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Utilizing Ionic liquid-Nonthermal Plasma Combination for CO_2 Conversion

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Global energy consumption will increase by 28% between 2015 and 2040, according to a report by the U.S. Department of Energy's Energy Information Administration (EIA). The increased energy use will be matched by a 16% increase in energy-related carbon dioxide (CO_2) emissions over that same period, with annual emissions rising from 33.9 billion metric tons in 2015 to 39.3 billion metric tons in 2040, according to EIA's report. Over the past decade, global CO_2 emissions increased by 50 % compared to the levels observed in 1990. The primary source of elevated CO_2 emissions is the use of fossil fuels for heat and power generation. Coal combustion as the major contributor is responsible for approximately 43 % of CO_2 emissions, while oil contributes around 37 %, and gas accounts for roughly 20 % of overall CO_2 emissions [1].

Therefore, there is an urgent need for prompt action from governments and industries across the globe to reduce the rising atmospheric concentrations of greenhouse gases. This emphasizes that there is a critical necessity to adopt negative emission technologies for achieving a net removal of greenhouse gases from the environment [2]. However, the transition of the energy infrastructure away from fossil fuels and toward renewable and nuclear energy resources is not an easy task. A potential solution lies in CO_2 capture from point sources, such as power plants and industries, which could play a crucial role in minimizing CO_2 emissions throughout this transition by integrating localized CO_2 capture and storage (CCS) technology [3]. The technology for capturing CO_2 from ambient air, known as "direct air capture" (DAC), has been advancing rapidly in recent years [4]. Despite significant advances in CCS technologies, there are still substantial limitations, such as high capital costs, reduced absorption, and desorption rates, solvent evaporation, etc. Ionic liquids (ILs) have recently gained considerable interest in CO_2 capture [5]. The absorption of CO_2 by ILs results from physical interactions between the anions and cations of the ILs and CO_2 molecules [6].

Plasma, known as the "fourth state of matter," is an ionized plasma made up of neutral ground-state molecules in addition to electrons, different types of ions, radicals, excited atoms, and molecules. The electrons may activate the CO_2 molecules and create new products without heating the entire gas, plasma is exciting for the conversion of CO_2 [7]. In our research, we have made significant progress by utilizing streamer plasma for the conversion of both CO_2 and N_2 into valuable plant nutrients [8]. In another study, we have shown how humidity is utilized in CO_2 conversion [9].

Nevertheless, the simultaneous capture and conversion of CO_2 using NTP is of great interest. Hence, in this pioneering effort, we employed an IL for CO_2 capture and storage followed by the conversion of the captured CO_2 into CO using NTP. In this study, we utilized the 1-Butyl-3-methylimidazolium chloride [Bmim]Cl IL, to convert captured CO_2 to CO. We observed that integrates plasma and [Bmim]Cl IL for the simultaneous capture, storage, and conversion of CO_2. Our experimental results indicate that, under atmospheric pressure and room temperature, the water + [Bmim]Cl solution can store CO_2. Moreover, the release of CO_2 during plasma treatment produces CO. Our MD simulation supports our experimental findings, suggesting that CO_2 molecules easily transition from the gaseous phase into the water + [Bmim]Cl solution. In contrast, the penetration of CO molecules into the water + [Bmim]Cl solution is more challenging compared to water alone. This observation implies that once plasma produces CO, its solubility in the IL solution may be limited, showcasing the potential of this technology for efficient CO_2 capture and conversion.

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