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Review Article

A review of microbial electrosynthesis applied to carbon dioxide capture and conversion: The basic principles, electrode materials, and bioproducts

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ABSTRACT

Atmospheric carbon dioxide (CO_2) concentrations are currently rising at an unstoppable rate, and it is urgent to curb this trend for a stable and sustainable atmospheric environment. Under this adverse situation, microbial electrosynthesis (MES) applied to CO_2 capture and conversion has received increasing attention in recent years for mitigating greenhouse effects while biosynthesizing higher-value products. Research on the CO_2 capture and conversion in MES has been increasing in recent years, in 2020 alone, there has been more than 1400 papers concerning the bioelectrochemical CO_2 capture and conversion. In this review, the basics of bioelectrochemical systems are first briefly summarized to provide an overall understanding about them. Then, several commonly used electrode materials such as carbonaceous materials, metallic materials, and carbonaceous-metallic materials, along with their advantages and disadvantages, are illustrated. Additionally, the features of pure/mixed cultures are discussed in this review. In particular, many biobased products obtained from CO_2 conversion *via* MES are proposed systematically according to their respective carbon chain lengths. Finally, perspectives on how to improve the MES performance and enable this process to be more suitable and feasible for the industrialization of CO_2 capture and conversion are presented here.

1. Introduction

Carbon dioxide (CO_2) plays an important role in the ecological environment and is an indispensable part of the global carbon cycle. In addition, CO_2, as one of the main greenhouse gases, helps regulate the temperature of our planet and is at the heart of climate change [1]. However, CO_2 emissions have grown so rapidly that they have reached unprecedented levels since the industrial revolution [2]. Exhaust emissions from factory chimneys in industrial production, vehicle emissions, and fossil fuel combustion in modern life are the main contributors. In addition, deforestation has made this trend even worse. Too much of the sun's heat is being trapped by the excessive CO_2, and the earth is becoming hotter via the "greenhouse effect" [3]. Under the influence of the greenhouse effect, extreme weather is becoming increasingly frequent, sea levels continue rising, and global desertification is becoming more severe. As CO_2 drives global weather systems, aspects such as global agricultural output are impacted, and devastating destruction of lives and property through hurricanes, extreme heat, and floods occurs. All these disasters will have a major impact on human life and the global economy. According to the *Intergovernmental Panel on Climate Change*, to maintain global warming at 1.5 °C for the rest of the 21 st century, approximately 100 to 1,000 Gt of CO_2 must be removed from the atmosphere [4], which means that CO_2 emissions must be restricted.

As a result of this dire situation, many efforts have been undertaken to reduce the excess CO_2 discharged into the atmosphere, such as CO_2 capture and storage and CO_2 capture and utilization [5,6]. CO_2 storage mainly includes underground storage, marine storage, and forest storage [5]. Underground reservoirs for CO_2 storage often require sizable economic investments and may lead to geological instability [7]; marine storage runs the risk of impacting the marine ecological environment and lacks suitable technology; and, finally, the capacity for forest storage is limited owing to the shrinking of forest areas, preventing this last approach from being used as a common storage method, despite its lower cost [8]. For these reasons, the application of CO_2 capture and storage is relatively limited. In the context of the shortage of fossil fuels,

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