

Current Research on CO₂ Reduction Technology

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Abstract. The technology of carbon dioxide reduction has become a focus of research in the fields of environmental protection and sustainable development. With the exacerbation of global warming and energy crises, the issue of carbon dioxide emissions has become increasingly severe, exerting immense pressure on human society and the natural environment. In this context, carbon dioxide reduction technology has emerged as one of the important approaches to addressing climate change and energy demands. This technology involves the reaction of carbon dioxide with hydrogen or other reducing agents to produce organic compounds or fuels. Its advent not only promises to reduce carbon dioxide emissions but also to convert carbon dioxide into useful organic compounds or fuels, thereby facilitating the recycling of resources. The development of carbon dioxide reduction technology holds significant implications for addressing climate change and energy demands. By employing this technology, discarded carbon dioxide can be transformed into valuable products, reducing reliance on fossil fuels, lowering greenhouse gas emissions, and providing new energy sources for sustainable development. Furthermore, carbon dioxide reduction technology has the potential to integrate with other fields such as photocatalysis and electrochemistry, further expanding its application scope and reducing costs. This paper aims to provide reference and guidance for further research and industrial application of carbon dioxide reduction technology, promoting its sustainable utilization and environmental friendliness in practical production.

Keywords: Carbon dioxide reduction, photocatalysis, electrochemical reduction.

1. Introduction

One of the hot areas of global concern is carbon dioxide reduction technology, which aims to address the severe challenges posed by global warming and the energy crisis. With the acceleration of industrialization, carbon dioxide emissions are increasing, increasing the pace and extent of global warming, and also increasing the pressure on energy supply. Therefore, finding an effective way to convert carbon dioxide into useful substances and energy sources has become an urgent problem. Carbon dioxide reduction technology has multiple advantages in converting carbon dioxide into useful chemicals or fuels, thus reducing reliance on fossil fuels and reducing carbon emissions [1]. By skillfully using renewable energy sources and catalysts to convert carbon dioxide into valuable chemicals and fuels, it can effectively slow global warming and reduce the consumption of fossil fuels, thus addressing the resulting environmental and energy security issues. CO₂ reduction technology has significant advantages in reducing carbon emissions and resource recovery. By capturing and utilizing industrial waste gas, power plant emissions, and carbon dioxide in the atmosphere, greenhouse gas emissions can be effectively reduced and converted into high value-added products to realize the recycling of resources. This process can not only reduce environmental pollution, but also bring economic benefits, and achieve a win-win situation of economic benefits and environmental benefits. In addition, the technology can convert waste and waste gas into resources for recycling and provide solutions for the storage and utilization of renewable energy sources. In the laboratory, some progress has been made in carbon dioxide reduction technology, but some challenges, such as the selection and design of catalysts, optimization of reaction conditions, and difficulties of large-scale production. However, with the continuous progress of science and technology and the emphasis on climate change, it is believed that carbon dioxide reduction technology will play an important role in the future and contribute to sustainable development. Chemical reduction method is one of the important means to realize carbon dioxide conversion.

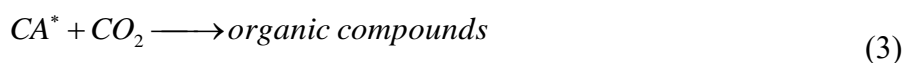
evolution potential, such as gold, silver, zinc, palladium, and gallium, are used to produce CO. For metal electrodes with low hydrogen evolution potential, such as nickel, iron, platinum, and titanium, the main reduction product is H₂, which means that they are mainly involved in the hydrogen evolution reaction and have relatively low activity against electroreduced CO₂. In particular, the metal copper has the characteristics of hydrogen inhibition reaction, and its reduced products are mainly hydrocarbons, so it has a special electrocatalytic activity in CO₂ reduction (Table 1).

Table 1. Main reduction products of the different metal electrodes [5-9]

Electrode category	Metal	Main reduction products
Hydrogen evolution with a higher potential electrode	Pb、In、Sn、Hg、Cd、Bi	HC00H
Hydrogen evolution potential medium electrode	Au、Ag、Zn、Pd、Ga	CO
The hydrogen evolution electrode is lower	Ni、Fe、Pt、Ti	H ₂
Hydrostatic reaction electrode	Cu	CH ₄ 、C ₂ H ₄

3. Photochemical Reduction of Carbon Dioxide

Photochemical reduction of carbon dioxide is mainly based on the illumination of the catalyst by stimulating the electrons of the catalyst and forming the catalyst radical. The reaction formula is as follows (CA is the catalyst).



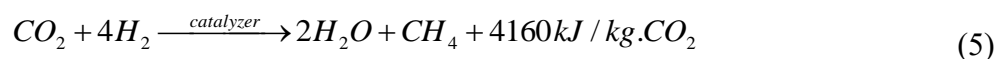
3.1. Selection and Design of the Catalyst

In the research process of photochemical reduction of carbon dioxide, catalytic systems include floating semiconductor photocatalytic system, transition metal complex catalytic system, enzyme catalytic system, etc. [10]. In addition, in recent years, some researchers have proposed to improve the performance of the catalyst by optimizing the semiconductor band structure to load light-absorbing materials on the photocatalyst.

4. Historical Development of Carbon Dioxide Reduction Technology

The development of carbon dioxide reduction technology dates back to the middle of the 20th century. The earliest studies focused on the photosynthetic process of using light energy to convert carbon dioxide into organic matter. However, this method is less efficient and is difficult to apply on a large scale. With the progress of science and technology, especially the development of catalysts, carbon dioxide reduction technology has gradually made important breakthroughs. After the 1980s, researchers began trying to use metal catalysts to promote the reduction reaction of carbon dioxide. Metal catalysts can reduce the energy barrier of the reaction and increase the reaction rate, thus effectively converting carbon dioxide into organic matter or fuel.

The French chemist Paul Sabatier (1854~1941) first proposed the Sabatier reaction, also known as carbon dioxide methanation and reduction reaction, its principle is as follows.



Under certain temperature and pressure conditions, the carbon dioxide and hydrogen according to a certain proportion into the catalyst reaction into water and methane, the catalyst is the key to the study of various catalyst performance abroad to determine the nail catalyst formed on aluminum oxide is one of the best carbon dioxide methane reduction catalyst.

The method is divided into five steps: checking the cleaning instrument, entering the hydrogen, activating the catalyst, adjusting the flow rate, recording the temperature change and opening the refrigeration system. Table 2 shows the calculation of the relationship between the methane content and the reaction temperature.

Table 2. Relationship between the content of CH₄ and the reaction temperature (t)

t(°C)	248.0	302.0	375.0	399.7	407.4	410.0	421.1	414.4	415.6
CH ₄ experimental value of (%)	5.60	12.70	28.10	35.80	37.70	38.00	38.70	39.40	42.55
CH ₄ calculated value (%)	5.76	12.20	27.70	35.30	37.90	38.90	39.60	40.50	40.90

Over time, researchers continuously improve the design and performance of catalysts to improve the efficiency and selectivity of CO₂ reduction. Some commonly used catalysts include precious metal catalysts (such as platinum, rhodium, rhodium, iridium, etc.), transition metal catalysts (such as iron, cobalt, nickel, etc.), and non-metallic catalysts (such as carbon materials, nitrogen materials, etc.). In addition, there are some new catalysts, such as metal-organic framework materials and nanomaterials. Researchers also face some challenges in the development of carbon dioxide reduction technology. For example, select the appropriate catalyst, optimize the reaction conditions, solve the stability and life problems of the catalyst, etc. Moreover, due to the inert and high stability of CO₂ molecules, the reduction reaction needs to overcome large energy barriers, so improving the reaction efficiency and selectivity is also a key issue.

In the process of carbon dioxide reduction technology, the study of biotechnology has played an important role. Biotechnology realizes the efficient conversion of carbon dioxide by using the enzymes, strains or other organisms produced in the organism, which provides new ideas and methods for the reduction of carbon dioxide. Biotechnology can learn from the metabolic pathways of some microorganisms in nature, and use their unique enzyme systems to convert carbon dioxide into organic substances. For example, some anaerobic bacteria and archaeobacteria are able to use carbon dioxide for methane or ethylene synthesis, which provides implications for humans for designing efficient CO₂ reduction reactions. On the other hand, through genetic engineering techniques, researchers can design and construct enzymes or metabolic pathways with specific functions to achieve the conversion of CO₂. For example, using gene-editing techniques to modify the metabolic pathways of plants or microorganisms to more efficiently utilize CO₂ for growth or produce useful compounds. Biotechnology can also combine natural biological processes such as photosynthesis to design artificial photosynthesis systems that use solar energy to directly drive the conversion reaction of carbon dioxide. This method can not only realize the efficient utilization of solar energy, but also convert carbon dioxide into organic substances, which has great application potential.

5. Conclusion

According to the thorough research and analysis of carbon dioxide reduction technology, it can be clearly concluded that carbon dioxide reduction technology is a kind of great potential sustainable development solution, there are a variety of carbon dioxide reduction technology, including photocatalysis, electrocatalysis and biological catalysis, their own advantages and limitations, need to consider choosing the appropriate technical path. Although some important advances have been made at the theoretical and laboratory stages, there are still many technical challenges and economic constraints to truly apply it to practical production and commercial applications. These include improving the efficiency and selectivity of catalysts, improving the stability and durability of reaction systems, reducing energy costs and increasing the difficulty of large-scale production. The design of

materials and the development of catalysts are key to the study of CO₂ reduction technology, which requires the deep exploration of efficient and stable catalysts and optimized reaction conditions to improve conversion and selectivity. These challenges need to be overcome through continuous research and innovation. Therefore, the government, industry and academia should strengthen cooperation to jointly promote the development and commercial application of carbon dioxide reduction technology. Policy support, capital investment and talent training are the key to promote the transformation of this technology. It is only through multidisciplinary collaborative research and combined with innovative technologies in related fields that the maturity and commercialization of carbon dioxide reduction technology can be accelerated. In conclusion, CO₂ reduction technology has great environmental and economic potential and can make important contributions to the sustainable energy and chemical industries. However, further research and efforts are still needed to overcome the current technical challenges and realize the wide application and popularization of this technology. Carbon dioxide reduction technology has great potential to convert carbon dioxide into organic compounds or clean fuels, helping to slow global warming and ease the energy crisis.

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