

Catalyst development for co-production of hydrogen and chemical via waste electrolysis.



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PROJECT BACKGROUND

As global warming increases, a large amount of investment is being put into the recycling of PET bottles specifically, through the process of depolymerization, PET waste derived Ethylene Glycol can be produced after subsequent Hydrolysis, Methanolysis and Glycolysis. The Waste produced Ethylene Glycol and NaOH can be used as anolytes and catholytes in Membrane Electrode Assemblies to monitor current densities and to measure hydrogen and chemical production. Glycolic acid is one of the main chemicals produced through this process and the market for this chemical is projected to increase to \$531M from \$310M as it is mainly used in skin care products, polyglycolic acid and chemical cleaning

INTRODUCTION

By feeding EG solution into an electrolyser, this process resembles water electrolysis but requires much lower thermodynamic energy input (<30 kWh/kg H₂ vs. 52.1 kWh/kg H from proton-exchange-membrane water electrolyser), which may bring green H₂ cost to < £2/kgH. The key to realising this technology is developing efficient electrocatalysts on the anode to drive the EG oxidation reaction with high activity and selectivity. This project aims to develop and test three active and selective Au-based catalyst, owing to its high activity towards alcohol oxidation.

EXPERIMENTAL METHODS

Sample Preparation

The home made 10% Au/c-Nitrogen 400 anodes were prepared with 180 mg Au/C catalyst that was dispersed in 8400uL DI water, 2880uL ethanol and 720uL sustainion XA-9 Alkaline ionomer binder, then placed in the ice bath for more sonication for a further 10 minutes. The ink produced was put in the spray gun using a pipette after four 3x3cm pieces of carbon paper were cut and placed on the hot plate till 60°C, the carbon paper was sprayed till the ink finished for 1-2 hours. This was done to achieve a coverage of 0.5mg/cm² of the carbon paper as seen in figure 1.

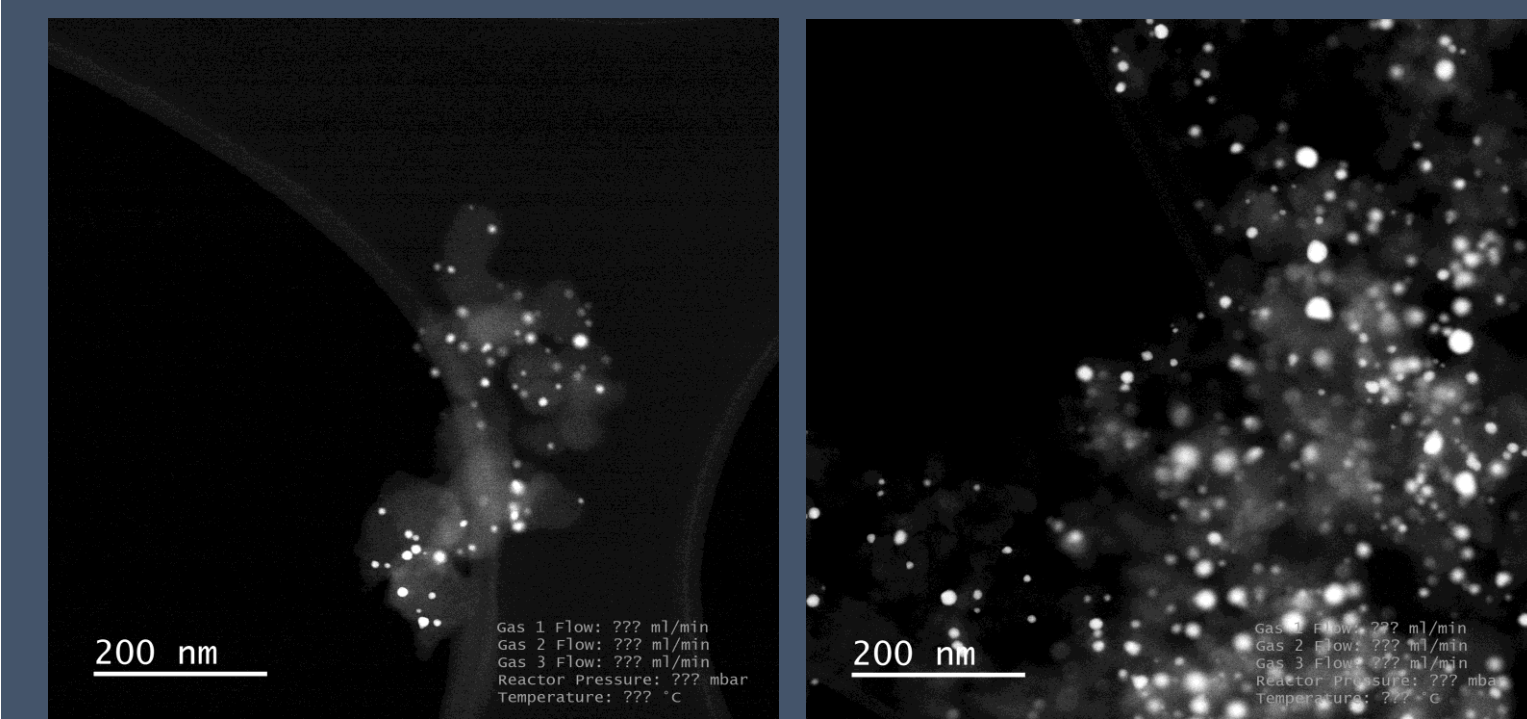
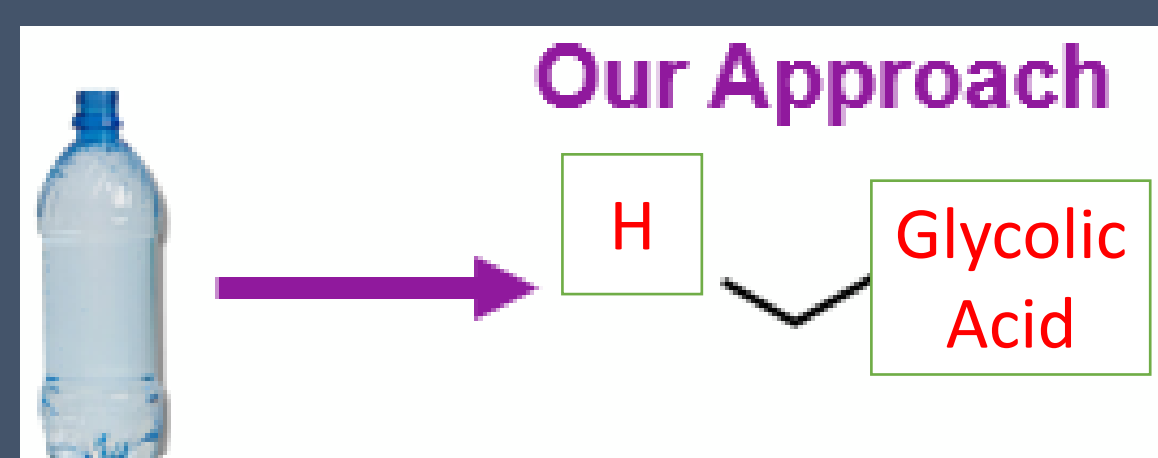


Figure 1: 10% Au/c-Nitrogen 400 Figure 2: 10% Au/c-Air 400

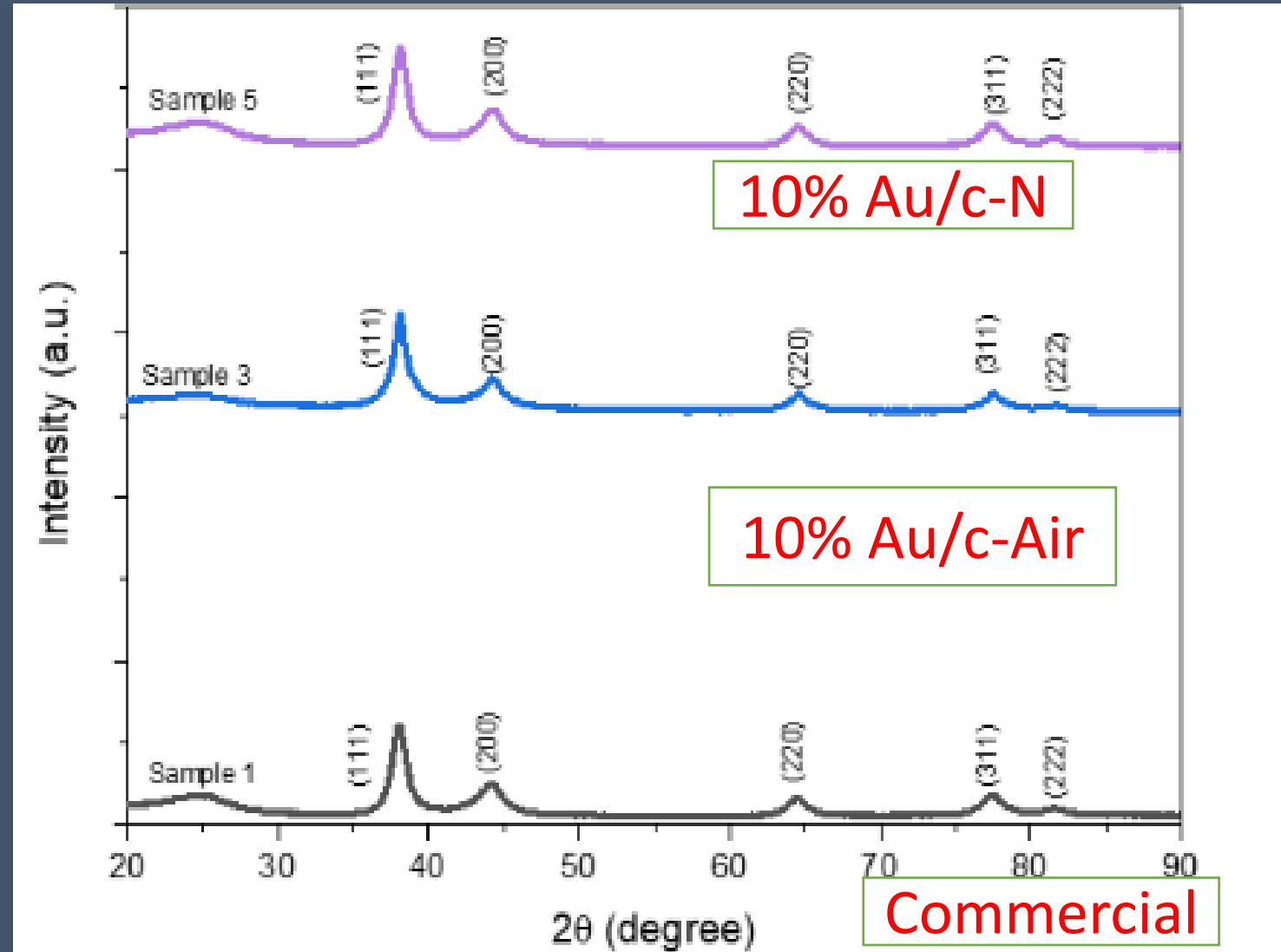


Figure 10: XRD results for all three electrodes

An identical preparation method was had for the 10% Au/c-Air 400 anode in Figure 2, the cathode electrode was pre-prepared for use with sufficient cathode electrodes being available.

The X-ray diffraction was performed on the 3 anodes that were tested, a face centered cubic shape was found and all the peaks were aligned according to literature provided.

Electrolysis Cell Preparation

MEA was used to run chronopotentiometry experiments in the different electrodes, the cell was assembled with the Au/c coated side of the anode placed facing the membrane then a separator was placed in between the membrane and the cathode which was also placed with the coated side facing the membrane. The anolyte was 1mol EG +NaOH while the catholyte was 1mol NaOH, 10mg of both were used during each experiment.

The MEA experiment is run at 0.05amp, 0.1amp, 0.25amp and 0.5amp currents, each experiment is run for an hour, 200microlitre of the anolyte and catholyte are collected in different vials and are put in the HPLC to determine chemicals that are formed after MEA.

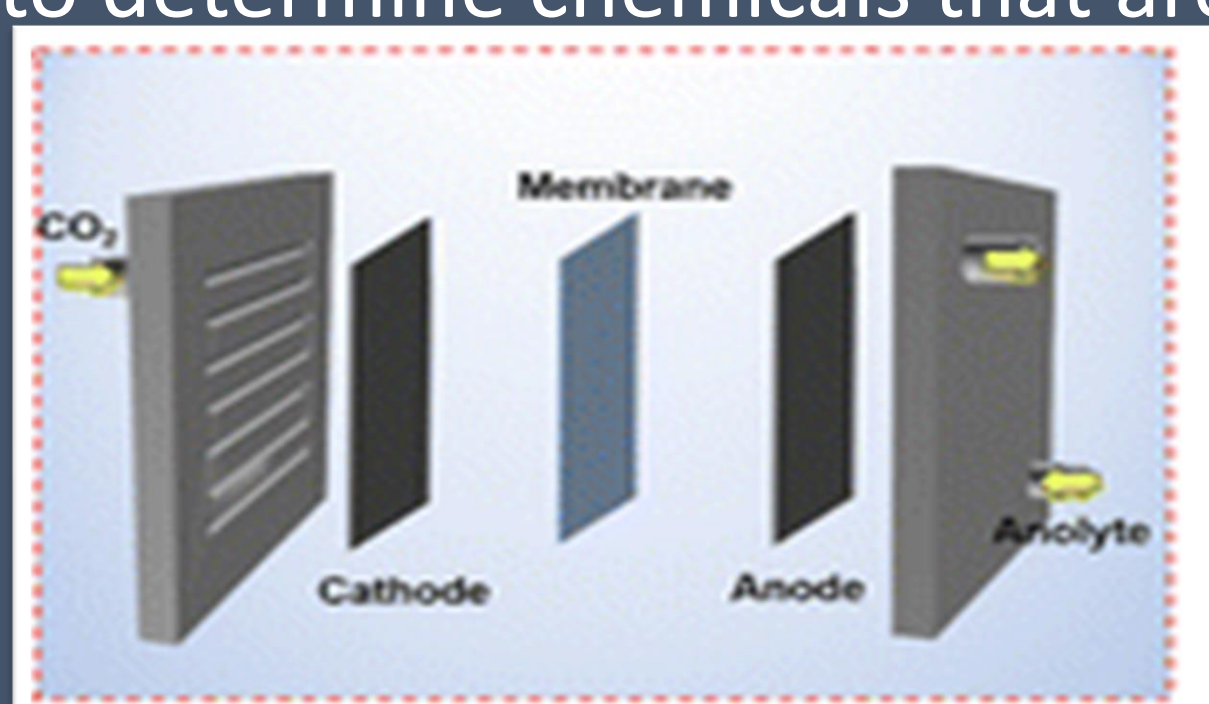


Figure 3: 10% Membrane electrode assembly

RESULTS

By compiling the results produced from the MEA for Voltage vs Time, all the three electrodes were run three times with a different set of the same electrode for each test date, the best result for each electrode was picked. HPLC to find concentrations of chemicals formed from waste electrolysis like Glycolic Acid, Oxalic Acid, Glyoxylic acid and Formic acid.

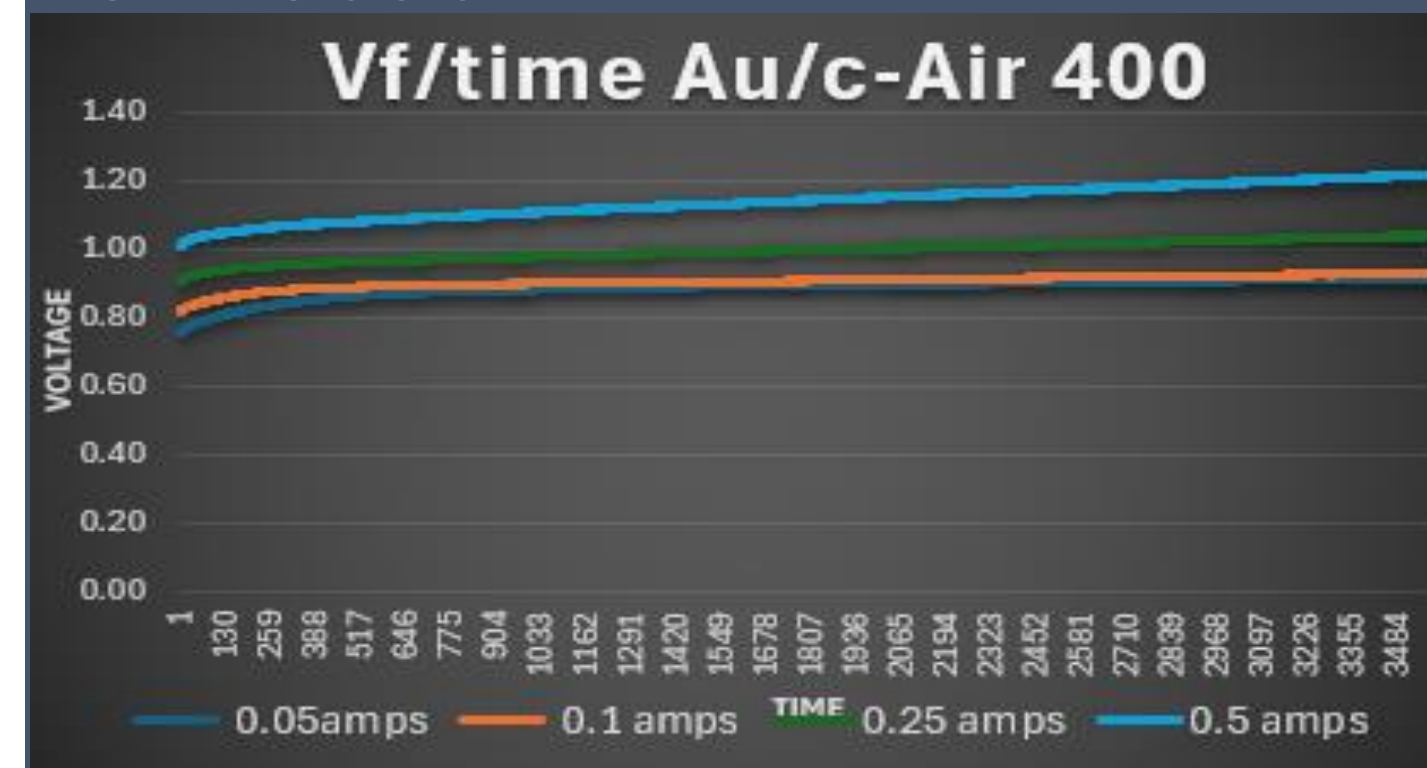


Figure 5: MEA result for 10% Au/c-Air 400 anode

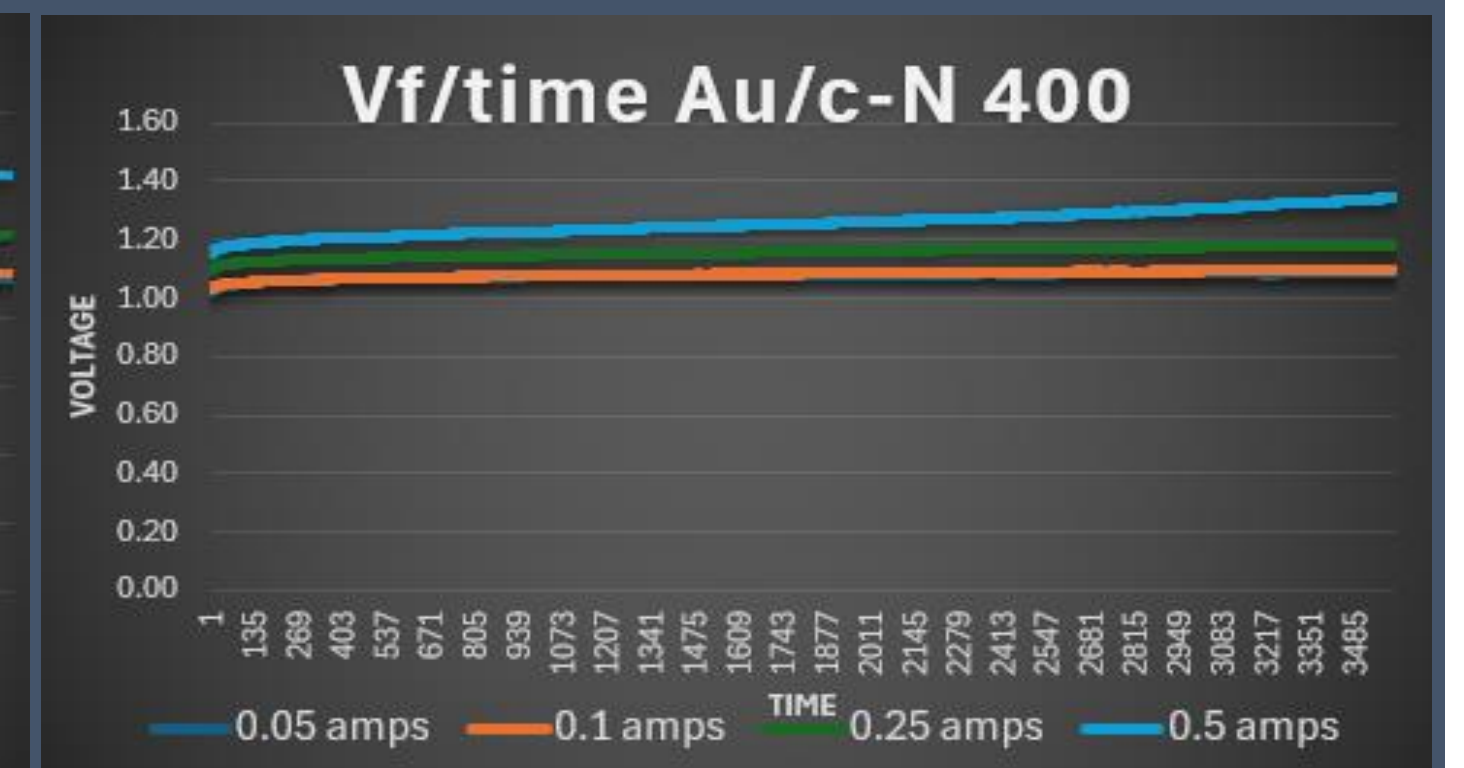


Figure 6: MEA result for 10% Au/c-Nitrogen 400 anode

The 10% AU/c-Air 400 electrode had a lower overall voltage than the 10%Au/c-N 400 electrode, this confirmed it to be the most effective electrode, and overall best performing electrode as it had a max voltage of 1.22v whilst the Nitrogen had a maximum of 1.39v.

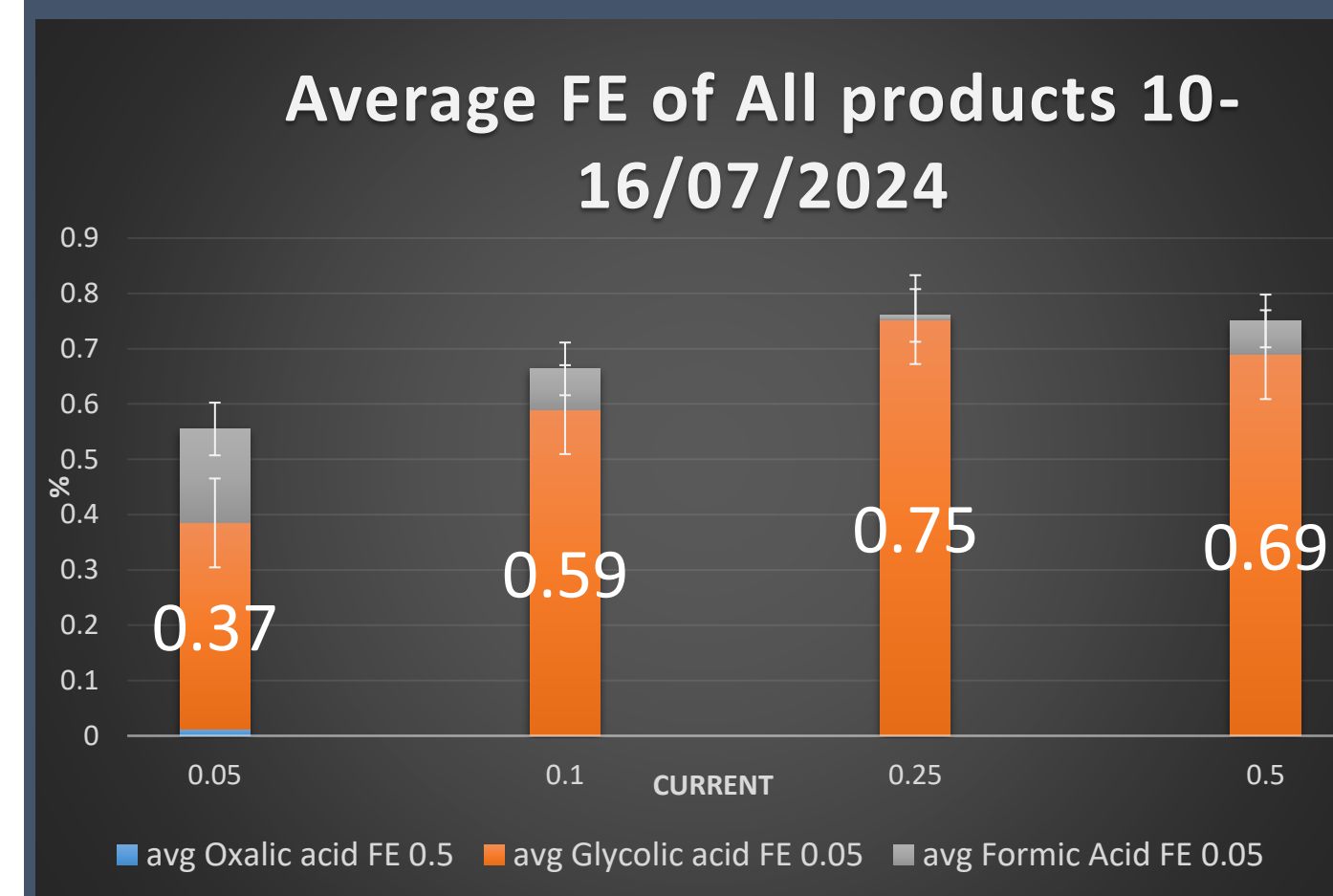


Figure 7: HPLC result for 10% Au/c commercial anode

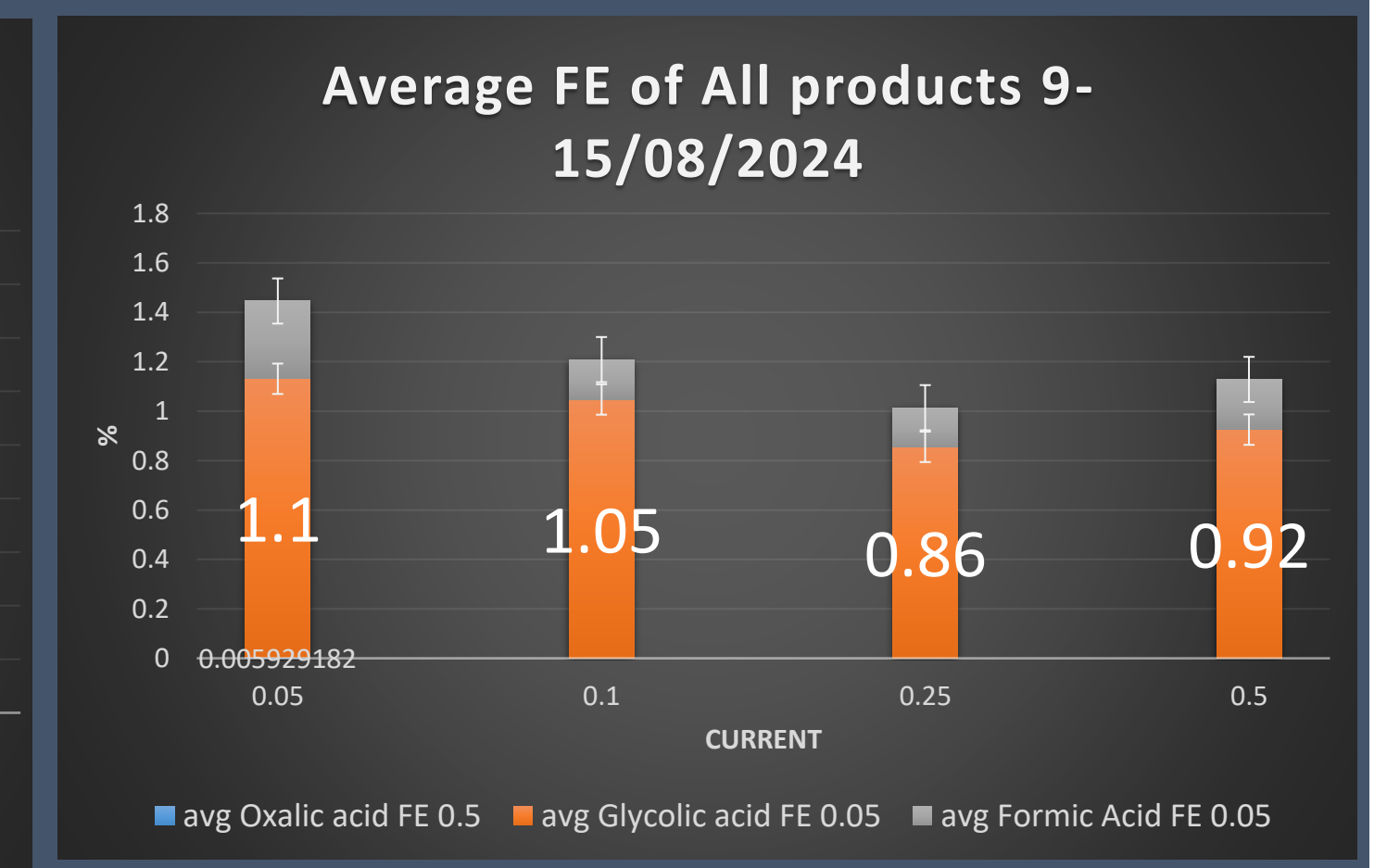


Figure 8: HPLC result for 10% Au/c-N 400 anode

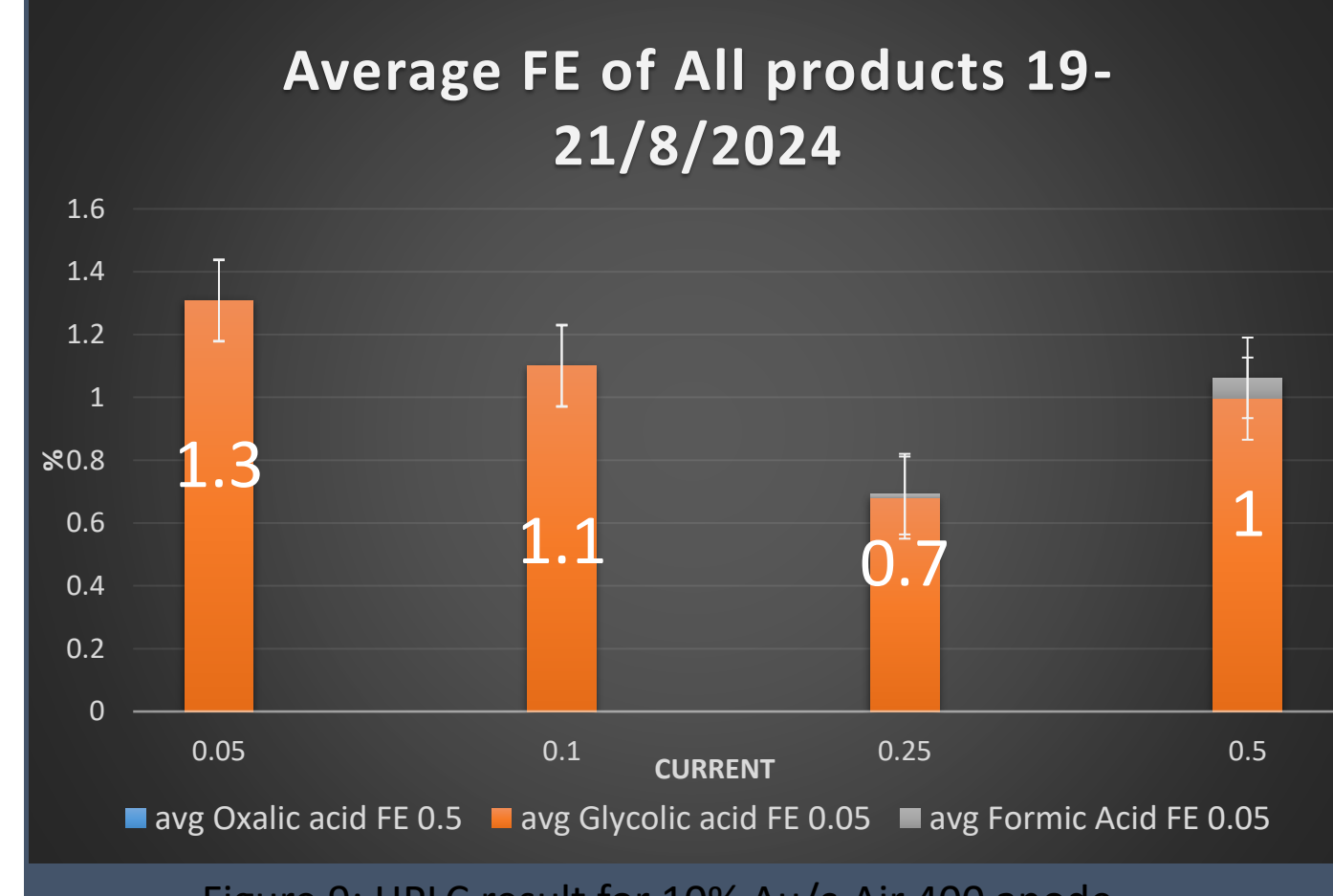


Figure 9: HPLC result for 10% Au/c-Air 400 anode

There was an inherent increase in the glycolic acid production from the tests ran on the commercial Au anode, and in both homemade electrodes, with the air electrode having a higher overall amount of Glycolic acid produced, rendering it the best performing electrode.

The process of formation of the above acids are represented in the figure below. The 10% Au/c-Air 400 has less of a poisoning effect thus producing more Glycolic acid than the other electrodes as it had the lowest amount of Formic acid, the presence of the Pt cathode produced glyoxylic acids which was then converted to oxalic acids with a tiny trace of it being produced within the Au/c-N 400 anode only.

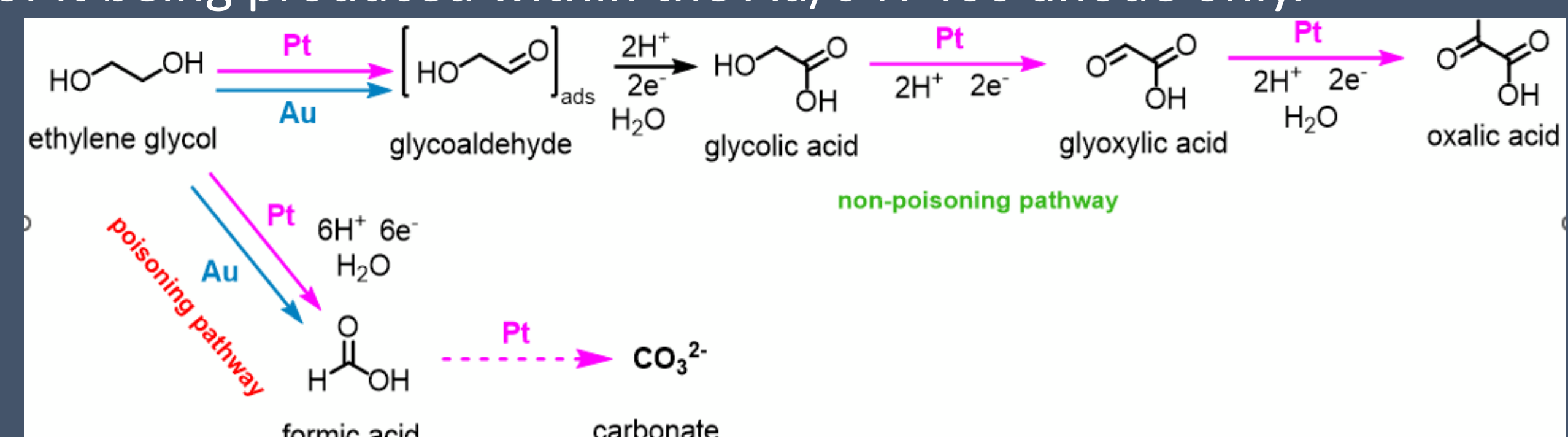


Figure 4: Schematic of chemical formation after MEA

CONCLUSION

The overall voltages for the 10% Au/c-Air electrode were lower than that of the N anode, with the average FE for Glycolic acid being higher for the air electrode, overall making it a better electrode material and a more efficient electrode for use in waste electrolysis. Both homemade electrodes outperformed the commercially produced electrode.

REFERENCES

<https://www.google.com/url?url=https://doi.org/10.1016/j.joule.2023.100008>