Pressurized electrochemical process for syngas production

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1. Introduction

Carbon Capture and Utilisation (CCU) comprise technologies that capture carbon dioxide and convert it into chemical products, such as fuels, chemicals and building materials that can replace the same products derived from fossil resources. These technologies can thus contribute to reach the ambitious 2030 targets set by the European Union for decarbonisation of the economy of 40% CO_2 reduction, introduction of 27% renewable energies in the energy mix and 27% energy efficiency. CCU technologies are at different stages of maturity and some are already commercially deployed. One of these commercial technologies is the production of methanol by CO_2 hydrogenation at high temperature using hydrogen produced by water electrolysis. Another CCU technology that is still at laboratory stage is electrochemical CO_2 reduction. In this process carbon dioxide is co-electrolyzed with water near room temperature. Hydrogen is produced *in situ*. Depending on process conditions and catalysts CO_2 reduction originates a series of products, such as CO, formic acid, hydrocarbons, alcohols etc. at the cathode. Oxygen is produced at the anode resulting from water oxidation reaction. Figure 1 illustrates the process. Electrochemical CO_2 reduction presents several technological challenges that have not been surpassed yet, such as low CO_2 conversions, poor stability of electrodes and low energy efficiencies. This work reports not yet published results of the development of a pressurized electrochemical process for producing syngas (CO + H_2) by electrochemical reduction of carbon dioxide. Green syngas produced using renewable energy can be an important platform for introducing renewable energy in the chemical industry. The development of a process that works at pressures higher then atmospheric pressure seems promising to circumvent the aforementioned challenges, namely low conversions and low energy efficiencies [1,2].

2. Results and discussion

An electrolyser with alkaline electrolyser architecture was built comprising two compartments for the cathode and the anode separated by a polymeric exchange membrane that can work in the temperature ranges of room temperature up to 80ºC and pressure ranges of atmospheric pressure up to 100 bar. The proof of concept of such electrolyser using an ionic liquid-based electrolyte was presented in a previous communication[3] and the influence of different type of membranes on productivities, faradaic efficiencies and cell potentials were reported working in batch mode. In this work, the results obtained in batch mode are compared with the results obtained with semi-continuous feed of the electrolyte. Fivefold increases in productivities were obtained working at pressures higher than atmospheric pressure. Despite these expected good results, pressurized processes are seldom

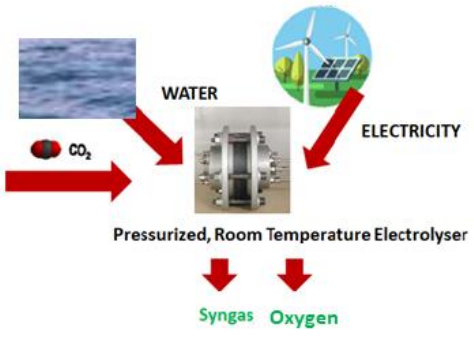

Figure 1. Schematic of the pressurized process for syngas production.

investigated in this type of application due to the technical difficulties of operating an electrolyzer at pressures higher than atmospheric pressure. This shows the relevance of applying high pressures technologies in this field to exploit fully the advantages of conversion of CO_2 at higher pressures coupled to supercritical CO_2 fluid separation of liquid products that are liquid at room temperature and pressures.

3. Conclusions

This work is focused on the optimization of the operation mode (batch vs. continuous) of CO_2 electrochemical reduction. Despite the increased productivities obtained due to the operation at higher pressures, advanced and stable catalysts need to be developed and tested before this technology can be used industrially. The need to capture, and store CO_2 in supercritical phase to avoid climate changes will boost the development of energy efficient and sustainable technologies, such as electrochemical reduction of CO_2 that can use high pressure CO_2 as raw material. In this way, CO_2 has the potential to become a source of renewable carbon for the chemical industry.

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References

1-A.S. Reis Machado, A.V.M. Nunes, M. Nunes da Ponte, *J. Supercrit. Fluids* **2018**, 134, 150-156.

2- T. Pardal, S. Messias, M. Sousa, A.S. Reis Machado, C. M. Rangel, D. Nunes, J.V. Pinto, R.Martins, M. Nunes da Ponte, J. of CO2 Utilization **2017**, 18, 62-72.

3-S. Messias, C.M. Rangel, T. Pardal, M. Nunes da Ponte, A.S. Reis Machado, Book of Abstracts of the 12th International Symposium on Supercritical Fluids 2018, oral communication, Antibes-Juan-les-Pins, 22-25 April.