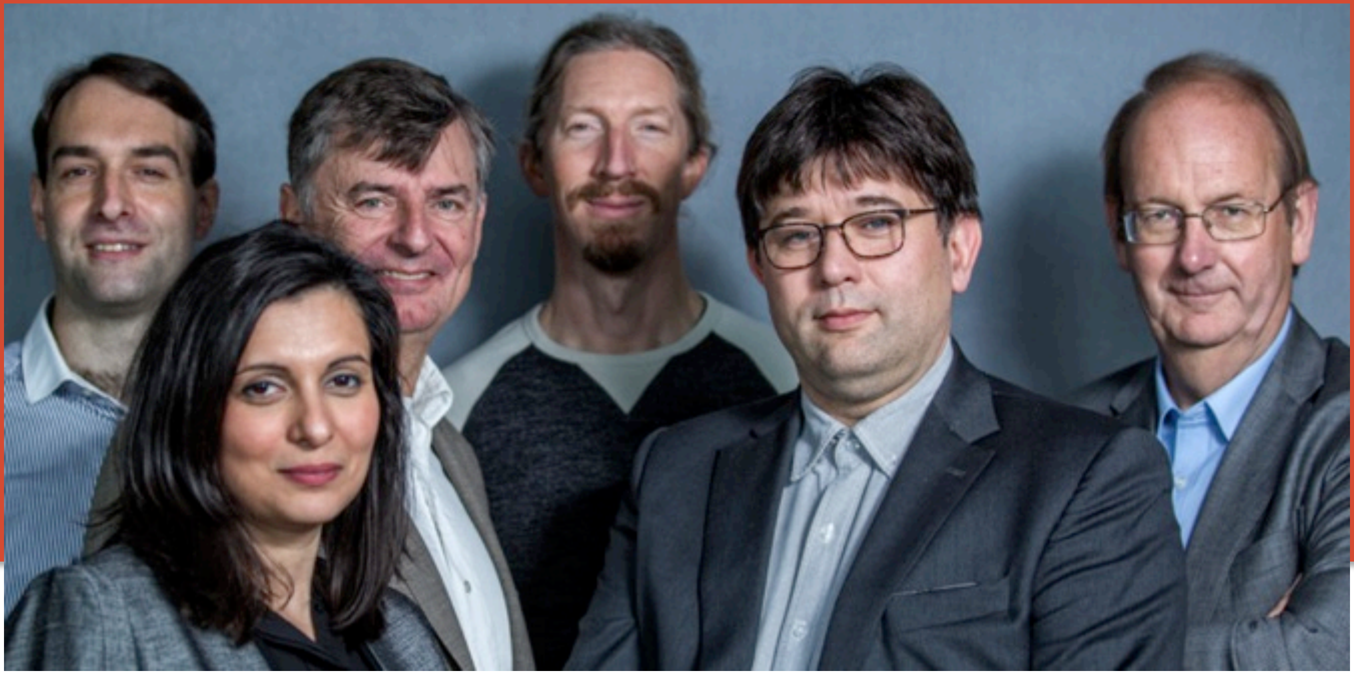
# syngaschem BV
## synthesis gas chemistry
## fundamental research projects

**Syngaschem moves to DIFFER : 1-1-2016**



Left to right: Kees-Jan Weststrate, Foteini Sapountzi, Jan-Karel Felderhof, Hans Fredriksson, Antonio Vaccaro, Hans Niemantsverdriet

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Syngaschem BV is research partner of Synfuels China Technology, Co Ltd

# Energy Landscape next decades

**Gas**

Affordable

Acceptable

Abundant

According to Shell 2014

**Oil**

Convenient

"Cheap," *but...*

Depleting

**Coal**

Affordable

Questionable

Abundant

*Opportunities for responsible use !!!*

renewables

**Ren.**

$e^-$: abundant!

$H_2$: ~feasible

bio: incidental

Electricity

How to store it?

# Syngas Chemistry

## in conventional and future scenarios

**Gas**
**Coal**
steam reforming
partial oxidation
→
gasification

**Bio**
**mass**
gasification
→
chemical looping

**Sun/Wind**
**$CO_2 + H_2O$**
electrolysis
→
+ rWGS

**Synthesis gas**

$CO + H_2$

(syngas)

water-gas-shift
→
reaction
**$H_2$** ($\rightarrow NH_3$)

**Fischer-Tropsch**
→
**synthesis**
**Synthetic fuels**

methanol
→
synthesis
**$CH_3OH$**
& DME, etc.

- **Storage of electrical energy in fuels via syngas increasingly important in Europe, USA**
- **Integrating renewable electricity in coal gasification technology: China**

DIFFER
Dutch Institute for Fundamental Energy Research

SYNFUELS CHINA

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# Syngaschem's Major Activities:

**SynCat @ Beijing**

The Synfuels China Laboratory for Fundamental Catalysis

Science & Technology for Clean Fuels from Coal

Synfuels China, Huairou, Beijing

**Directors:**

**Yong-Wang Li & Hans Niemantsverdriet**

**15 scientific staff, 5 tech staff, students**

**surface + materials science; catalysis**

**computational modeling**

## Eindhoven: SynCat@DIFFER

- Fundamental Catalytic Surface and Electro Chemistry Research
- Development syngas based storage technology for renewable electricity
- Exploration chemical transistor concept – with Prof Ton Backx, Dept Electrical Engineering

## Coordination of International Research Projects:

- iNano Aarhus; University of the Free State; University of Cape Town

**Development SynCat Academy for Scientific Leadership – with Jan-Karel Felderhof, Impetus**

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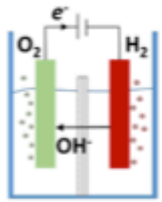
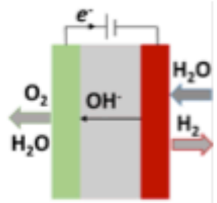
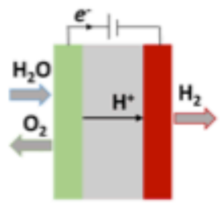
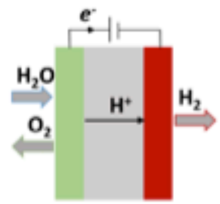
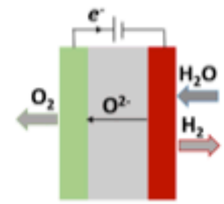
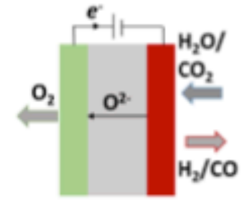
**Sponsoring of scientific and cultural activities**

| | Low Temperature Electrolysis | | | High Temperature Electrolysis | | |
|---|---|---|---|---|---|---|
| | *Alkaline ($OH^-$) electrolysis* | | **Proton Exchange ($H^+$) electrolysis** | | *Oxygen ion($O^{2-}$) electrolysis* | |
| | *Liquid* | *Polymer Electrolyte Membrane* | | *Solid Oxide Electrolysis (SOE)* | | |
| | *Conventional* | *Solid alkaline* | *$H^+$ - PEM* | *$H^+$ - SOE* | *$O^{2-}$ - SOE* | *Co-electrolysis* |
| ***Operation principles*** |  |  |  |  |  |  |
| ***Charge carrier*** | $OH^-$ | $OH^-$ | $H^+$ | $H^+$ | $O^{2-}$ | $O^{2-}$ |
| ***Temperature*** | 20-80°C | 20-200°C | 20-200°C | 500-1000°C | 500-1000°C | 750-900°C |
| ***Electrolyte*** | liquid | solid (polymeric) | solid (polymeric) | solid (ceramic) | solid (ceramic) | solid (ceramic) |
| ***Anodic Reaction (OER)*** | $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ | $4OH^- \rightarrow 2H_2O + O_2 + 4e^-$ | $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$ | $2H_2O \rightarrow 4H^+ + 4e^- + O_2$ | $O^{2-} \rightarrow {}^1/_2O_2 + 2e^-$ | $O^{2-} \rightarrow {}^1/_2O_2 + 2e^-$ |
| ***Anodes*** | Ni>Co>Fe (oxides) Perovskites: $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$, $LaCoO_3$ | Ni-based | $IrO_2$, $RuO_2$, $Ir_xRu_{1-x}O_2$ Supports: $TiO_2$, ITO, TiC | Perovskites with protonic-electronic conductivity | LSM-YSZ | LSM-YSZ |
| ***Cathodic Reaction (HER)*** | $2H_2O + 4e^- \rightarrow 4OH^- + 2H_2$ | $2H_2O + 4e^- \rightarrow 4OH^- + 2H_2$ | $4H^+ + 4e^- \rightarrow 2H_2$ | $4H^+ + 4e^- \rightarrow 2H_2$ | $H_2O + 2e^- \rightarrow H_2 + O^{2-}$ | $H_2O + 2e^- \rightarrow H_2 + O^{2-}$<br>$CO_2 + 2e^- \rightarrow CO + O^{2-}$ |
| ***Cathodes*** | Ni alloys | Ni, Ni-Fe, $NiFe_2O_4$ | Pt/C<br>$MoS_2$ | Ni-cermets | Ni-YSZ<br>Substituted $LaCrO_3$ | Ni-YSZ<br>perovskites |
| ***Efficiency*** | 59-70% | | 65-82% | up to 100% | up to 100% | - |
| ***Applicability*** | commercial | laboratory scale | near-term commercialization | laboratory scale | demonstration | laboratory scale |
| ***Advantages*** | low capital cost, relatively stable, mature technology | combination of alkaline and $H^+$-PEM electrolysis | compact design, fast response/start-up, high-purity $H_2$ | enhanced kinetics, thermodynamics: lower energy demands, low capital cost | | + direct production of syngas |
| ***Disadvantages*** | corrosive electrolyte, gas permeation through diaphragm, slow dynamics | low $OH^-$ conductivity in polymeric membranes | high cost polymeric membranes; acidic: noble metals | mechanically unstable electrodes (cracking), safety issues: improper sealing | | |
| ***Challenges*** | Improve durability/reliability; Enhance OER | Improve electrolyte | Reduce noble-metal utilization | microstructural changes in the electrodes: delamination, blocking of TPBs, passivation | | C deposition, microstructural change electrodes |

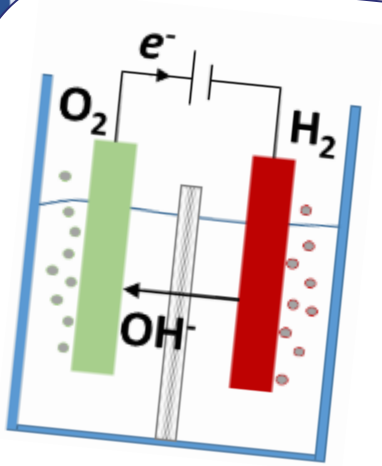
**Low Temperature Electrolysis** | **High Temperature Electrolysis**

*Alkaline ($OH^-$) electrolysis* | *Proton Exchange ($H^+$) electrolysis* | *Oxygen ion($O^{2-}$) electrolysis*

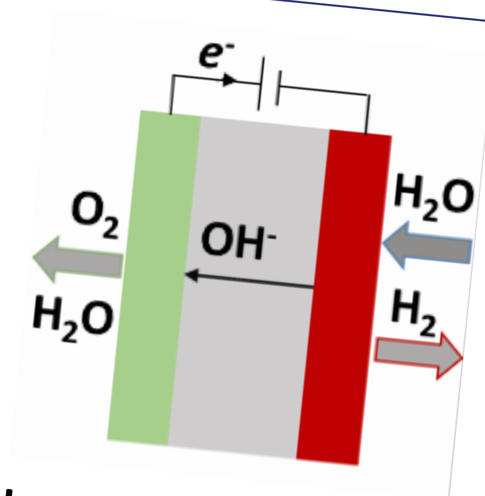
*Liquid* | *Polymer Electrolyte Membrane* | *Solid Oxide Electrolysis (SOE)*

*Solid alkaline* | *$H^+$ - PEM* | *$H^+$ - SOE* | *$O^{2-}$ - SOE* | *Co-electrolysis*

*Operation principles*

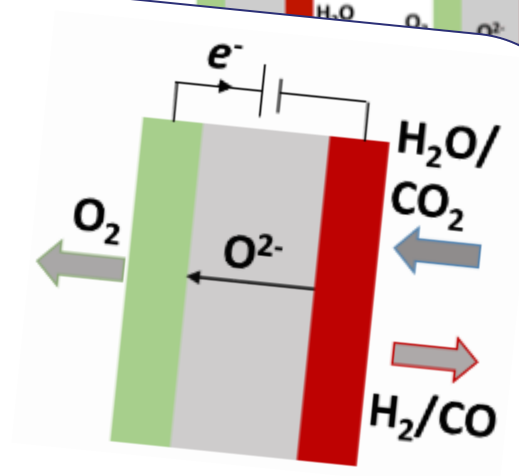



**Novel perovskites for oxygen evolution Theory + Testing**




**OH-conducting membranes + novel iridium complexes**

***EU-H2020 subsidy!!***

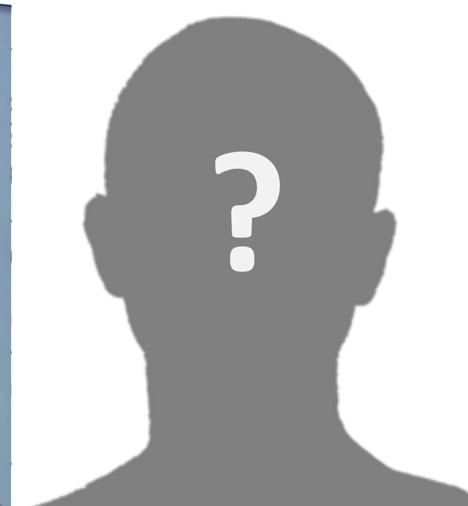



**SOEC (high T) Co-electrolysis New materials**

*Charge carr* | *Temperatu* | *Electroly* | *Anodic Reaction (* | *Anode* | *Cathod Reaction (HE* | *Cathodes* | *Efficiency* | *Applicability* | *Advantages* | *Disadvantages* | *Challenges*

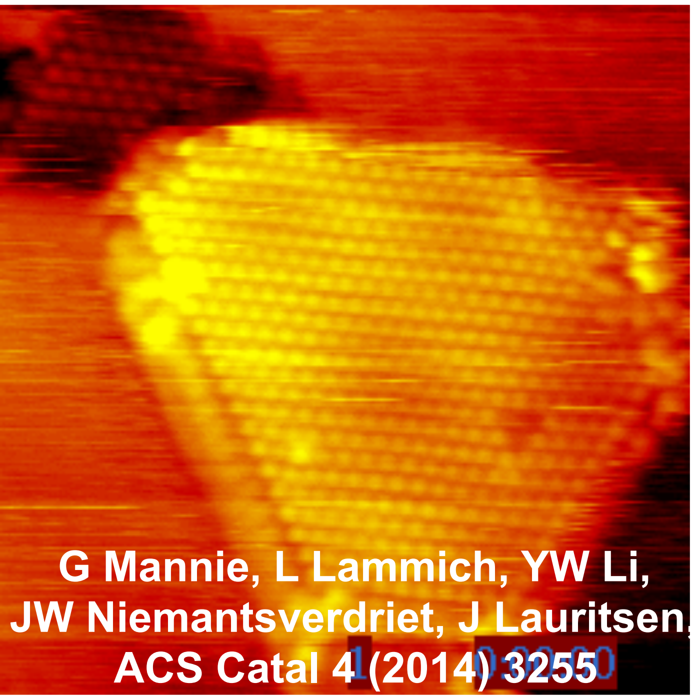
| | | | |
|---|---|---|---|
| *Applicability* | co | le / demonstration | laboratory scale |
| *Advantages* | low relativel te | anced kinetics, lower energy demands, low capital cost | + direct production of syngas |
| *Disadvantages* | corrosive perme diap | anically unstable electrodes (cracking), safety issues: improper sealing | |
| *Challenges* | durabi En | changes in the electrodes: locking of TPBs, passivation | C deposition, microstructural change electrodes |

Dr Foteini Sapountzi



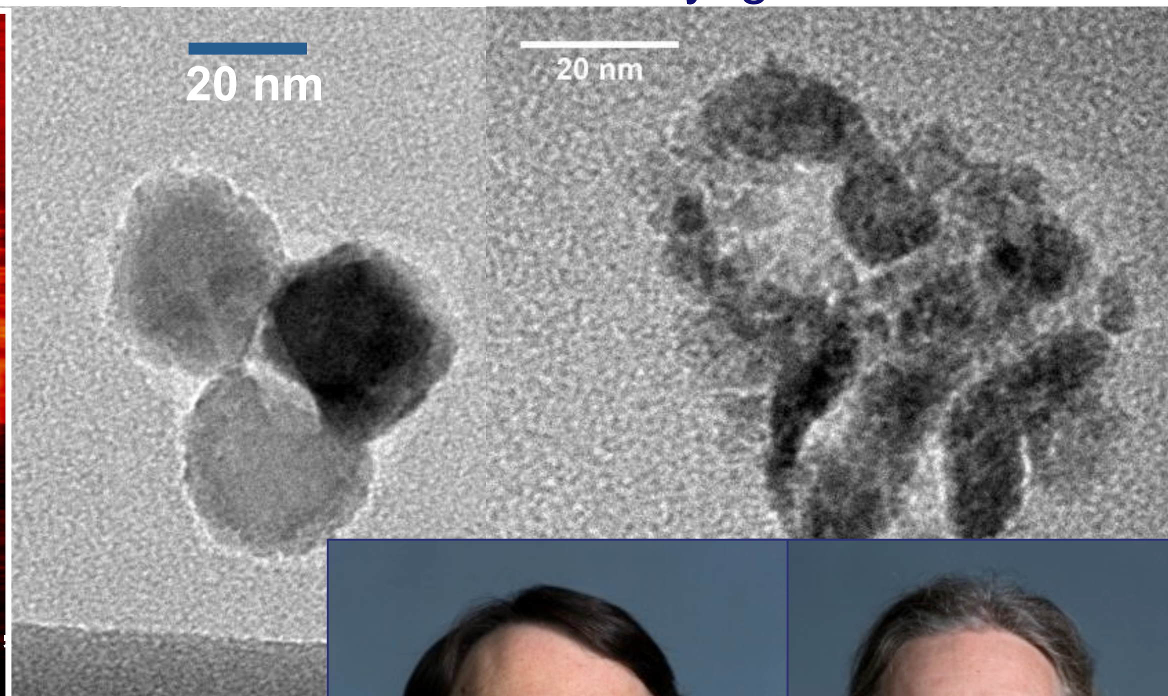
# Fischer-Tropsch Catalyst Modeling

$Fe_xC$ on Au(111)




28 nm iron oxide particles on $SiO_2$/Si(100)

calcined & reduced after syngas 270ºC




Catalyst modeling, Surface Science
in situ characterization, synchrotrons

## Particle dynamics

## Catalytic mechanisms

Kees-Jan Weststrate Hans Fredriksson

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# Syngaschem BV

## Private Research Enterprise; 4,5 fte R&D

- Located at DIFFER Institute on TU/e Campus, Eindhoven
- Dutch Ownership - Chinese (+EU) funding
- Partner SynCat@Beijing of Synfuels China Technology Ltd
- International research in China, Denmark, South Africa
- SynCat Ac@demy for Scientific Leadership Development

**Focus:**

**green electricity in syngas technology**

**electricity storage in NL – greening CTL in China**

Syngaschem moves to DIFFER, January 2016

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