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Metal-organic framework-based photocatalysts for carbon dioxide reduction to methanol: A review on progress and application

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ABSTRACT

Due to global warming and shortage of energy, the demand for sustainable energy sources has been increased over the years. Among all, carbon emission has a significant contribution to the problem of global warming thus, it is required to convert it into sustainable energy. This opportunity can be targeted with a green chemistry route and incorporating unique compounds like Metal-organic frameworks (MOFs) through phototechnology. MOFs are used in many fields like energy storage, heterogeneous catalysis, gas sensing, and gas storage, thus found to be very promising. MOFs can be used as both CO_2 capture materials and as an effective photocatalyst to yield value-added products. The photocatalytic CO_2 conversion through MOFs can be conducted either by using pure MOFs as a catalyst or by structural modification through linkers and metal nodes or constructing hybrid systems. Several value-added products like methane, formaldehyde, ethane, and carbon monoxide can be produced during the photocatalytic CO_2 reduction process. In this review, synthesis of MOF, performance parameters, recent technologies, significant developments, and MOF based photocatalyst for carbon dioxide conversion to methanol has been discussed. This helps to evaluate the progress, application, and opportunities to explore the possibility of modified forms of metal-organic framework-based photocatalysts for the conversion of carbon dioxide to methanol. Finally, the conclusions and future perspectives of MOF-based photocatalytic CO_2 reduction system also been deliberated.

1. Introduction

The rate of energy consumption has been increasing sharply over the years due to industrialization and exponential population growth. There is also a rise in energy demand, although current energy sources are limited to provide a sustainable supply of clean energy. The majority of the energy requirement is satisfied through fossil fuel which constitutes coal, gas, oil [1]. Carbon dioxide is the major greenhouse gas (GHG) emitted as a by-product of combustion reactions. Over the years, the CO_2 concentration was 408 ppm, but the permissible CO_2 concentration is only 350 ppm. This has contributed to variety of environmental issues such as global warming and rising sea levels. Developing countries like India, have therefore taken steps to implement carbon capture and storage (CCS) to resolve these issues. CCS targets the elimination of CO_2 from fossil fuel in power plant [2]. The Intergovernmental Panel on Climate Change (IPCC) has reported that, by integrating Carbon-dioxide

Abbreviations: MOF, Metal-Organic Framework; CO_2, Carbon dioxide; GO, Graphene oxide; CCS, Carbon Capture and Storage; CH_3OH, Methanol; CH_4, Methane; EC, Electrocatalytic; PEC, Photo Electro Catalytic; MW, Mega Watt; VLR, Visible Light Reduction; BET, Brunauer Emmett Teller; LUMO, Lowest Unoccupied Molecular Orbital; BCN, Bulk g-C_3N_4; TCN, microstructures of the as-prepared pure g-C_3N_4 nanotubes; TCNZ8, a typical ZIF-8 grafted g-C_3N_4 nanotubes; sample p, Z: pure ZIF-8 nanocrystals; VB, Valence Band; CB, Conduction Band; FESEM, Field Emission Scanning Electron Microscopy; TEM, Transmission Electron Microscopy; HRTEM, High-Resolution Transmission Electron Microscopy; XRD, X-ray Diffraction; DFT, Density Functional Theory; GHSV, Gas Hourly Space Velocity; IPCC, Intergovernmental Panel on Climate Change; IEA, International Energy Agency; TGA, Thermogravimetric analysis; DRS, Differential Reflectance Spectroscopy; SBU, Secondary Binding Unit.

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