# Material and Process Innovations for High-Performance MCFC Technologies

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Molten Carbonate Fuel Cells (MCFCs) are a promising solution for reducing carbon dioxide ($CO_2$) emissions, especially in hard-to-abate sectors. These fuel cells are highly efficient and offer flexibility in the type of fuel that can be used at the anode side. A key advantage of MCFCs is their ability to capture $CO_2$ directly during normal operation. This makes them attractive not only for power generation but also for applications in carbon capture, utilization, and storage (CCUS). However, large-scale implementation of MCFCs for carbon capture remains challenging. Major issues include the durability of key components and the overall cost-effectiveness of the technology.

This study focuses on improving critical components of MCFCs, including the electrodes, current collectors, electrolyte, and ceramic matrix. The production processes for both the matrices and electrodes were revised compared to traditional approaches reported in the literature, with the goal of eliminating environmentally unfriendly materials and introducing manufacturing methods and processing times compatible with large-scale industrial development. Special attention was given to simplifying fabrication steps and reducing the number of thermal treatments, which typically consume significant energy and time in standard procedures.

For the current collectors and electrolyte, several tests were carried out to optimize performance. In the case of the current collectors, the focus was on achieving a more uniform gas distribution and maximising gas-electrode interface surface. Regarding the electrolyte, particular attention was paid to the start-up phase, during which the matrix develops a porous structure and the molten electrolyte infiltrates and fills the pores.

In addition to the experimental advancements, the study included process simulations based on test data from individual MCFC components. These simulations helped evaluate how MCFC systems would work in real carbon capture scenarios, such as in steel plants and ships. The results showed that MCFCs could be an effective and practical way to remove $CO_2$. Overall, the combination of improved materials, scalable production methods, and system-level simulations supports the future use of MCFCs in reducing emissions on an industrial scale.

**Keywords**: *Carbon capture and storage (CCS), Molten carbonate fuel cells (MCFC), hydrogen, scalability, modelling*