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Enriching the methanol generation via CO_2 photoconversion over the cockscomb-like fibrous silica copper

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ABSTRACT

Carbon dioxide (CO_2) photoconversion into methanol (CH_3OH) was recognized as a beneficial approach to overcoming future energy and environmental issues. Here, CO_2 photoconversion into CH_3OH was intensively evaluated over fibrous silica-copper (FSCu) and copper-supported fibrous silica (CuO/KCC-1) generated through a microemulsion and incipient wetness impregnation approach, respectively. The physicochemical attributes of the generated photocatalysts were characterized via UV–vis spectroscopy, X-ray diffraction, N_2 physisorption, Field-emission scanning electron microscopy, and Fourier-transform infrared spectroscopy analysis. Depiction of the characterization results revealed that FSCu possessed a considerable surface area (299.7 $m^2\ g^{-1}$) as well as pore volume (0.70 $cm^3\ g^{-1}$) than those of CuO/KCC-1 and CuO. Indeed, the excellent CuO dispersion and intense CuO-interaction resulted from the alternately aligned CuO and SiO_2 in the fibrous framework. As a result of these great attributes, the FSCu photocatalyst recorded a superior yield of CH_3OH (412.4 μmol $g_{cat}^{-1}\ h^{-1}$) with triethylamine assistance as a sacrificial reductant, followed by CuO (310.3 μmol $g_{cat}^{-1}\ h^{-1}$) and CuO/KCC-1 (189.6 μmol $g_{cat}^{-1}\ h^{-1}$). Additionally, the ideal bandgap position for FSCu compared to CuO/KCC-1 contributed to the greater yield of CH_3OH. The parameter evaluations recorded that the highest yield of CH_3OH for FSCu was acquired at a catalyst of 0.6 g L^{-1}, 100 mL min^{-1} of CO_2, and the amount of TEA of about 50 mL. This paper also proposes a photoconversion mechanism for synthesized photocatalysts, as well as a comparative assessment of their performance with recently developed CuO-based photocatalysts.

1. Introduction

Anthropogenic carbon dioxide (CO_2) levels in the atmosphere have been steadily elevating in recent years, most likely corresponding to fossil fuels' expanded usage to address the fast growth of global energy markets. This uncontrolled situation inevitably initiates harsh environmental matters like global warming [1]. In response to this significant issue, tremendous efforts have been reported in the literature toward finding an efficient approach to lessening the emission of CO_2.

To date, the transformation of CO_2 into solar fuel, methanol (CH_3OH) via photoreduction routes, has acquired substantial lookout since this green path is driven by renewable solar energy for converting undesired CO_2 [2,3]. Indeed, the photoreduction pathway appears intriguing, as it is typically carried out with a low energy input and under reasonably benign circumstances. However, since CO_2 is undoubtedly a chemically inert substance, it demands vast energy to transform into carbon-based fuels. Thus, developing highly efficient photocatalysts under an expansive light range is critical to guarantee the effectual harnessing of light energy.

Numerous semiconductors have been evaluated as prospective photocatalysts for CO_2 photoreduction [4–7]. Among these semiconductors, the p-type semiconductor, copper oxide (CuO), has garnered considerable interest owing to its strong absorption coefficient, narrow bandgap (1.2–1.9 eV), and appropriate electronic features for photoreduction

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