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Electrochemical upgrading of bio-oil: A proof-of-principle investigation

Mehmet Pala

Kun Guo

Wolter Prins

Frederik Ronsse

Korneel Rabaey

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Authors
Mehmet Pala, Kun Guo, Wolter Prins, Frederik Ronsse, Korneel Rabaey, and Antonin Prévoteau

FACULTY OF
BIOSCIENCE ENGINEERING

DEPARTMENT OF GREEN CHEMISTRY AND TECHNOLOGY
RESEARCH GROUP THERMOCHEMICAL CONVERSION OF BIOMASS

TCCB

Electrochemical upgrading of fast pyrolysis bio-oil

Mehmet Pala[1], Kun Guo[2], Antonin Prévoteau[2], Korneel Rabaey[2], Frederik Ronsse[1], Wolter Prins[1]

[1] TCCB Research Group, Department of Green Chemistry and Technology, Ghent University, Ghent, Belgium

[2] CMET, Department of Biotechnology, Ghent University, Ghent, Belgium

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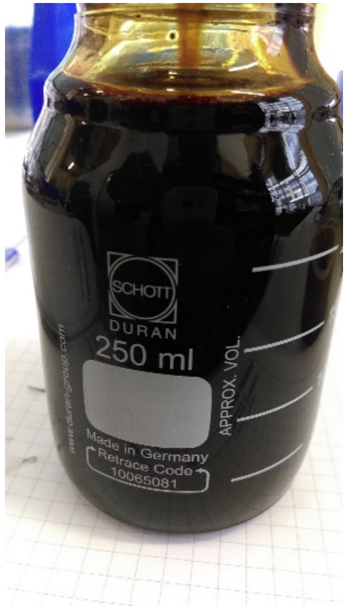
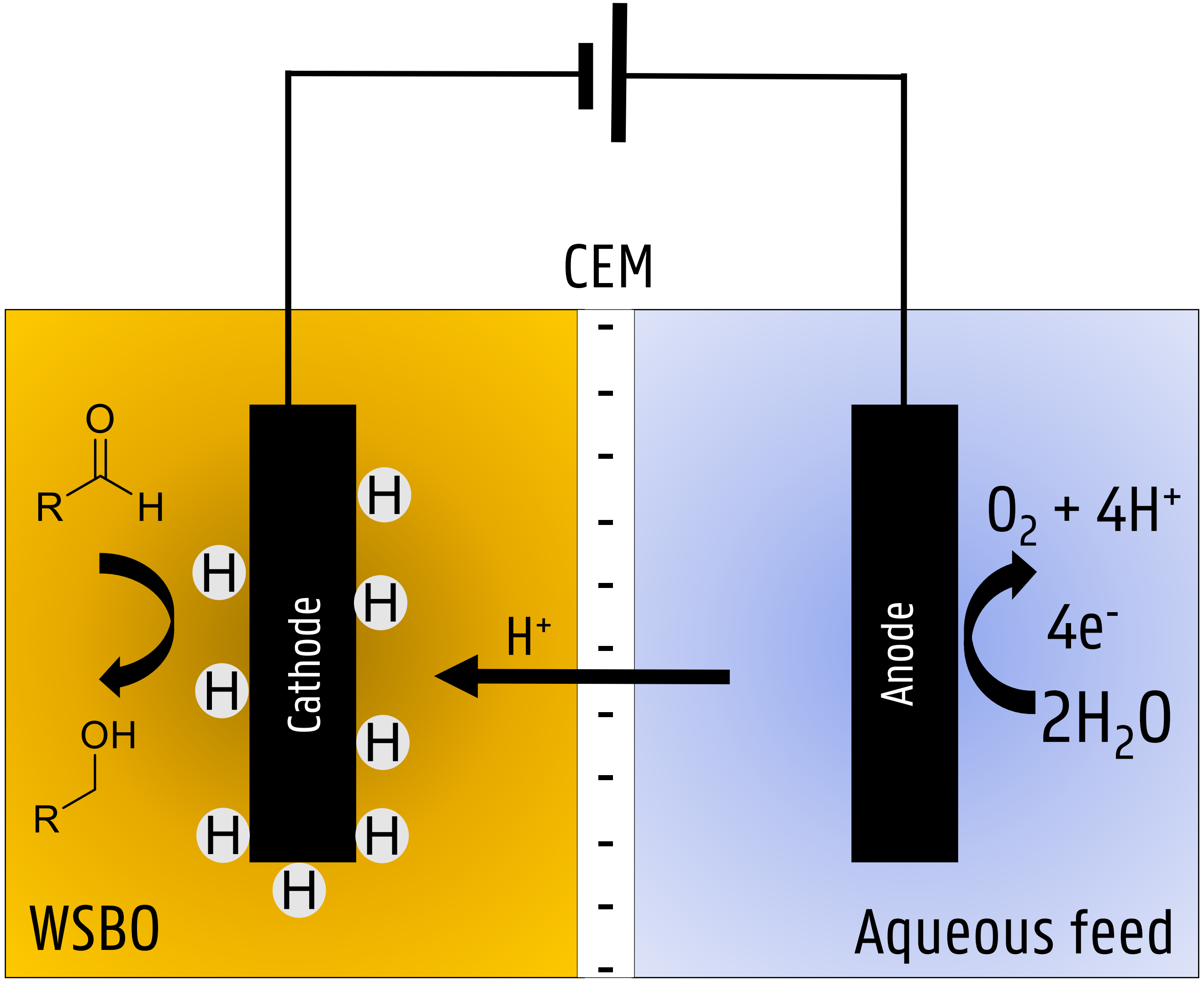
Fast pyrolysis bio-oil needs upgrading



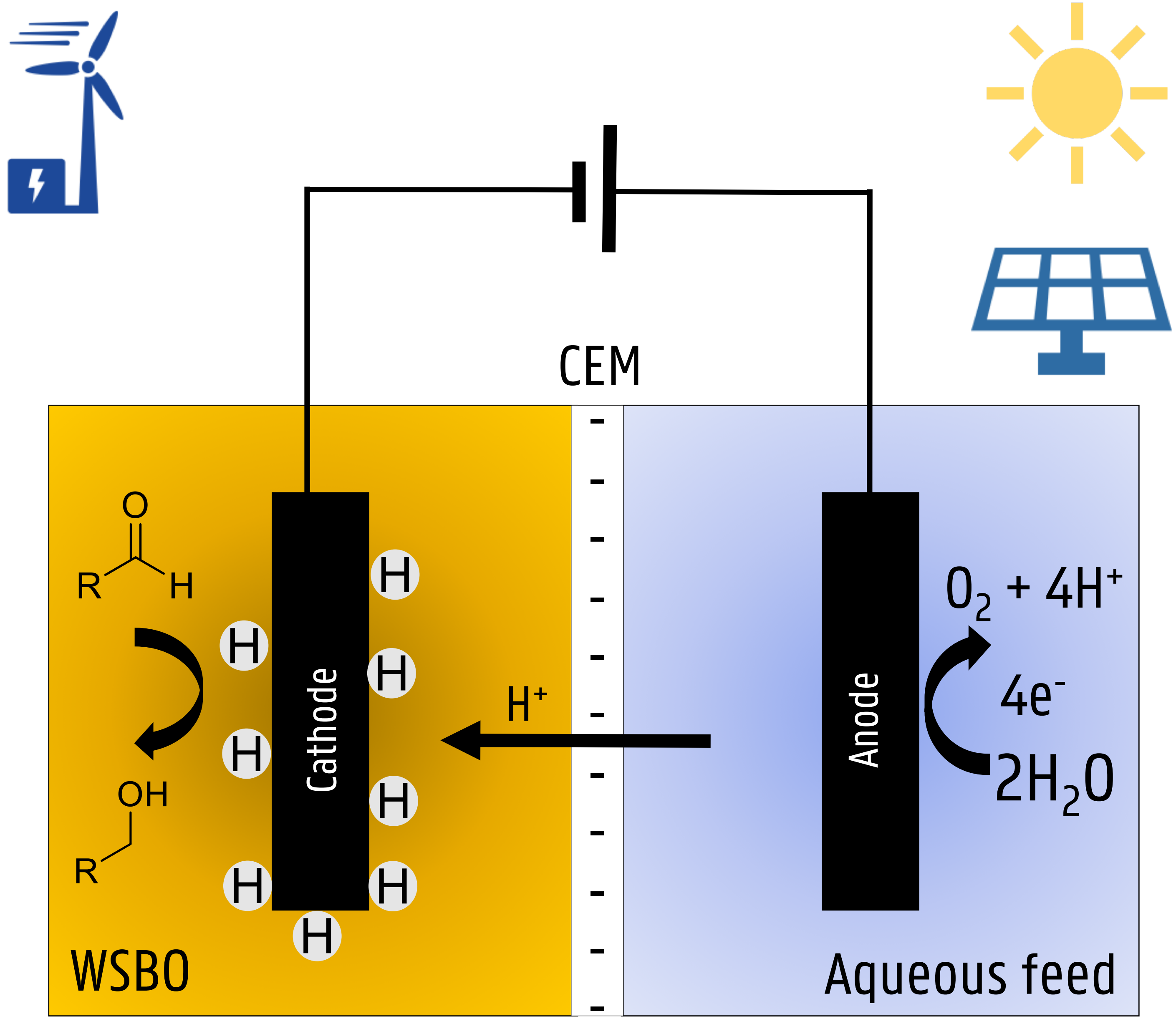
- ⚠ Highly oxygenated
- ⚠ High water content
- ⚠ Unstable
- ⚠ Acidic
- ⚠ Immiscible with HCs

Electrochemical hydrogenation as an attractive alternative



Z. Li, Green Chem., **2014**, 16, 844.

Electrochemical hydrogenation as an attractive alternative



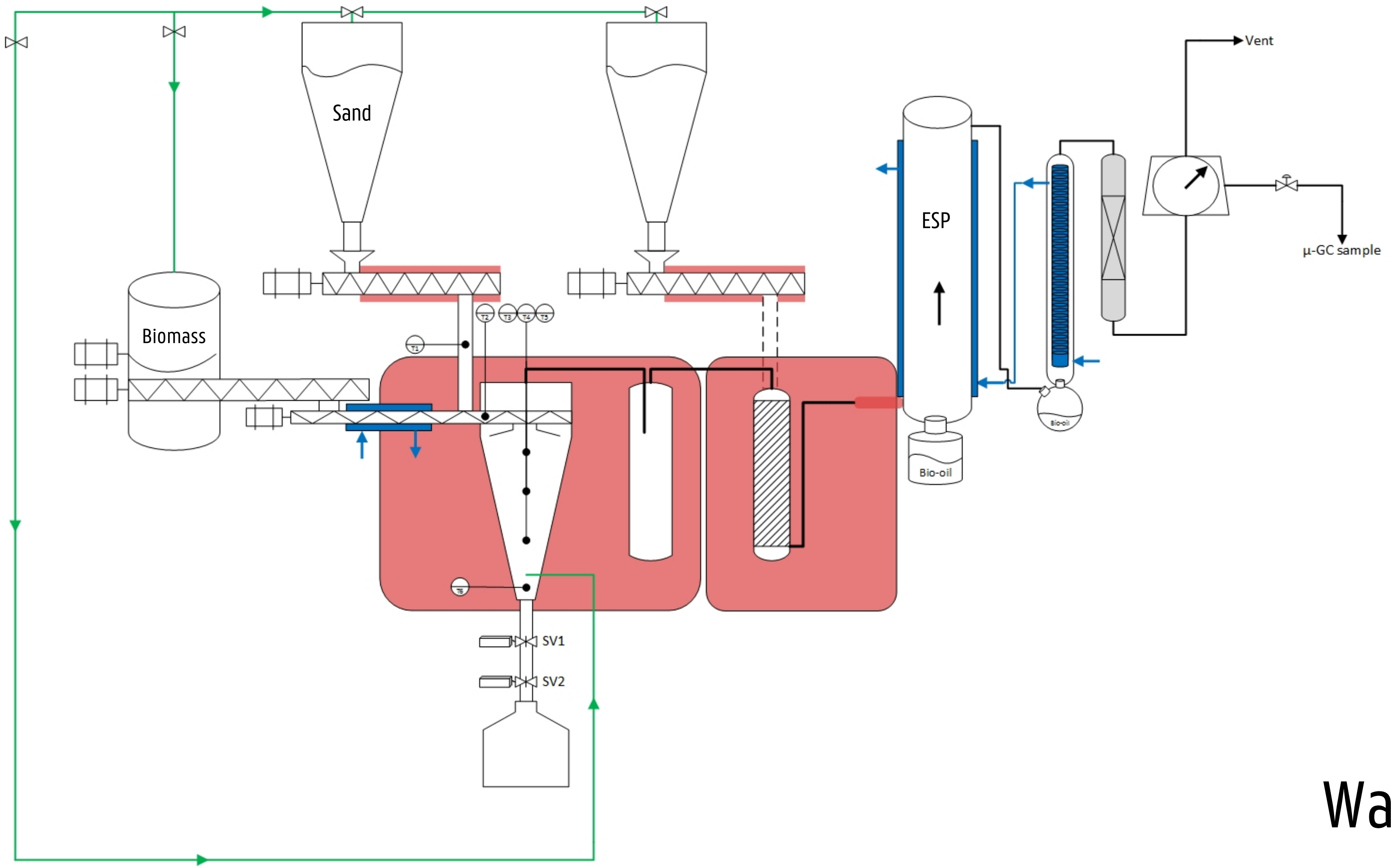
- Water in bio-oil as H_2 source
- Mild operating conditions
- Intermittency of solar and wind power
- Production of stable chemicals
- Electrocatalysts are to be found

Z. Li, Green Chem., **2014**, 16, 844.

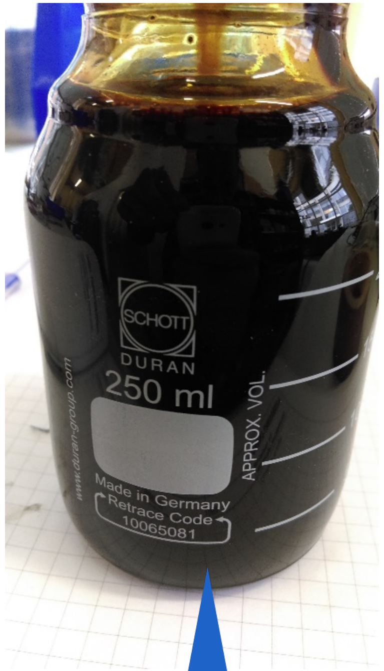
Research objective

Proof-of-principle investigation of upgrading water-soluble bio-oil by electrochemical means

Fast pyrolysis set-up



Pine wood bio-oil



1:1 H_2O fractionation

Water soluble bio-oil

(ca. 20 wt.% organics)

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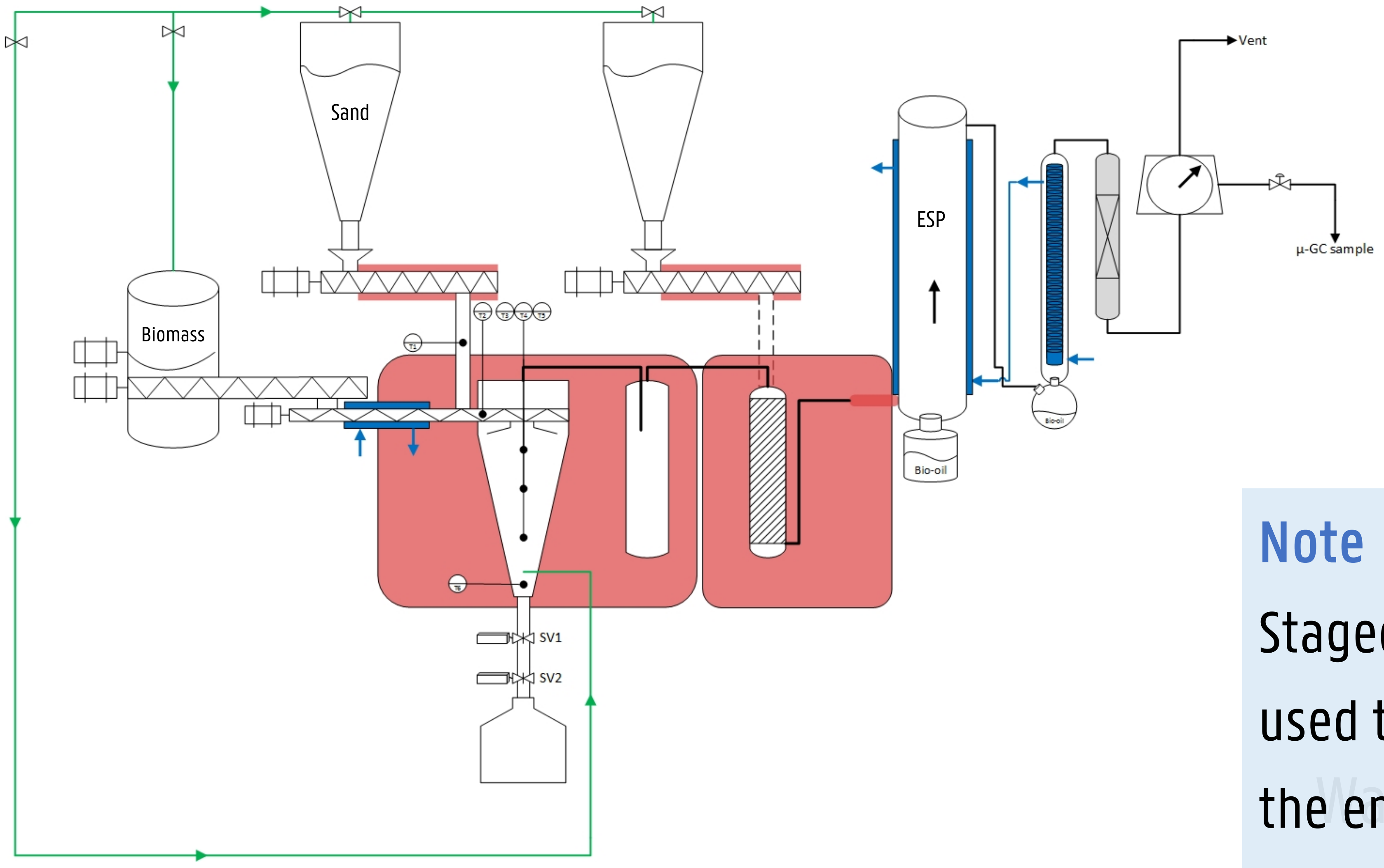
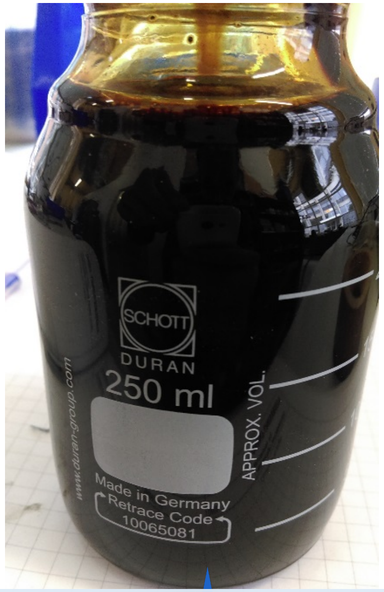
Fast pyrolysis set-up



Pine wood bio-oil



Note

Staged condensation could also be used to obtain a similar fraction at the end of the process

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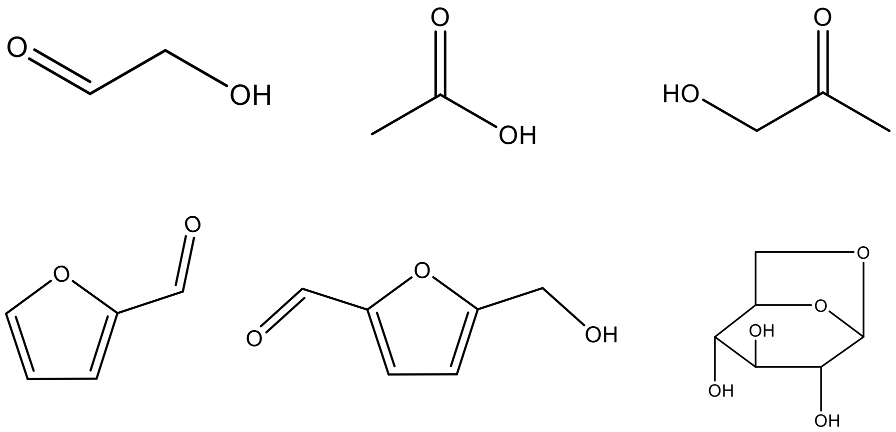
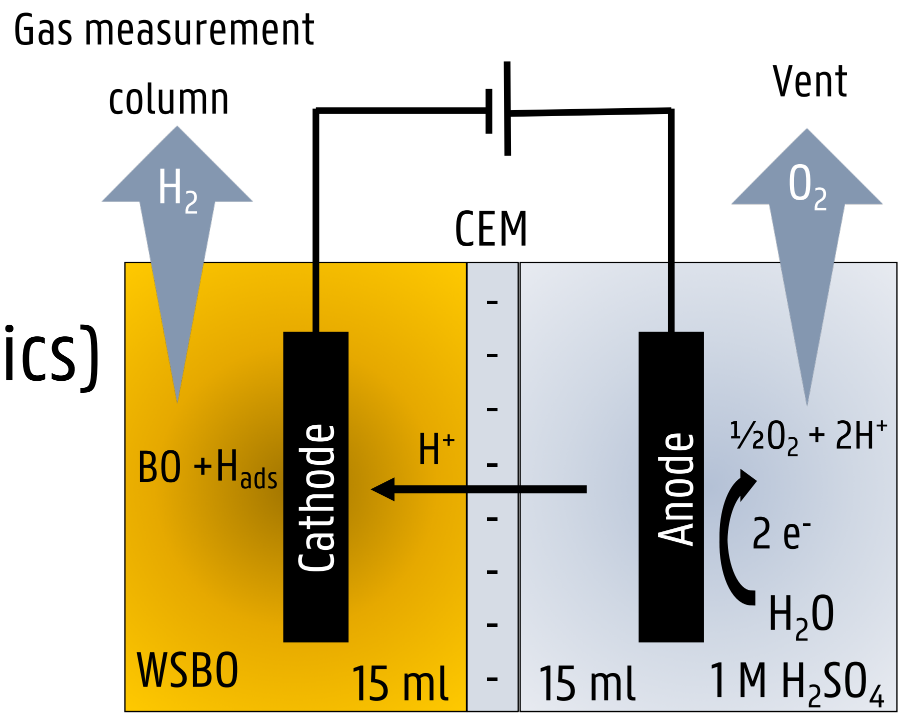
Experimental plan

Feedstock

Water soluble bio-oil (ca. 20 wt.% organics)

Major compounds in WSBO





Process parameters

Chronopotentiometry up to 48h

Current density: 44 mA/cm^2

Temperature and pressure: ambient

Cathodes: **Ti, Pt, Ru, SS, CuZn**

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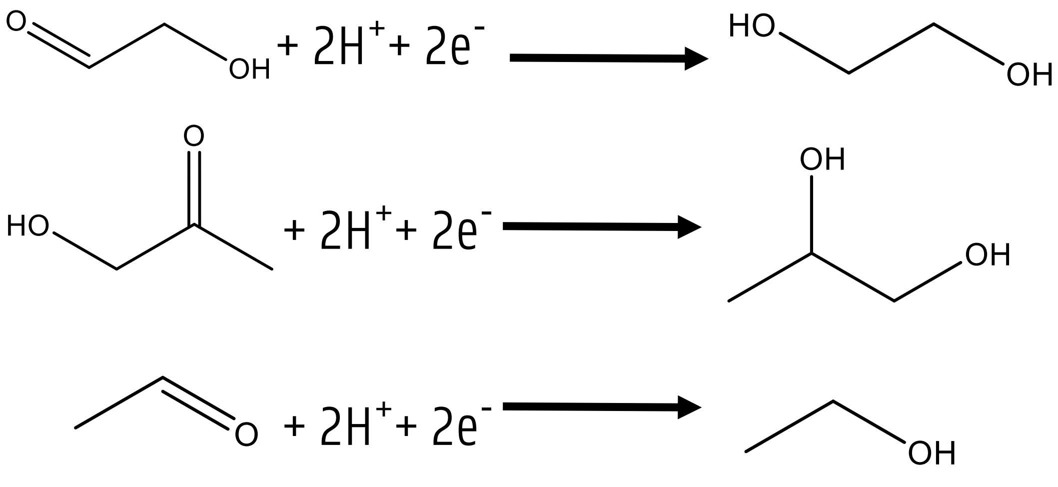
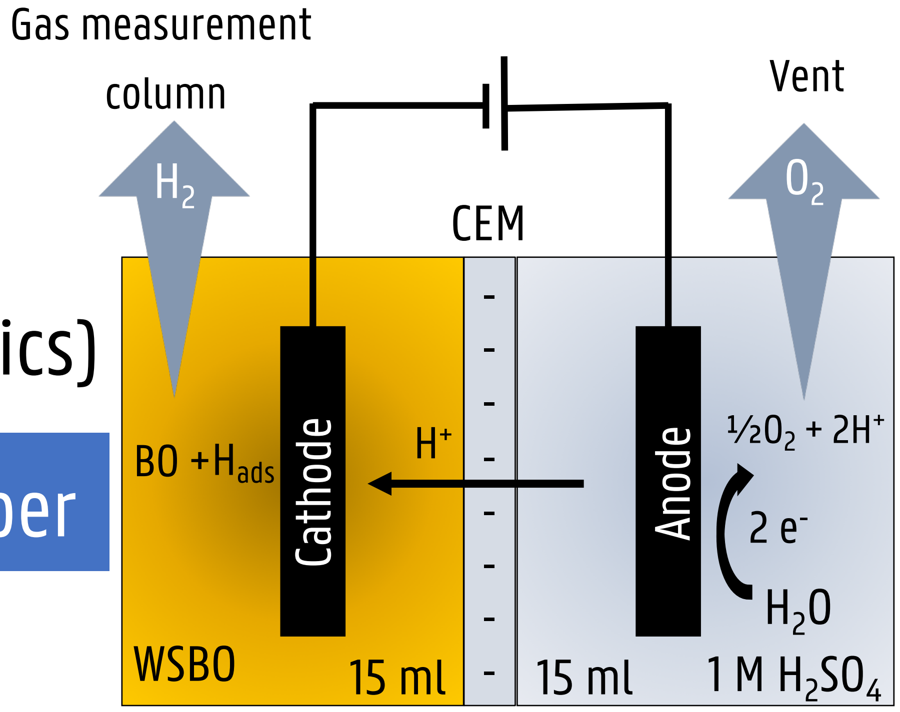
Experimental plan

Feedstock

Water soluble bio-oil (ca. 20 wt.% organics)

Expected conversions in cathode chamber





Process parameters

Chronopotentiometry up to 48h

Current density: 44 mA/cm^2

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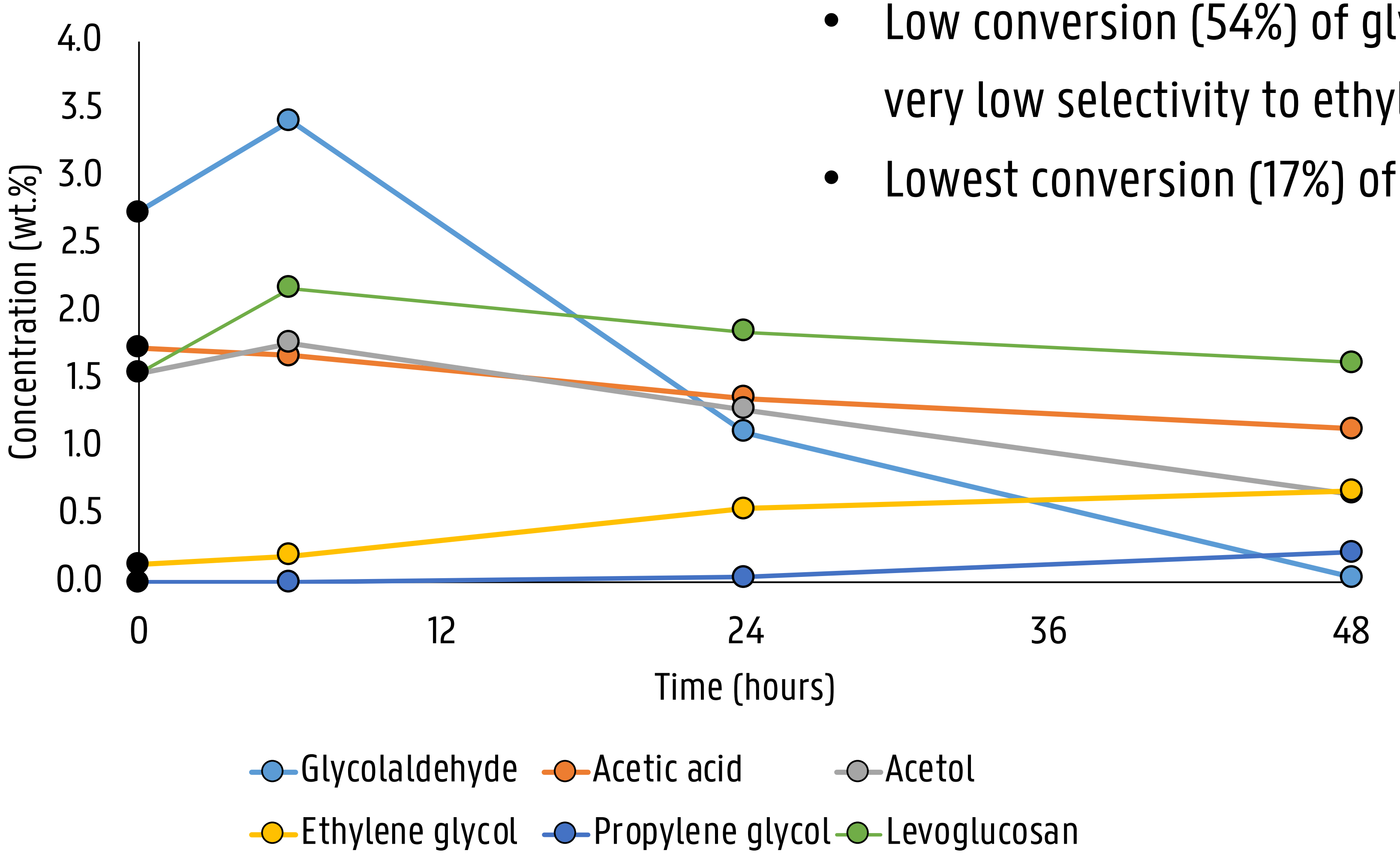
Ruthenium cathode

- Low conversion (54%) of glycolaldehyde after 24h, very low selectivity to ethylene glycol (15%).
- Lowest conversion (17%) of acetol among tested electrodes.



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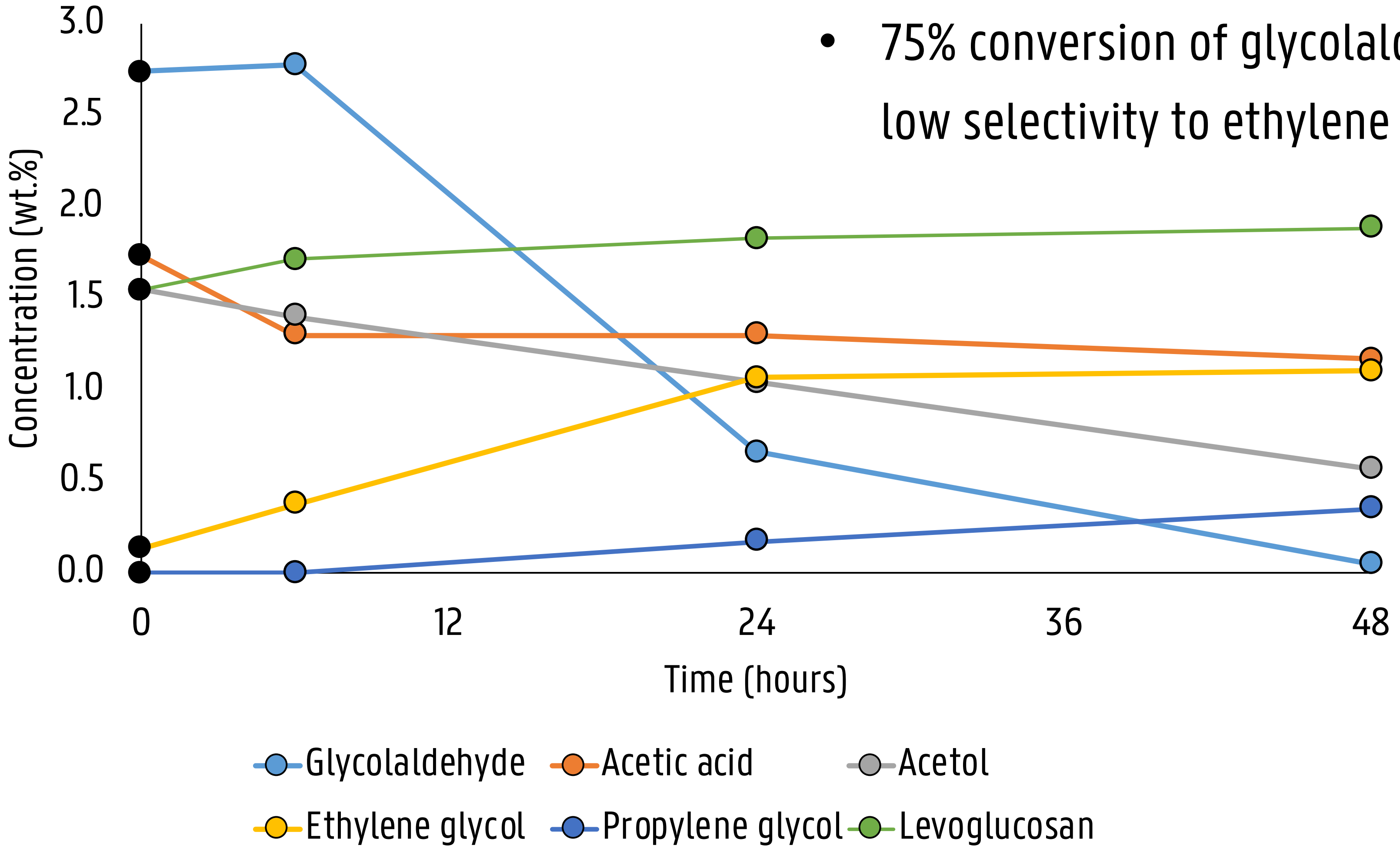
Platinum cathode



- 75% conversion of glycolaldehyde after 24h, low selectivity to ethylene glycol (34%).

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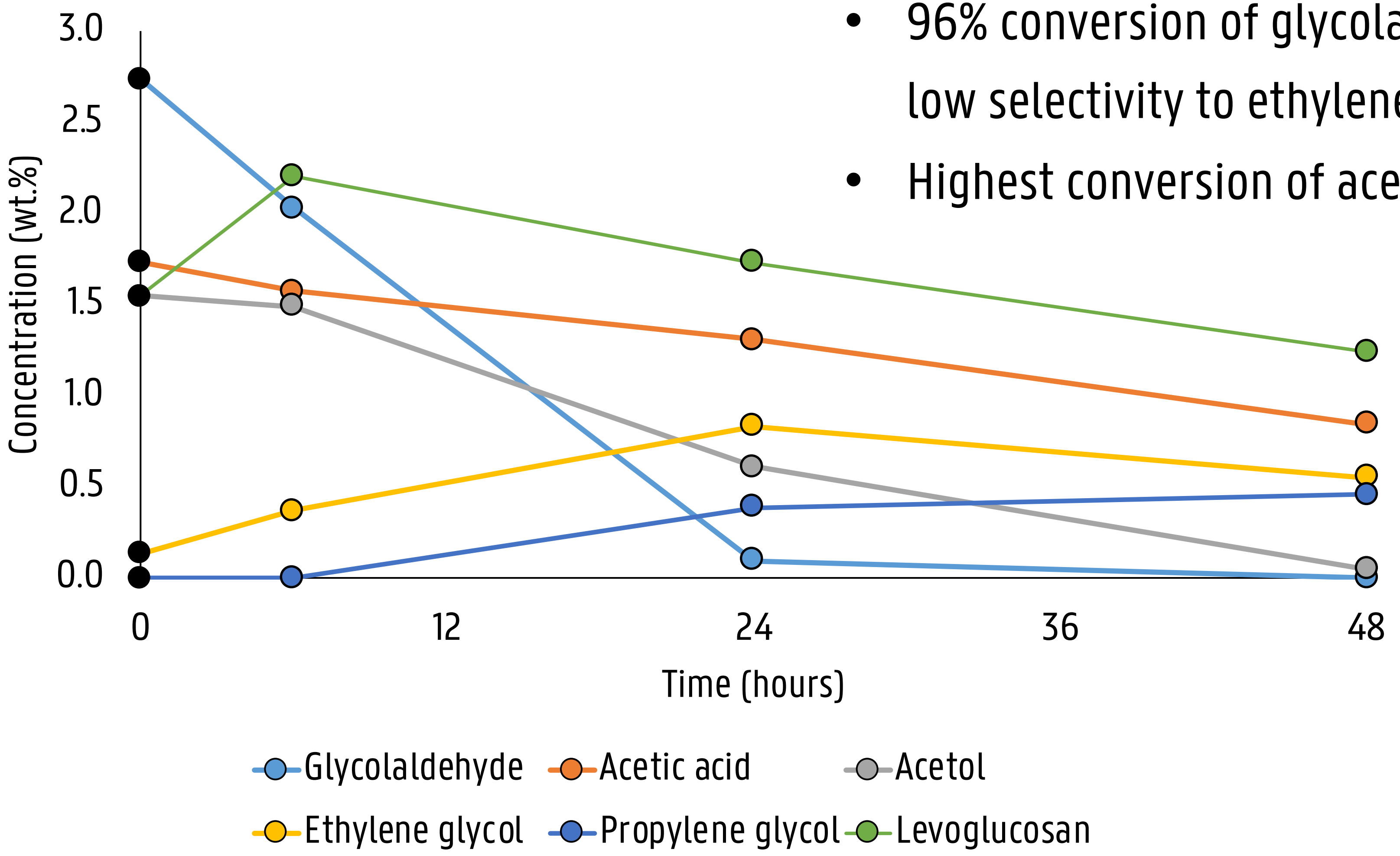
Titanium cathode



- 96% conversion of glycolaldehyde after 24h, low selectivity to ethylene glycol (25%).
- Highest conversion of acetol (60%) among tested electrodes.

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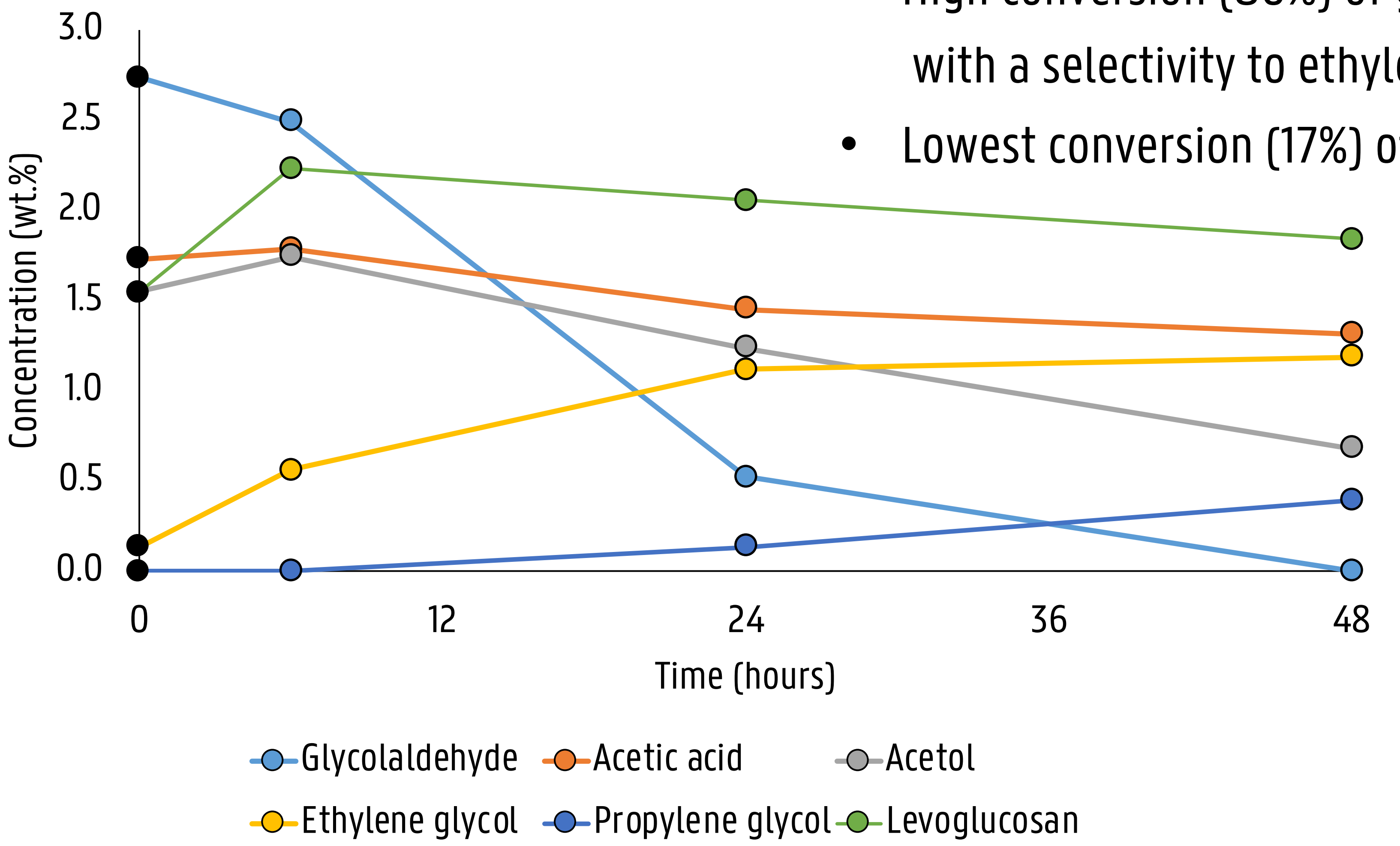
Stainless steel cathode

- High conversion (80%) of glycolaldehyde after 24h, with a selectivity to ethylene glycol (36%).
- Lowest conversion (17%) of acetol among tested electrodes.



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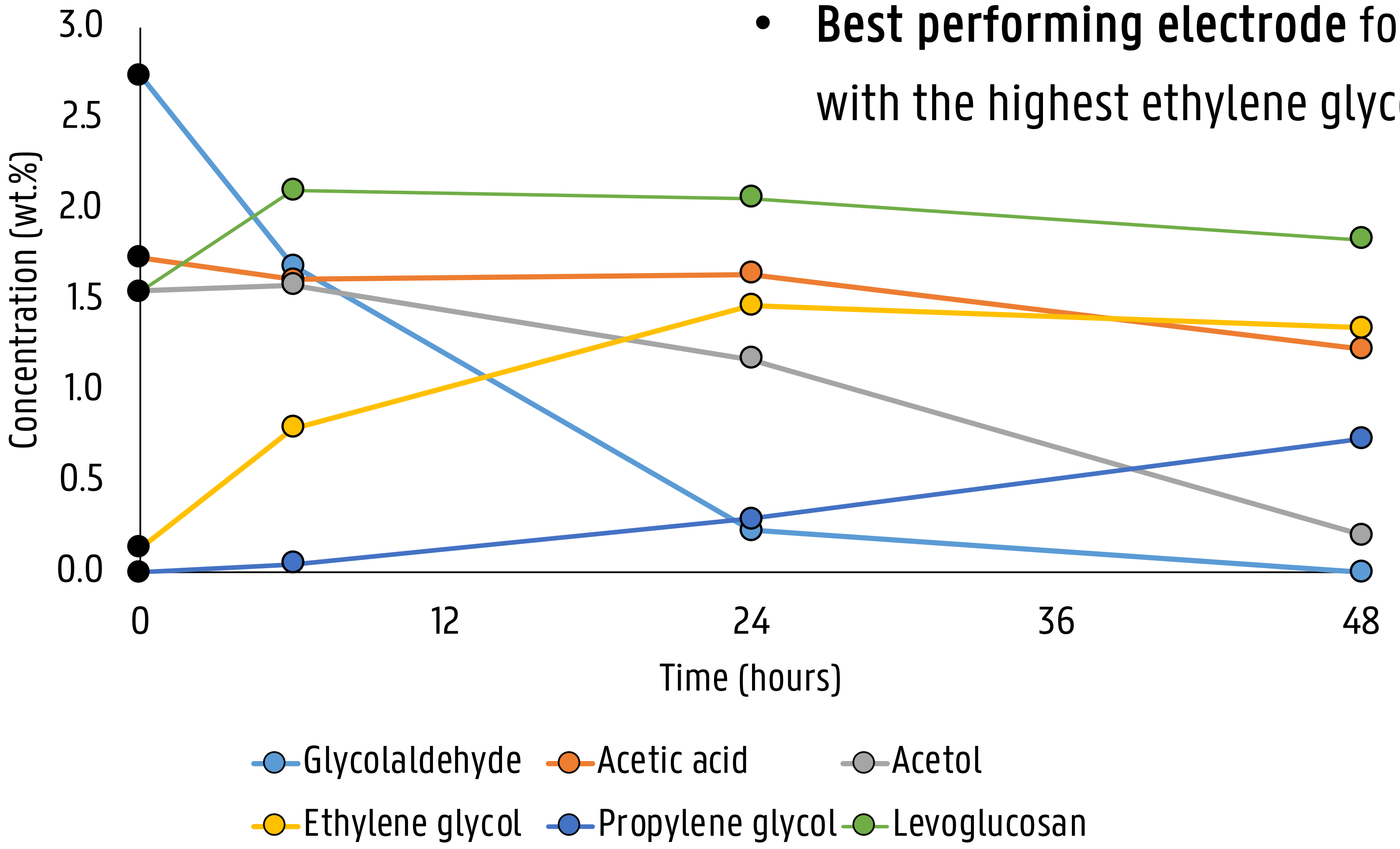
CuZn (brass) cathode



- **Best performing electrode** for glycolaldehyde conversion (90%), with the highest ethylene glycol selectivity of 49%.

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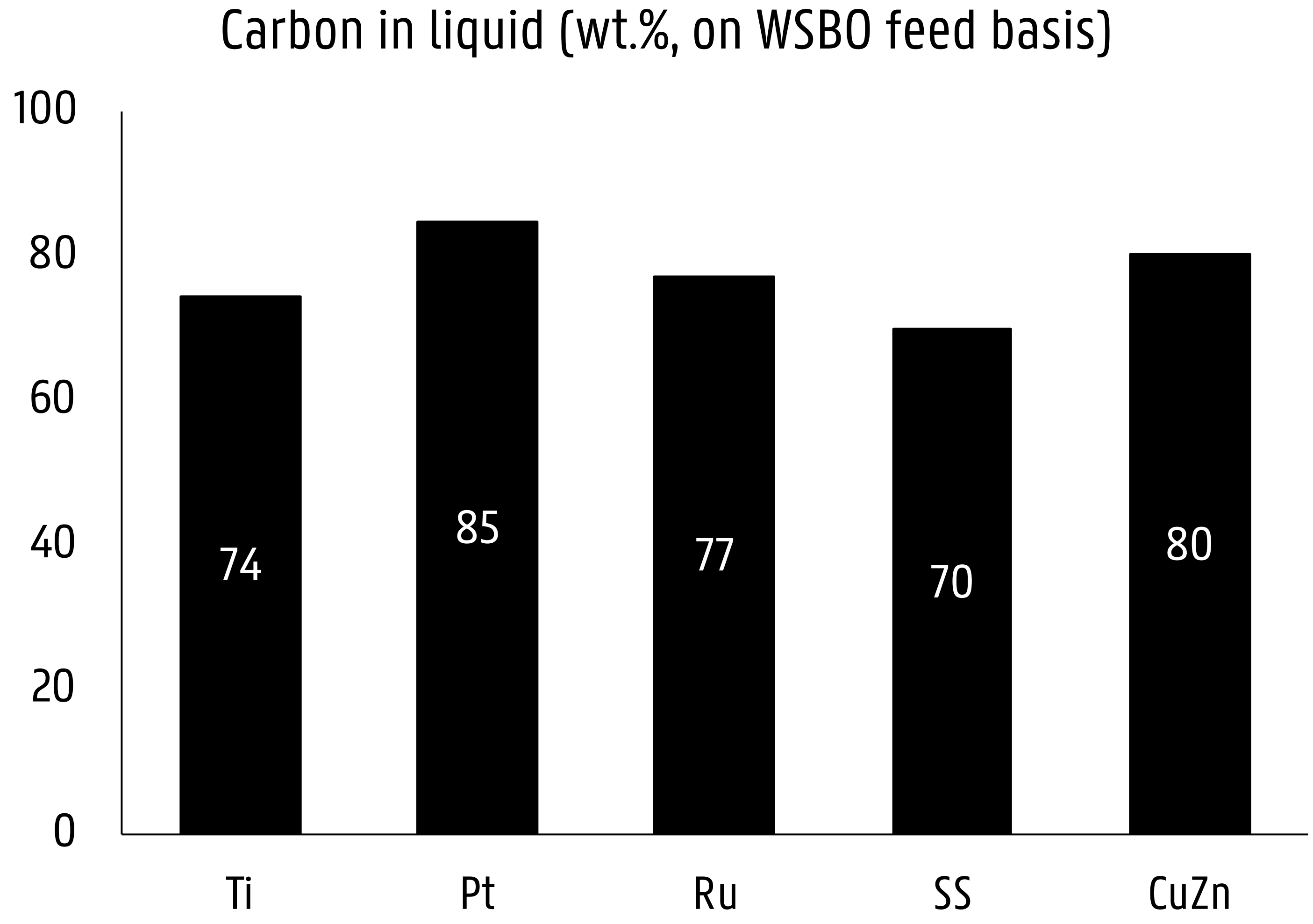
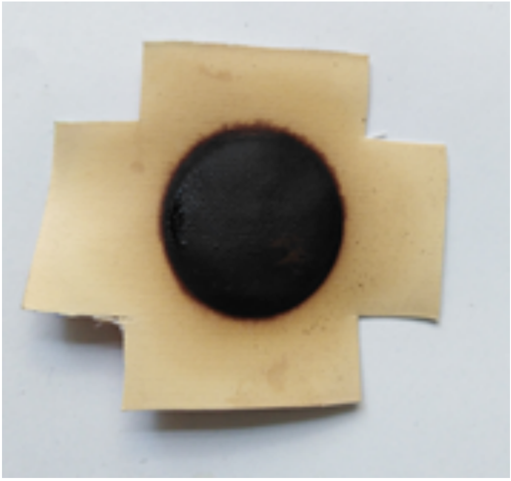
Polymerization occurs to a certain extent, evidenced visually and by loss in carbon





Cation exchange membrane (post-reaction)

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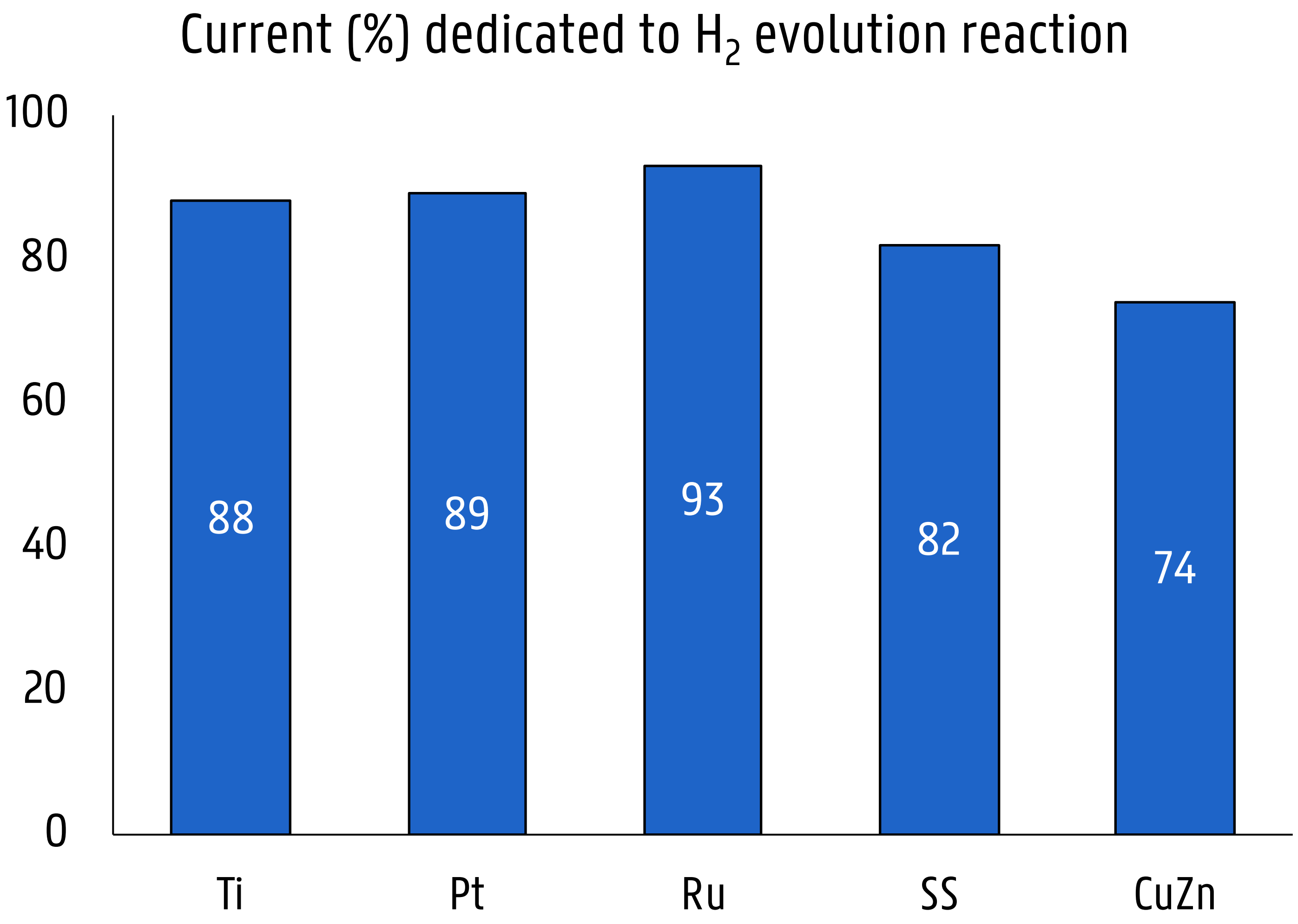
Activity towards ECH is closely related with hydrogen evolution reaction



- Electrodes with high hydrogen overpotential and low organics potential are needed for the ECH of bio-oil components.

Conclusions

- Electrochemical hydrogenation is a viable technology to upgrade / stabilize bio-oil.
- All electrodes converted the carbonyl groups to a certain extent, the order being CuZn>SS>Ti>Pt>Ru, the trend explained in close relation with hydrogen evolution reaction.
- Low energy efficiencies obtained, however, highlight the need for further research.
- ECH is a technology capable of reducing the H_2 requirement for further processing
- Further improvement in the selection of catalytic cathode materials and processing options (e.g. paired process, Kolbe electrolysis in anode to produce HCs.)

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