Highly Efficient Ambient Temperature CO_2 Photomethanation Catalyzed by Nanostructured RuO_2 on Silicon Photonic Crystal Support

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Sunlight-driven catalytic hydrogenation of CO_2 is an important reaction that generates useful chemicals and fuels and if operated at industrial scales can decrease greenhouse gas CO_2 emissions into the atmosphere. In this work, the photomethanation of CO_2 over highly dispersed nanostructured RuO_2 catalysts on 3D silicon photonic crystal supports, achieving impressive conversion rates as high as 4.4 mmol g_{cat}^{-1} h^{-1} at ambient temperatures under high-intensity solar simulated irradiation, is reported. This performance is an order of magnitude greater than photomethanation rates achieved over control samples made of nanostructured RuO_2 on silicon wafers. The high absorption and unique light-harvesting properties of the silicon photonic crystal across the entire solar spectral wavelength range coupled with its large surface area are proposed to be responsible for the high methanation rates of the RuO_2 photocatalyst. A density functional theory study on the reaction of CO_2 with H_2 revealed that H_2 splits on the surface of the RuO_2 to form hydroxyl groups that participate in the overall photomethanation process.