Chapter 2
Plasma Technology for Carbon Dioxide Conversion

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ABSTRACT

Carbon dioxide (CO_2) is one of the major greenhouse gases that contributes to global warming and environmental variations. The increasing concentration of CO_2 in the atmosphere is posing severe threats to human health and the environment. With the increasing concerns about climate change and CO_2 levels, the need for advanced and effective technologies to mitigate CO_2 emissions is more critical than ever. Plasma technology, with its unique features and versatile capabilities, has shown immense potential for the conversion of CO_2 into valuable products and fuels. This proposed chapter aims to explore the recent advances in plasma-based CO_2 conversion processes. The chapter covers the fundamental principles, plasma generation systems, reaction mechanisms, and implications of plasma technology in CO_2 conversion, presenting a comprehensive understanding of this transformative field.

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1. INTRODUCTION

As the world confronts the increasingly urgent challenge of climate change, the search for innovative technologies to combat rising CO_2 levels and reduce greenhouse gas emissions has gained paramount importance. One such groundbreaking approach is the use of plasma technology for CO_2 conversion a process that holds the promise of addressing both environmental and energy sustainability concerns (Legg, 2021). Developing a sustainable and low carbon-based energy economy is crucial for reducing dependence on non-renewable fossil fuels. In addition to exploring renewable energy sources like solar, hydro, and wind, recycling and utilizing CO_2 to synthesize high-value products offer an alternative solution to combat climate change. Plasma-based CO_2 decomposition, particularly using microwave discharge technology, has garnered significant interest due to its exceptional capability to efficiently produce non-equilibrium plasma with high ionization power. This technology shows promise for converting CO_2 efficiently and sustainably into valuable resources. (Ong, Nomanbhay, Kusumo, & Show, 2022). This chapter serves as an introductory exploration of the fusion of plasma technology and CO_2 conversion, aiming to shed light on the potential of this transformative field.

1.1 Plasma Technology

Plasma, often referred to as "fourth state of matter," is a remarkable physical state distinct from solids, liquids, and gases. Unlike these more conventional states, plasma is characterized by its ionized nature, where electrons and positively charged ions coexist in abundance. This ionization results in a highly conductive medium capable of generating immense energy and diverse chemical reactions. The utilization of plasma technology spans a wide spectrum of applications, ranging from industrial processes such as metal cutting and welding to cutting-edge fields like aerospace propulsion and medical treatments. Thermal and non-thermal plasma are the two main subcategories of plasma. Thermal plasmas, characterized by their high temperatures, are commonly used in industrial applications, while non-thermal or cold plasmas operate at lower temperatures, making them ideal for various scientific and environmental applications, including CO_2 conversion (López et al., 2019; Sardella, Palumbo, Camporeale, & Favia, 2016).

1.2 Rising and Mitigating CO_2 Levels: A Global Challenge

The unprecedented increase in atmospheric CO_2 levels due to human activities, primarily deforestation, industrial processes, and burning of fossil fuels, has culminated in a global environmental crisis-climate change. The scientific consensus, as articulated by bodies like Intergovernmental Panel on Climate Change (IPCC), underscores the role of elevated CO_2 levels in driving rising sea levels, global warming, and extreme weather events. This global issue necessitates immediate and substantial action to mitigate its adverse effects on ecosystems, economies, and human well-being (Lackner, 2003).

While traditional approaches to addressing CO_2 emissions, such as carbon capture and storage (CCS), have made significant strides, they still face challenges in terms of cost, scalability, and sustainability. To meet ambitious climate targets and transition toward a low-carbon future, there is a growing need for innovative technologies capable of not just capturing CO_2, but transforming it into valuable resources. This is where plasma technology emerges as a game-changing solution (Ashford & Tu, 2017).