Final Report
(12.2019 – 11.2023)

Project Title (and ID): Study on membrane-microbial interactions to understand the biologically-induced fouling of ionic liquid-containing membrane separators used in microbial fuel cells (FK 131409)
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In this (young investigator - FK) project, the opportunities, status and challenges of supported ionic liquid membranes (SILMs) and other membrane separators for microbial fuel cells (MFC) have been highlighted and investigation was carried out to establish the proper fabrication methods for SILMs installed into MFC [1,2]. Vaccum-assisted SILM fabrication was tested throughly and stability studies were performed to reveal the appropriateness of the so-obtained SILMs under static and dynamic process conditions simulating the final experimental circumstances in the MFC. After preparation, the different SILMs were characterized in terms of their physico-chemical properties based on mass transfer and electrochemical measurements. As a matter of fact, the proton and ion transfer properties of SILMs made with ionic liquids (ILs) containing imidazolium cation and $[PF_6]^-$/$[NTf_2]^-$ anions were studied and compared to Nafion for benchmarking. It turned out that both of these SILMs showed better proton mass transfer and diffusion coefficient than the reference polymer material (Nafion). The results implied the presence of water microclusters permeating through [hmim][PF_6]-SILM to assist the proton transfer. Ion transport numbers of K^+, Na^+, and H^+ showed that the IL with $[PF_6]^-$ anion could be beneficial in terms of reducing ion transfer losses in MFC. Moreover, the conductivity of [bmim][PF_6]-SILM at low electrolyte concentration (which is typical in MFC) was comparable to Nafion [3]. Furthermore, regarding the issue of membrane biofouling in MFC, novel (with polystyrene-block-poly(ethylene-ran-butylene)-block-polystyrene backbone) and commercial membrane separators were studied to get insights into the microbial communities growing on their surfaces and investigate how the membrane features (e.g. oxygen mass transfer) might affect the community structure. It was found via metagenomic assessment (involving bacterial 16S rRNA gene sequencing) that the membrane surface could be colonized mostly by microorganisms with better tolerance to oxygen (in contrast to what we found on the anode electrode surface, where mainly anaerobes were located) [4,5]. The biofouling issue of several other polymeric membranes was also sought to determine what changes this phenomenon may have caused on the physico-chemical properties of the used membranes and how this potentially influenced the working efficiency of the MFC [6]. In addition, by highlighting the importance of the oxygen mass transfer characteristics of separators (i.e., the membrane), we have reported in a short survey about a related strategy of approaching the membrane biofouling issue in microbial fuel cells [7]. The comprehensive research methodology deployed to approach the membrane biofouling issue with the polymeric membranes [4-6] was considerably useful and fully adaptable to evaluate the behavior and performance of membranes prepared with different ionic liquids. Accordingly, it was aimed to test membranes containing imidazolium-type ionic liquids in MFC and see how their properties and stability could influence the process efficiency, by keeping an eye on the membrane biofouling aspects. As a result, a novel membrane was prepared on polyethersulfone (PES) physical support from the mixture of microcrystalline cellulose and [bmim][Cl] ionic liquid and used subsequently in MFC. Through several weeks of experimentation, severe biofouling was observed on the cellulose/[bmim][Cl]/PES membrane and our evaluation showed that the cellulose-degrading species, *Clostridium termitidis* was present with a notably high (>23 %) relative abundance on the surface of the membrane, which may have caused its deterioration and the consequent colonization of the cathodic compartment of the MFC [8].

Overall, in the opinion of the principal investigator, the goals of the project have been achieved and the high quality/quantitiy of scientific outcomes is well-displayed by the papers published (or submitted to peer-review) in the leading (mainly D1/Q1) journals of the field (see the References).

References

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