Current Status and Challenges for the Implementation of Electrocatalytic CO_2 Reduction

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Carbon dioxide coming from the use of fossil fuels accounts for about 65 % of the global greenhouse gas emission, and it plays a critical role in global climate changes. Among the different strategies that have been considered to address the storage and reutilization of CO_2, its transformation into chemicals or fuels with a high added-value is considered a winning approach. This transformation can reduce the carbon emission and induce a “fuel switching” that exploits renewable energy sources (e.g. sunlight). Among all the proposed methods, the electrocatalytic reduction of CO_2 is considered an interesting technology for the storage and reutilization of CO_2 from both economic and environmental points of view. It can be used to transform CO_2 into CO, formic acid, alcohols or higher molecular weight hydrocarbons, such as oxalic acid. However, the main challenge for the establishment of this technology, at an industrial level, is to find suitable electro-catalysts as well as optimized process conditions for the selective production of a single compound with a high conversion efficiency. Since the electrochemical reduction of CO_2 is generally performed in aqueous media, the hydrogen evolution reaction (HER) from the reduction of water or protons (H^+) is in inevitable rivalry with the CO_2 conversion. Hence, the intrinsic nature of the electrolysis process could be exploited, in a competitive approach, by combining CO_2 reduction and HER to produce syngas (see Fig. 1). The great advantage of syngas with respect to other direct CO_2 reduction products, are the several established technologies that can be used to generate ammonia or more reduced products, like alcohols and hydrocarbons (via Fischer-Tropsch catalysis), depending on the H_2/CO ratio of the mixture. [1]
In such context, recently, our group have critically reviewed and analyzed the main efforts that have been made and results that have been achieved concerning the electrochemical reduction of CO_2 to produce CO. [1] In the present work, the different methods, catalysts and reactor systems that have been used for this purpose are outlined. We have seem that, although remarkable activities have been undertaken and scientists have achieved high efficiency and selectivity with acceptable kinetics, there are still some serious obstacles to overcome before this process can become viable. In fact, the most efficient catalysts for the reduction of CO_2 to CO are still based on noble metals; long-term tests and a complete understanding of the deactivation mechanisms have still not been investigated for the most promising catalysts, as well as, proposed systems so far only produce CO in µmoles per minutes, which is quite far from industrial productivity levels. Thus, challenges and prospective trends towards a practical application of this CO_2 conversion technology are highlighted and future research directions on this topic are envisaged.