

Development of a New Type of Electrochemical Reactor for Low Temperature Lime and Cement Production

Maxime Loudeche¹, Rémy Rouxhet¹ and Joris Proost¹

¹Division of Materials and Process Engineering, UCLouvain

Abstract

The cement industry is responsible for more than 8% of the global CO₂ emissions, making it one of the largest contributors to global warming. Two-thirds of these emissions are coming from unavoidable process gases caused by the calcination reaction of limestone (CaCO₃). The remaining emissions are mainly coming from the combustion of fossil fuels. Due to the high temperature requirement ($\approx 1500^{\circ}\text{C}$), direct electrification is difficult to consider. For these two reasons, the cement industry is therefore known as a challenging sector to decarbonize.

A new electrochemical pathway for cement production has gained prominence in the scientific literature in recent years [1]. This technology has the potential to electrify the cement and lime production while producing at the same time valuable gases (O₂, CO₂, H₂). It is based on a new type of hybrid electrolyser capable of working with solid, liquid and gaseous phases. Thanks to the acidity generated by water oxidation at the anode, the solid limestone feed, precursor of cement, is being dissolved. This dissolution produces pure CO₂ which is mixed with pure O₂ generated by electrolysis and which is easily captured for later use. The calcium ions are then migrating towards the cathode under the effect of the electric field. The OH⁻ hydroxyl ions, produced at the cathode by water reduction, meet the calcium ions to form the final solid product, hydrated lime (Ca(OH)₂). This lime can be used as such or converted into cement by additional steps.

In this research, a laboratory-scale setup has been developed to study the feasibility of such a process. Different geometries have been tested and the main operational parameters affecting the different steps of the process have been investigated. Our results show first of all the formation and stabilization of a pH gradient within the electrolyser, which allows at the same time for the complete dissolution of CaCO₃ in the acidic anodic environment while producing a white precipitate of Ca(OH)₂ at the cathode. The setup also presents ideal faradaic efficiencies when using an IrO₂ coated titanium anode and a nickel cathode in a 1M NaClO₄ electrolyte. Alternative electrode materials, including a 316L stainless steel anode and an Inconel 718 cathode, have been considered as well. Finally, it was shown that the energetic efficiency can be further improved by pushing the kinetics of the dissolution and precipitation reactions through increasing the mobility of calcium ions, using Ca-based electrolytes, like Ca(ClO₄)₂. Based on our results, all the elementary concepts behind the hybrid electrolyser have been established, and a first blueprint of a continuous industrial process will be proposed.

[1] - L. D. Ellis, et al. (2019). Toward electrochemical synthesis of cement—An electrolyzer-based process for decarbonating CaCO_3 while producing useful gas streams. *PNAS*, 117, 12584-12591.

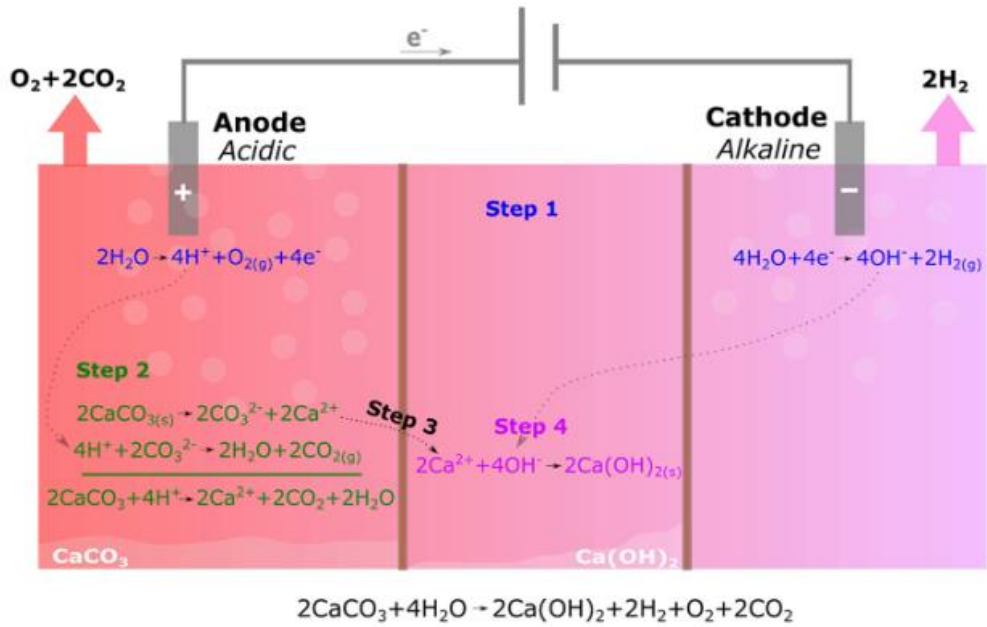


Figure 1. – Representation of the hybrid electrolyser and its main reactions (adapted from [1]).