**Electrochemical production of biobased maleic acid.**

Roman Latsuzbaia, Richard van Heck, Vinita Lachman, Amanda Garcia, Marc Crockatt, Earl Goetheer1

*1 TNO, Dept. of Sustainable Process and Energy Systems, Leeghwaterstraat 44, 2628 CA;*

*\*Corresponding author: roman.latsuzbaia@tno.nl*

**Highlights**

* Furfural oxidation
* Electrochemical maleic acid
* Electro-organic synthesis
* Scale-up

**1. Introduction**

Lignocellulosic biomass is abundant, cheap, and many platform chemicals can be derived from it. An example of such chemical, furfural is a C5 compound, which is already industrially produced from biomass. Many of value added chemicals can be produced from furfural, for instance, maleic acid. Latter is used in variety processes, such as in production of lubricants, plasticizers, pharmaceuticals [1]. Importantly, maleic anhydride, which is easily made from maleic acid, is used for production of bio-based aromatics [2]. Industrially, produced maleic acid currently is fossil based and is produced by hydrolysis of maleic anhydride, which on the other hand is produced by gas phase thermocatalytic oxidation of butane by oxygen catalyzed by vanadium-based V-P-O catalysts, however the process yields only 50-65 % maleic anhydride, therefore very inefficient. Alternatively, electrochemical oxidation allows selective and less energy demanding conversion at ambient pressures and temperatures using cheap catalysts, such as Pb/PbO2 [1, 3].

Our research focused on scaling-up of the production of maleic acid to industrially relevant conditions (>5wt %) utilizing a plate-and-frame type electrolyser.

**2. Methods**

Electrolysis was performed in a divided cell and plate-and-frame type electrolyser (Nafion® membrane) at RT under acidic conditions with anode Pb/PbO2 and Pt or Pb cathode with anolyte: 0.5 M H2SO4 with/without 0.02 M V2O5 or 0.02 M NaMoO4 and catholyte 0.5 M H2SO4. Potentiostatic and galvanostatic electrolysis modes were used for production of maleic acid.

**3. Results and discussion**

The electrolysis was investigated directly on Pb/PbO2 electrode, and the effect of mediators such as V2O5 and NaMoO4 was investigated. Optimal potentiostatic operation was performed at 1.5 V vs SCE, whereas the optimal galvanostatic operation was performed at a current density of ~10 mA/cm2. With starting concentration of 0.05 M furfural, the yield on maleic acid was ~80% with a main side product an oxidation intermediate, formyl acrylic acid. Almost quantitative yields can be achieved if all formylacrylic acid is converted to furfural. Effect of reactant concentration was investigated (0.05- 0.5M furfural). The reaction was tested at temperatures of 25 and 35 0C, realizing higher reaction rates and yields of maleic acid at elevated temperatures. Permeation of the reactants, products and mediators through membrane was investigated and process optimized. Additionally, downstream processing possibilities of maleic acid have been investigated. Based on the obtained results techno-economic feasibility study has been performed and showed economically favorable production costs.



**Figure 1.** Conversion and yield of electro-oxidation of furfural to maleic acid on PbO2 electrode in 0.5 M H2SO4.

**4. Conclusions**

Electrochemical production of biobased maleic acid by oxidation of furfural was demonstrated for the first time in a plate-and-frame type electrolyser at industrially relevant conditions. Yields >80% were obtained. Preliminary techno-economic analysis shows that the production process has a high potential to replace fossil based maleic acid production.

**References**

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