Final Report

Project acronym: *BioElectroCathode*

Project number: 5135

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Period covered: 1/11/2018 to 30/4/2022

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Project website: ***https://bioelectrocathode.weebly.com/***
TRL: at the beginning of the project: 2-3 and at the end of the project: 4-5

2. Publishable project summary

Biological or Microbiological ElectroSynthesis (BES or MES) is a biological pathway to convert CO_2 into chemical energy carriers such as CH_4 or organic compounds using electrical energy and microorganisms. This project aimed to systematically change the characteristics of the cathode to achieve an optimized performance in terms of biological electrosynthesis (BES) for the conversion of CO_2 to methane. At WP1, the objective was to synthesize and systematically change the characteristics of the cathode to achieve an optimized performance in biological electrosynthesis (BES). Towards this end, several materials with specific microstructural characteristics have been synthesized and tested in MES for production rates and overall performance. Specifically, the following types of cathodes were developed (manufactured at CUT): Carbon foams decorated with carbon fibres/tubes, Carbon Cloth Decorated with Metallic Nanoparticles. Commercial carbon cloth was decorated with metallic nanoparticles at various coverage ratios by varying the nanoparticle's deposition time. A set of electrodes from 3D graphene and pure nickel foam were fabricated using NanoGen50 for 3D. An MES experiment lasted 144 days (6 cycles-batch mode) with the developed cathodes and their controls (without voltage). The methane was consistently higher in the MES with the developed electrodes and applied voltage compared to the same samples without voltages. The highest CH_4 (around 70%) was found in the second cycle after 16 days by nickel graphene electrodes. The second highest was found by the Cu NPs functionalized carbon cloth electrodes at around (46%), and the carbon cloth electrodes produced slightly lower methane at around 44%. The system's performance declined during the following 4 cycles. Nevertheless, the CH_4 composition was always higher in MES than the controls. Concerning the mechanisms (WP2) of methane production by methanogens, metallic iron and stainless steel were initially used to simplify the system. Methanogenesis was found due to the H_2 production by metallic iron followed by its utilization along with CO_2 for methane production. Experiments showed that the direct electron transfer between electrodes or $Fe^{(0)}$ and methanogens was not a primary mechanisms for CH_4 production. Spent extract was not contributed significantly to the release of hydrogen. Also, it was found that the creation of $FeCO_3$ due to anaerobic metallic iron oxidation entrapped the $Fe^{(0)}$ and stopped H_2 production. Experiments with MES with no proton exchange membrane and the addition of L-Cysteine showed that the mechanisms for methane production were Hydrogen based. These results can explain the performance of the MES operated with the developed electrodes. Design and construction of MEBR reactors that contained baffles with a high surface area for rapid and thick biofilm development were developed and delivered to CUT by RIC (Polland). The validated prototype of the industrial 3D-printer for customized applications MES fabrication by AM technique was developed (WP4) by 3RD. At CUT (Cyprus), the operation of MEBRs with four and two electrodes took place by supplying soluble CO_2 under batch mode. Results showed that the MEBRs with four electrodes perform better than two electrodes, and adding L-Cysteine as an oxygen scavenger resulted in around 40% CH_4. A similar system was operated at RIC in a continuous mode. Specifically, during the tests 2 MEBRs (with 2 and 4 electrodes respectively) 5L, the influence of the following variables was tested: electrolyte flow velocity (40, 80 and 160 mL/min); the use of supplements (vitamins and minerals, glucose, L-cysteine); different values of potential difference; composition of the gas fed into the aeration chamber (pure CO2 or model mixture representing exhaust gases, flow 10 mL/min). In total, the reactors worked for 200 days. The addition of additives vitamins, minerals and L-cysteine showed a positive effect on the share of methane in the gas (around 15%) under the continuous mode.