An experimental investigation on the green hydrogen production through Electrodialysis with Bipolar Membranes process

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In the last decade, the increasing temperatures in the world represents the biggest problem the mankind faces, as global warming causes environmental disasters that can permanently change the life on the planet. In order to solve or at least mitigate this problem as much as possible, the major world leaders have established that the use of fossil fuels, the main producers of greenhouse gases, needs to be stopped and the path to renewable sources promoted [1]. In this framework, the hydrogen has been identified as the energy carrier under which renewable energy can be stored. The hydrogen is the lightest and most abundant element in the universe, and it has the highest gravimetric energy density of all known substances, i.e., the lower heating value is 120 MJ kg^{-1} and the higher heating value is 141 MJ kg^{-1}. Hydrogen can be produced with zero emissions and in a totally sustainable way by coupling the electrolysis of water with the renewable energy resources and, in this case, it is called green hydrogen. The focus of the international community is strongly on hydrogen, just consider that in 2021 more than 200 MW of electrolyzers became operational, including 160 MW in China and more than 30 MW in Europe to produce green hydrogen [2]. The most well-known electrolyzers in the state-of-the-art are [3]: (i) Alkaline Electrolyzers, the most studied and mature; (ii) Proton Exchange Membrane Electrolyzers, the most promising; (iii) Anion Exchange Membrane Electrolyzers, under development; and (iv) Solid Oxide Electrolysis Cells, high temperature electrolyzers under development. In this context, new types of electrolyzers were also developed, enabling the production of green hydrogen in an electro-membrane process, all in one technology.
The electro-membrane process that has been investigated in the literature, although not in detail, is Reverse Electrodialysis (RED), in which the energy produced from the salt gradients is consumed in the system itself in hydrogen production [4]. An earlier study has also been carried out on Electrodialysis (ED), for the simultaneous production of hydrogen and the water desalination [5]. The literature study, however, clearly shows that the main limitation of these technologies is the current density, which is two orders of magnitude lower than the values of conventional electrolyzers. To overcome this limitation, the present work proposes to combine the membrane process known in literature as Electrodialysis with Bipolar Membranes (EDBM) with the hydrogen production, resulting in the Hydrogen - Electrodialysis with Bipolar Membranes Electrolyzer (H-EDBM). The EDBM is a technology that can support much higher current densities (i.e., 0.1 A cm^{-2}) than ED/RED, and it is comparable to that used in state-of-the-art electrolyzers. Through a current applied to the system, the EDBM is able to desalinate the salt stream fed, producing acid and base, due to the presence of the bipolar membranes. The aim of this work is to characterize for the first time the cathodic and anodic compartments in which hydrogen and oxygen are produced, and from simple 'by-products' of the process, they are brought to the leading role. In particular, a comprehensive experimental campaign of H-EDBM has been carried out studying different configurations and testing different operating conditions, obtaining maximum faradic efficiencies for both hydrogen and oxygen, and achieving hydrogen productivity of up to 18 mol h^{-1} m^{-2}.

References

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