Motivation

Using biomass (carbohydrates) as the renewable feedstock for chemicals and fuel creates unacceptable competition between food and fuel. Meanwhile, the land, water and fertilizers required to cultivate biomass are scarce. CO2 and low grade waste biomass would be appropriate source of renewable feedstock for chemicals and fuel in the context of fossil resources depletion and threats of global warming & climate change. Bioelectrochemical systems (BESSs) offers unique possibilities for clean and efficient production of high-value fuels and chemicals from low-value waste(waters) or even CO2, which is referred to as Microbial Electrosynthesis.

Ethanol, produced from acetate, is an attractive renewable fuel as it can be easily integrated into the current energy infrastructure. In addition, it is used as a feedstock for production of other chemicals.

Technological challenge

Bio-electrochemical reduction of CO2 and/or acetate at the cathode of a Microbial Electrolysis Cell (MEC) can produce ethanol in a continuous fashion using a pure or mixed bacterial culture as biocatalysts (Fig. 1). An oxidation reaction at the anode of MEC will produce the required protons and electrons for the cathodic reduction. Some additional electrical energy is required to drive the electrons from anode to cathode.

At Cathode:

CO2 based:

\[ 2 \text{HCO}_3^- + 14 \text{H}^+ + 12 \text{e}^- \rightarrow \text{C}_2\text{H}_6\text{O} + 5 \text{H}_2\text{O} \]

Acetate based:

\[ \text{C}_2\text{H}_3\text{O}_2^- + 5 \text{H}^+ + 4 \text{e}^- \rightarrow \text{C}_2\text{H}_6\text{O} + 2 \text{H}_2\text{O} \]

Figure 1. Microbial electrosynthesis of ethanol from CO2

The study focuses primarily on the microbial cathodic reduction. Any oxidation reaction, such as oxidation of organics, can be incorporated. The technology can synthesize ethanol from CO2 and/or acetate with small electrical energy input. The project is aimed to prove the new innovative principle and to prove the concept of continuous and energy efficient production using a bioanode in a MEC. The challenge is to develop this technology in combination with product recovery, thereby focusing on optimization of cell components like electrodes and membranes (Fig. 2) to increase the volumetric reactor productivity and decrease the energy consumption.

Figure 2 (a) Graphite foam for bioelectrode (b) Membrane Electrode Assembly (MEA)