Chapter 3
Plasma-Assisted Carbon Dioxide Conversion:
Applications, Challenges, and Environmental Impacts

Erfan Nouri
https://orcid.org/0000-0002-6558-7848
University of Guilan, Iran

Alireza Kardan
University of Guilan, Iran

Vahid Mottaghitalab
https://orcid.org/0000-0001-7211-3141
University of Guilan, Iran

ABSTRACT

This book chapter explores the fascinating realm of plasma-assisted carbon dioxide (CO_2) conversion, focusing on its applications, challenges, and environmental impacts. The authors begin with an introduction, followed by an examination of key parameters that influence the efficiency of plasma-based CO_2 conversion. Next, the authors delve into various applications and products derived from this process, including plasma-catalytic CO_2 conversion and the synthesis of fuels and value-added chemicals. They then address the challenges and limitations surrounding plasma-based CO_2 conversion, such as cost considerations, catalyst selection, and scaling-up for industrial applications. Finally, the authors explore the environmental benefits of this technology and evaluate its economic feasibility and potential market opportunities. This chapter serves as a comprehensive overview of the field and aims to shed light on the potential of plasma-assisted CO_2 conversion in contributing to a sustainable future.

DOI: 10.4018/979-8-3693-0904-9.ch003

1. INTRODUCTION

In order to mitigate environmental risks, there is a need for innovative CO_2 management in the process of transitioning towards a sustainable society (Valluri et al., 2022). The main objective of carbon capture and utilization (CCU) is to capture CO_2 from sources that emit it and simultaneously utilize it as a raw material for cleaner processes (Hepburn et al., 2019). Numerous pathways for CCU are currently being developed. Extensive research has been conducted on diverse techniques for converting CO_2 into liquid fuels, such as photochemical, electrochemical, and thermal conversion routes (Al-Mamoori et al., 2017; Mikulčić et al., 2019; Sabri et al., 2021; Saleh, 2022; Wanten et al., 2023).

Plasma technology has become of great interest in recent decades as a means of converting CO_2 (Snoeckx & Bogaerts, 2017). Plasma is a type of gas that has been ionized. It has the ability to transform stable molecules into valuable chemicals, such as CO_2 conversion (Chen et al., 2021; Snoeckx & Bogaerts, 2017), and also convert molecular nitrogen for the production of fertilizers (Jardali et al., 2021; Rouwenhorst et al., 2021). The capability of this technology to handle various gases as input and provide immediate control over the process allows for its effective use in electrified production alongside the variable supply of renewable electricity (Snoeckx & Bogaerts, 2017). In addition, there is no need for the utilization of limited resources (Snoeckx & Bogaerts, 2017), and the technique has already been proven effective in a range of industrial contexts, such as generating ozone and operating arc plasma furnaces in the steelmaking industry (Delikonstantis et al., 2022; Wanten et al., 2023).

The review paper conducted by Snoeckx and Bogaerts (2017) extensively discussed the performance of plasma technology in comparison to other CCU technologies. It is evident from their research that there is a range of plasma reactors utilized for gas conversion, which vary in terms of design, applicable currents, flow rates, pressures, voltages, and other factors. A comprehensive analysis of these reactors and their effectiveness in converting CO_2 is outlined in their research paper and other recent literature references (e.g. Refs.(George et al., 2021; Liu et al., 2020; Ong et al., 2022; Vadikkeettil et al., 2022)). This evaluation holds great significance in the advancement of this technology. In order to conduct this evaluation, it is crucial to possess a defined, accurate, and reliable procedure for assessing the various measures of performance.

This book chapter provides a comprehensive exploration of plasma-based CO_2 conversion. It covers the important parameters affecting efficiency, various applications and products, challenges and limitations, and environmental benefits. The chapter aims to contribute to a comprehensive understanding of this technology and its implications for addressing environmental challenges.

2. KEY PARAMETERS AFFECTING THE EFFICIENCY OF PLASMA-BASED CO_2 CONVERSION

Numerous attempts have been made to enhance the efficiency of the plasma catalytic system by modifying various operational factors to achieve maximum conversion and energy effectiveness. In their research conducted in 2016, Mei et al. (2016) examined how reducing the flow rate of the feed gas can elongate the time the gas remains in the reactor, thereby leading to a higher conversion rate of the reactant. According to reports, the energy efficiency is inversely related to the specific energy density. In the subsequent section, we will delve into an array of additional elements that impact energy efficiency.

Related Content