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A review on modification of facet-engineered TiO_2 for photocatalytic CO_2 reduction

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ABSTRACT

Energy shortages and global warming are two main problems the world is currently facing. Photocatalytic CO_2 reduction is one of the most promising solutions to the above issues. Among the various photocatalysts, faceted TiO_2 crystals have attracted wide attention due to their excellent photocatalytic performance for CO_2 reduction. This review encompasses the recent advances in the application of facet-engineered TiO_2-based catalysts for CO_2 photocatalytic reduction. The review begins with the fundamentals of CO_2 photocatalytic reduction over TiO_2. In the following section, we discuss the surface atom structure and electronic structure of faceted TiO_2 crystals and the related the CO_2/water adsorption and charge transfer/separation properties. Then, we outline the modification strategies for faceted TiO_2 and their influence on the CO_2 photocatalytic reduction performance. Finally, a summary and the future perspectives of facet-engineered TiO_2 photocatalysts for CO_2 photoreduction are presented.

Contents

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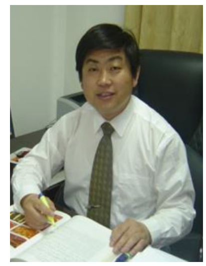

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1. Introduction

With the rapid development of human society, the global energy demand will continue to increase in future decades. Fossil fuels have provided stable power for the development of human society over the past centuries; however, they are limited and will be exhausted soon. Meanwhile, the extensive utilization of fossil energy has released large quantities of the greenhouse gas CO_2, which is regarded as the main contributor to global warming. CO_2 photocatalytic reduction is an effective approach towards solving the above problems and can utilize sustainable and environmentally friendly solar energy to convert CO_2 into value-added chemicals, simultaneously reducing CO_2 emissions and providing renewable energy.

Photocatalysts play a very important role in CO_2 photocatalytic reduction because they almost determine the efficiency of photocatalytic reactions. Since 1979, when Inoue et al. first reported the photocatalytic reduction of CO_2 [1], various photocatalysts, such as TiO_2 [2–4], ZnO [5,6], and CeO_2 [7,8] have been applied in photocatalytic CO_2 reduction. Among them, TiO_2 is one of the most popular photocatalysts due to its good photostability, low cost, and environmental friendliness [9–11]. However, TiO_2 still suffers from a low quantum efficiency and low utilization rate of visible light due to its fast recombination of photogenerated charges and relatively wide band gap [12,13]. Over the past decade, engineering TiO_2 crystals with specific facets has been realized as an effective approach to improve the photocatalytic performance of TiO_2 for CO_2 reduction [14–17]. The different TiO_2 facets have different atomic and electronic structures, which has enabled them to have different optical properties, different adsorption capacities for CO_2 and water, and different transfer and recombination rates of the photogenerated charges [18,19]. Ingenious design of TiO_2 facets by facet engineering to improve these properties of TiO_2 crystals can greatly promote the CO_2 photocatalytic reduction over them. Thus far, several reviews have summarized the progress of the synthesis and photocatalytic performance of facet-engineered TiO_2 [19–22]; however, they have focused mainly on the application for photocatalytic degradation, oxidation, and water splitting. A review on the photocatalytic reduction of CO_2 over facet-engineered TiO_2 is still absent.

This review aims to summarize the recent progress in photocatalytic CO_2 reduction over faceted TiO_2, in particular, the special properties and modification of faceted TiO_2 for photocatalytic CO_2 reduction. Furthermore, a deeper understanding of the mechanism of CO_2 photoreduction over faceted TiO_2 is provided. Finally, per-