Electrochemical Conversion of Carbon Dioxide: effect of the cell and of operating parameters on the performances of the process

Federica Proietto[a], *Simona Sabatino*[a], *Benedetto Schiavo*[a], *Alessandro Galia*[a], *Onofrio Scialdone*[a]

[a] *Dipartimento dell'Innovazione Industriale e Digitale – DIID – Ingegneria Chimica, Meccanica, Informatica, Gestionale. Università degli Studi di Palermo, Viale delle Scienze Ed. 6, 90128 Palermo, Italy.*
e-mail: federica.proietto@unipa.it

Recycling technologies of CO_2 allow to introduce renewable energy in the chemical and energy chain, storing a renewable energy in the chemical form. In this context, electrochemical conversion of CO_2 is considered one of the more interesting approaches, using excess electric energy from intermittent renewable sources. (1) Furthermore, products can be selectively controlled by changing the operating conditions of electrolysis. In particular, in the last years, an increasing attention has been devoted to the electrochemical conversion of CO_2 to formic acid or formate in water. (2,3,4) The main hurdle of the reduction of CO_2 from water solution is the low CO_2 solubility in water. In this work, a systematic study on the effect of the CO_2 pressure and of other operating parameters on the conversion of CO_2 at tin flat cathodes to formic acid was performed to overcome this obstacle.

The reduction of CO_2 was first studied in a glass undivided cell at atmospheric pressure to evaluate the effect of various operating parameters, including the nature of the anode and of the supporting electrolyte, the mixing rate, the current density and cathode to anode area ratio. Subsequently, in order to improve the performance of the process, a series of electrolysis was performed in a batch stainless steel undivided cell in a wide range of pressure of CO_2 and current density. It was shown that an increase of the pressure leads to a drastic enhancement of the final formic acid concentration. Indeed, the utilization of relatively high CO_2 pressures (15–30 bar) allowed to achieve high concentrations of formic acid (up to 0.46 mol L^{-1}) at high current density (up to 90 mA cm^{-2}) and with cheap and simple undivided cell. (5)

Several researchers have discussed the economic feasibility for large-scale design of the CO_2 mitigation electrochemistry system, by suggesting that could be operationally profitable. Therefore, in the last stage, the process was performed in a pressurized filter-press cell, suitable for scale-up on applicative scale. The goal of this research is to provide an electrochemical process sustainable at applicative point of view characterized by a high yield and selectivity of the product. Long-term stability has also to be acquired in order to obtain an interesting alternative at commercial level for the conversion of carbon dioxide.

References:

1. Ma, S., & Kenis, P. J. (2013). Electrochemical conversion of CO 2 to useful chemicals: current status, remaining challenges, and future opportunities. *Current Opinion in Chemical Engineering*, *2*(2), 191-199.
2. Lu, X., Leung, D. Y., Wang, H., Leung, M. K., & Xuan, J. (2014). Electrochemical reduction of carbon dioxide to formic acid. *ChemElectroChem*, *1*(5), 836-849.
3. Ikeda, S., Takagi, T., & Ito, K. (1987). Selective formation of formic acid, oxalic acid, and carbon monoxide by electrochemical reduction of carbon dioxide. *Bulletin of the Chemical Society of Japan*, *60*(7), 2517-2522.
4. Chaplin, R. P. S., & Wragg, A. A. (2003). Effects of process conditions and electrode material on reaction pathways for carbon dioxide electroreduction with particular reference to formate formation. *Journal of Applied Electrochemistry*, *33*(12), 1107-1123.
5. Scialdone, O., Galia, A., Nero, G. L., Proietto, F., Sabatino, S., & Schiavo, B. (2016). Electrochemical reduction of carbon dioxide to formic acid at a tin cathode in divided and undivided cells: effect of carbon dioxide pressure and other operating parameters. *Electrochimica Acta*, *199*, 332-341.