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Tailoring perovskite quantum dots heterojunction nanocomposite toward photocatalytic reduction of CO_2

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ABSTRACT

The application of photocatalytic reduction technology has a great potential to address the greenhouse impact caused by the excessive burning of fossil fuels. Perovskite quantum dots (PQDs) are excellent candidates for photocatalytic applications due to their tunable bandgap, long charge diffusion length, high- surface volume ratio, and wide visible light absorption spectrum. However, due to severe charge recombination, poor stability, and inefficient charge extraction, catalytic performance in photocatalytic CO_2 reduction of pristine PQDs is limited. In this review, a brief description of CO_2 photocatalysis by PQDs is given first. The varieties of perovskite-based photocatalyst heterojunctions and a few examples are listed. The most recent research on PQD composites with different dimensional materials and their synthesis techniques are presented. The catalytic characteristics of the reduction products of PQDs composites are discussed later. This review sums up the remaining deficiencies and prospects of PQDs heterojunction nanocomposite for photocatalytic CO_2 reduction.

1. Introduction

Due to the excessive use of fossil fuels, the concentration of CO_2 in the atmosphere, often considered the main culprit in the greenhouse effect, is constantly rising. A promising solution for reducing the environmental impact of climate change and modern society's reliance on fossil fuels is solar-powered fuel production from CO_2 reduction [1]. Up till now, various photocatalytic materials, such as metal-free compounds (e.g. C_3N_4) [2], metal oxides (e.g. TiO_2, ZnO) [3], metal sulfides (e.g. CdS, ZnS) [4], and metal-organic frameworks (MOFs) [5] have been used to carry out the photocatalytic chemical reaction of CO_2 in reaction systems by visible or ultraviolet light. Although, a significant progress has been made, a multitude of these photocatalysts still have several problems including, limited gathering of visible light due to large bandgap energy, fast recombination of charge carriers generated by photosynthesis, and a weak environmental stability [6]. Moreover, its wide applicability is further constrained by low carrier separation efficiency, poor catalytic, and selectivity [7].

As a highly effective photocatalyst material with superior optoelectronic capabilities, metal halide perovskite (MHP) has recently risen as a candidate due to its excellent absorption capacity, nifty carrier transport capacity, low exaction binding energy, and adjustable bandgaps [8]. More significantly, MHP can be easily and inexpensively synthesized as a nanocrystal or architecture of quantum dots, which have a high proportion of nifty surface-to-volume and tunable chemical compositions and structures [9]. Since the variable band composition and extended transfer distance for carriers, plenty of research has been done on perovskite quantum dots (PQDs) for photocatalytic CO_2 reduction [10]. The high light absorption coefficient allows for better light absorption for photocatalytic CO_2 reduction. Perovskite's configurable bandgap makes it simple to tailor its redox potential energy and bandgap, and the elongated transportation distance for carriers offers an excellent chance for them to travel to functional locations. It is one of the promising compounds for photocatalytic CO_2 reduction owing to these unique features [11]. However, owing to severe recombination of charges, absence of functional sites, poor stability, and inefficient charge extraction make pristine PQDs exhibit increasingly poor catalytic performance in photocatalytic CO_2 reduction [12]. Heterogeneous materials were designed by combining them with other materials to improve stability and catalytic performance.

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