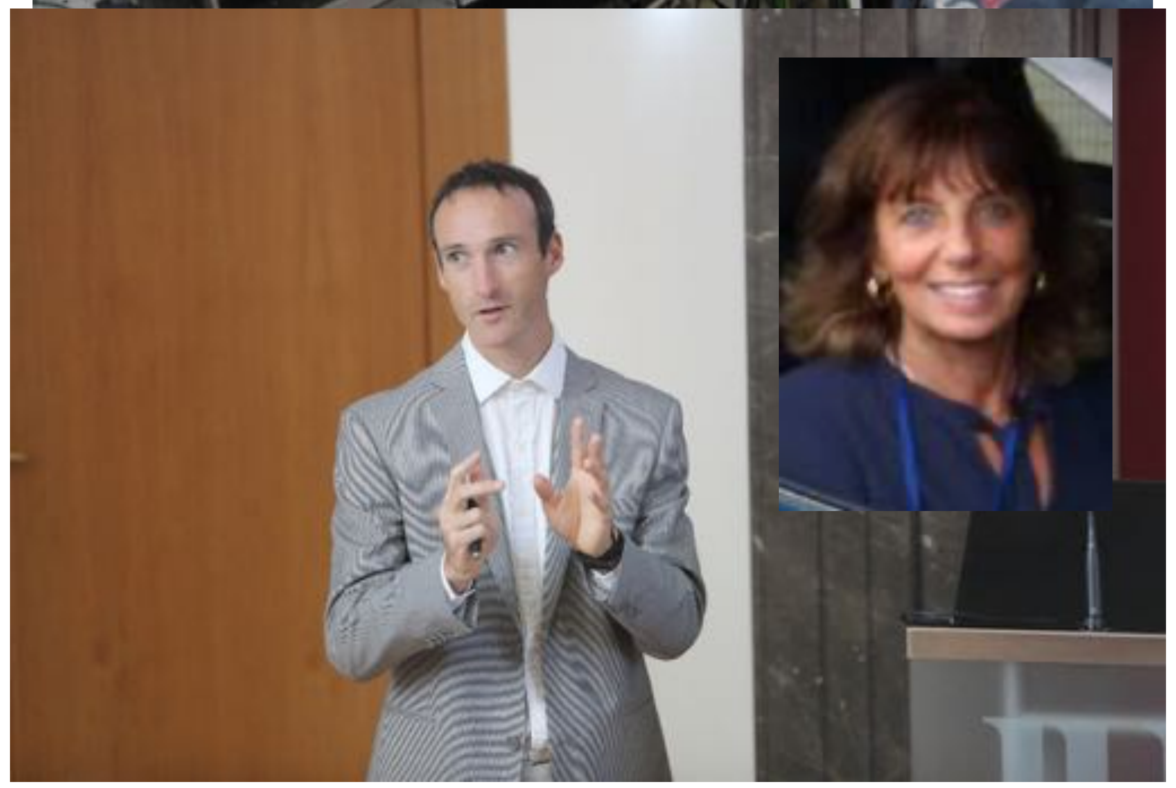
Prof. W. Jaegermann



J. Electrochem. Soc. **2018**, 166, H3208

Integrated A-LEAF





Prof. S. Perathoner

UNIVERSITÀ DI MESSINA

Prof. F. Jaouen

Cell design and construction

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Use-inspired
Basic research
UNDERSTANDING

Applied research
TECHNOLOGY

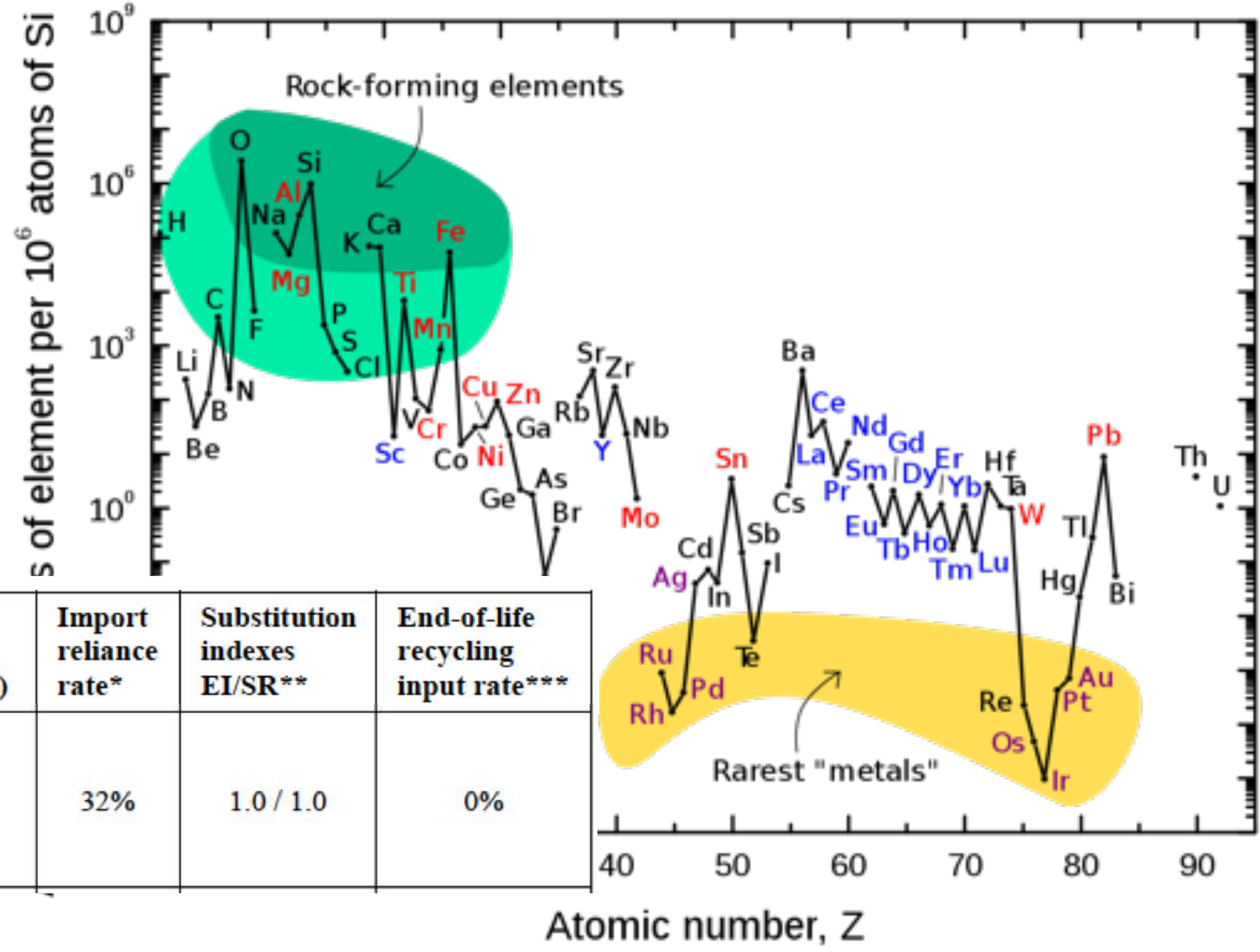
- Surface science
- Modeling
- Mechanisms
- Interfaces

- Efficient and fast
- Robust (10 years?)
- Earth abundant materials
- Scalable processes
- Economically **competitive** (with fossil fuels!)

Dr. J. Kintrup

RESTRICTIONS

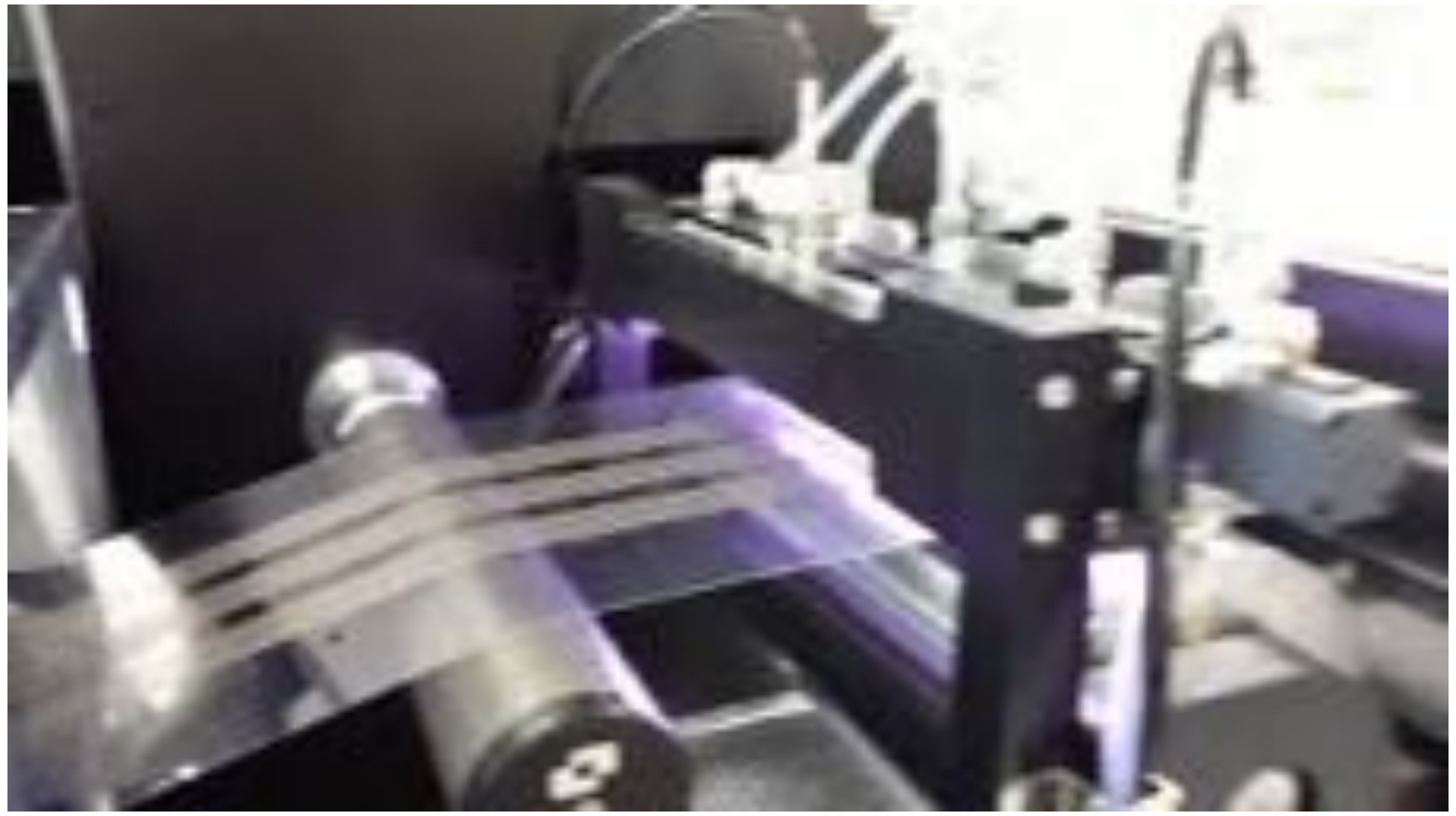
- Only earth abundant materials

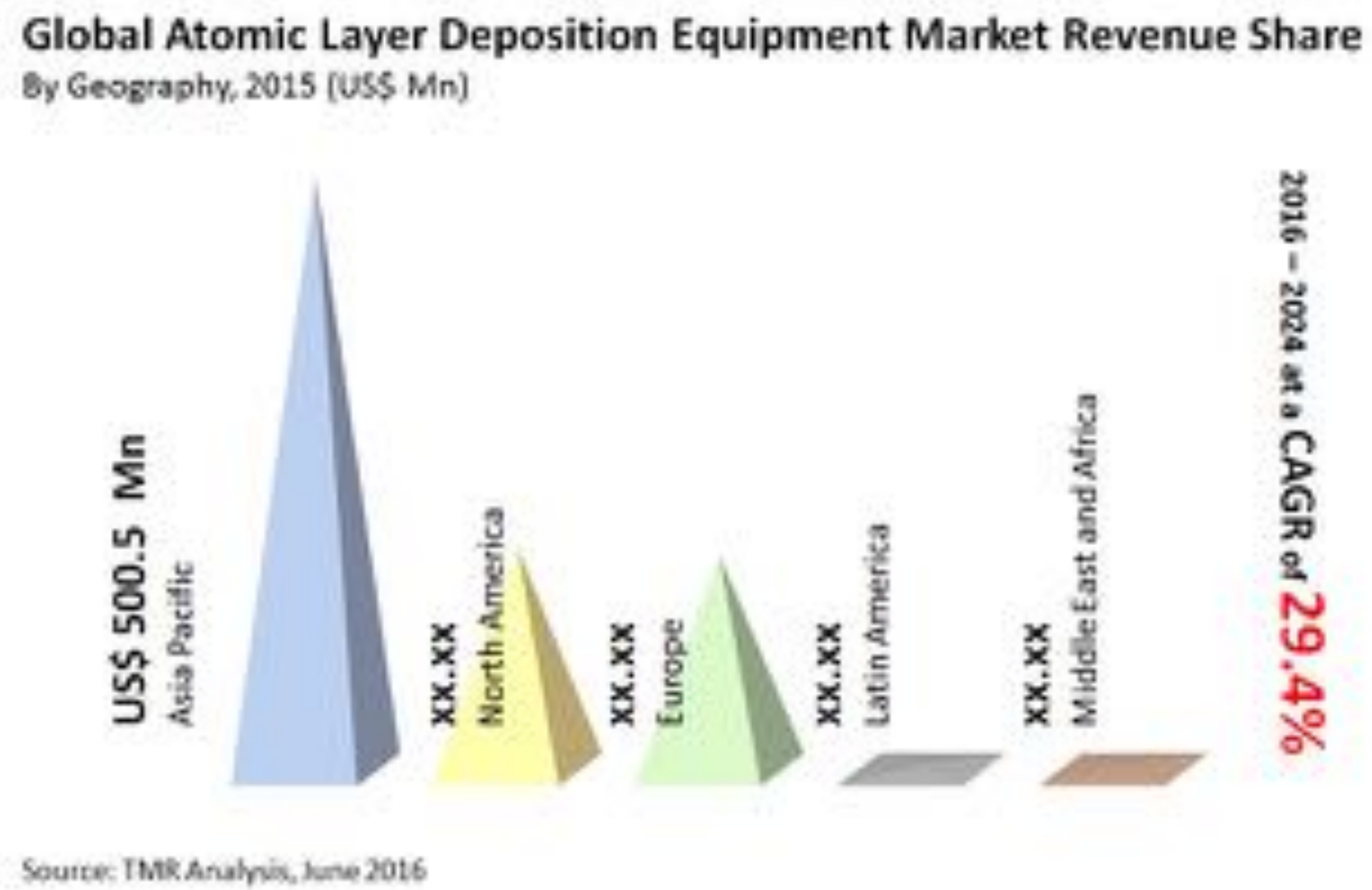


Raw materials	Main global producers (average 2010-2014)	Main importers to the EU (average 2010-2014)	Sources of EU supply (average 2010-2014)	Import reliance rate*	Substitution indexes EI/SR**	End-of-life recycling input rate***
Cobalt	Democratic Republic of Congo (64%) China (5%) Canada (5%)	Russia (91%) Democratic Republic of Congo (7%)	Finland (66%) Russia (31%)	32%	1.0 / 1.0	0%

RESTRICTIONS

- Only earth abundant materials
- Scalable processes (industry-ready)





RESTRICTIONS

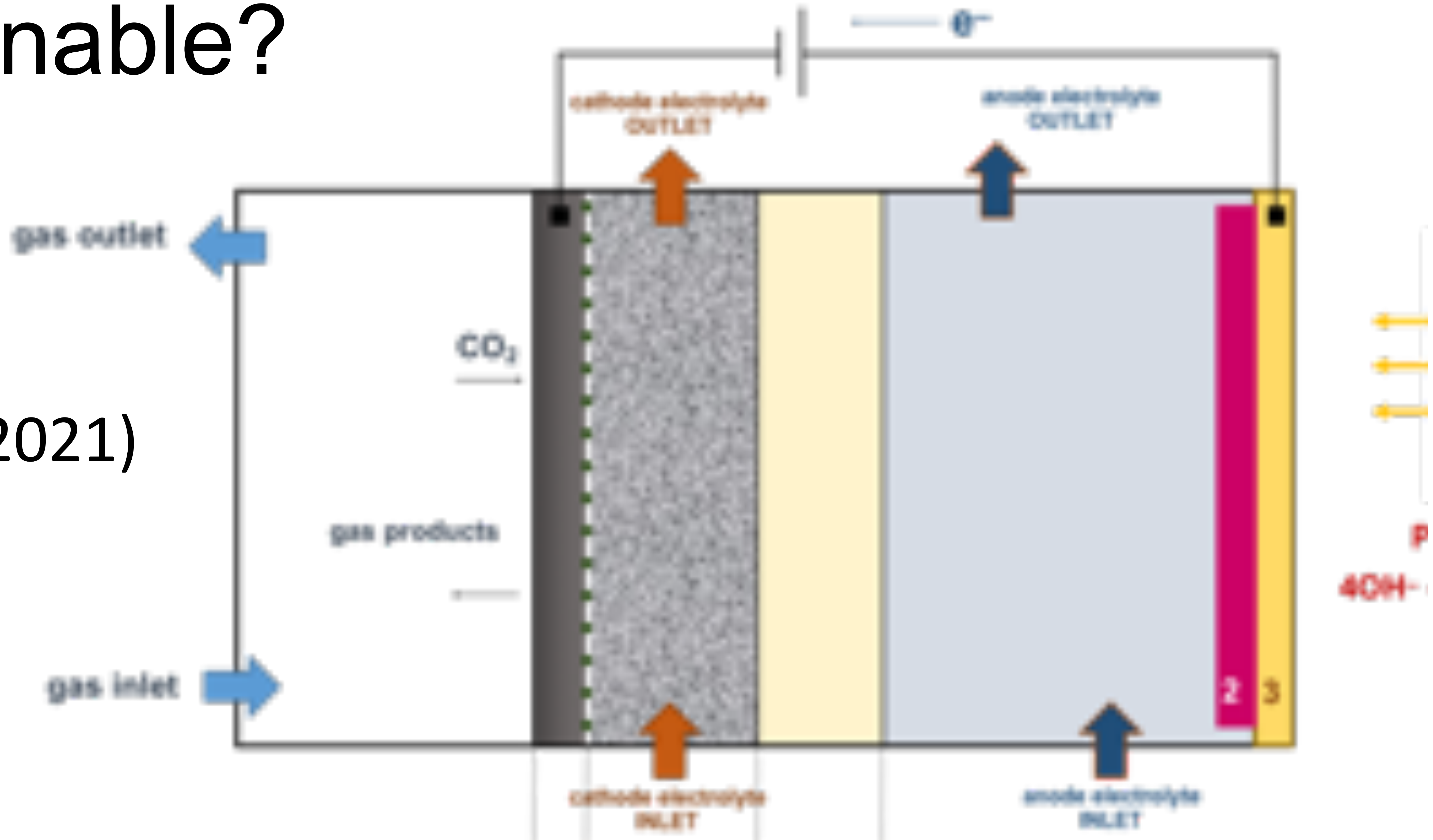
- Only earth abundant materials
- Scalable processes (industry-ready)
- Integration

Optimization of the whole, NOT of the parts

RESTRICTIONS

- Only earth abundant materials
- Scalable processes (industry-ready)
- Integration
- Economically reasonable?

A-LEAF device performance targets (2021)



Our success

- **Advance** the field of artificial photosynthesis
- **Increase** its critical mass and society awareness
- **Facilitate** the next generation of experts
- **Consolidate** the European Research landscape in renewable energy vectors

For more information: **http://www.a-leaf.eu/**

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A_LEAF Project

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THANK YOU!!!!