Electrochemical Conversion of CO_2 to Useful Products

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Electrochemical conversion of CO_2 to value added products such as formic acid, methanol, ethylene and syngas is being increasingly pursued. Electrochemical reduction of CO_2 has received considerable attention over the last several decades [1, 2, 3], but until recently there have been only a few studies of the commercial viability of such a process [4 – 6]. To make this manufacturing route economically viable, four technical targets must be met: high current efficiencies (>70%), high current densities (>100 mA/cm^2), long catalyst life (>4000 hours), and low specific power (<500 kWh/kmol). Development of the ECFORM ^{TM} (electrochemical conversion of CO_2 to formate/ formic acid) technology focuses on evaluating and improving the various aspects of the process in order to make it economically feasible for commercial application. A multi-level approach has been undertaken to improve catalyst properties, optimize continuous operating conditions and maintain high product generation over long operating times. Tin has been employed as a highly selective electrocatalyst for aqueous CO_2 conversion to formate salt/formic acid. High surface area electrodes were developed by electrodepositing tin on a porous carbon substrate and these were evaluated in a continuously operating three chamber flow cell. A focus area is understanding and optimizing the process chemistry. Selection of anolyte and catholytes, along with the applied potential regime, affects product selectivity, electrode degradation, and chemicals consumption. This paper reviews the state of knowledge in this area and identifies research required to address the gaps.

Arguments against the viability of CO_2 conversion identify the energy requirements as a barrier to economic viability. In this context, it would be advantageous to view CO_2 conversion to chemicals as an energy storage medium. Products created electrochemically from CO_2 have higher energy densities than modern battery technologies (Figure 2). In this context, the process is open to electricity markets that are unavailable to conventional petrochemical processes, such as ancillary services, energy arbitrage, and renewables integration. These services can generate revenues in one- or two-way exchanges with the local transmission operator [7, 8]. When integrated with waste heat capture technologies, the process can be powered renewably with zero carbon output while simultaneously working with grid services. Finally, while more CO_2 would be avoided if renewable energy were directly used on the grid, the variability of renewable power might not lend to matching of supply with demand. Using CO_2 conversion as an energy storage medium for renewables could produce more value per ton of CO_2 avoided than competing processes.

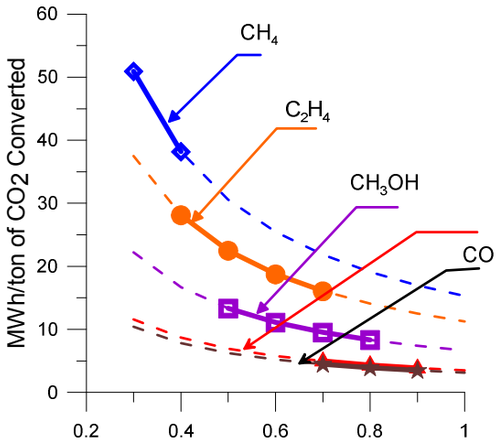

Figure 1. Current status (2011) of electrical energy demand for electrochemical CO_2 conversion.

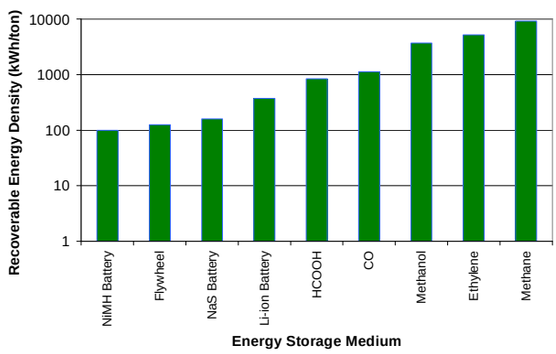

Figure 2 Products produced from CO_2 can have recoverable energy densities higher than traditional electrical energy storage technologies.

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