TiO_2-based photocatalysts for hydrogen production from lactic acid: a supercritical antisolvent approach

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The constantly rising energy demand and the depletion of non-renewable fossil fuels have highlighted the need for more sustainable energy alternatives. Hydrogen is widely considered a promising clean energy carrier, as its combustion does not produce greenhouse gas emissions. In recent years, hydrogen production technologies have significantly advanced, with photocatalytic water splitting emerging as a sustainable method for efficient hydrogen generation.

Due to the thermodynamic uphill nature of water splitting and the rapid reverse reaction, sacrificial agents are often introduced to increase electron availability for H^+ reduction to H_2. Organic acids, which decompose into CO_2 during oxidation, can inhibit electron-hole recombination, thereby promoting H_2 production. This enables the use of renewable sources and the valorization of waste-derived materials. Among these, lactic acid is a particularly promising sacrificial agent due to its ease of oxidation - attributable to the hydroxyl group on the α-carbon next to the carbonyl - and its wide use in pharmaceutical, cosmetic, and food industries. Nevertheless, photocatalytic hydrogen production using lactic acid remains relatively underexplored.

Supercritical antisolvent (SAS) precipitation is a promising technique for photocatalyst synthesis, offering control over particle morphology and size, as well as complete removal of residual solvents that might interfere with photocatalytic activity.

This research focuses on photocatalytic hydrogen generation from an aqueous solution of lactic acid. The SAS process was used to micronize titanium oxide (IV) acetylacetonate, a precursor for TiO_2, reducing particle size. After calcination, the resulting photocatalyst was tested for hydrogen production. To enhance H_2 evolution, the TiO_2 was also doped with copper (2Cu-TiO_2 SAS).

Photocatalytic tests were carried out in a batch Pyrex cylindrical reactor irradiated by four lamps for up to 240 minutes. The system included a nitrogen distribution (N_2 flow rate= 0.250 NL min^{-1}), and gas-phase data were collected using an ABB analyzer connected to LabVIEW software for real-time H_2 and CO_2 monitoring. Various photocatalyst dosages were tested, and the role of water in hydrogen production was assessed. Photocatalyst reusability tests were also performed.

The performance of the SAS-produced photocatalyst was compared with that of a non-micronized counterpart, revealing that the first one enabled higher hydrogen production (4040 µmol/L) compared to the non-micronized catalyst (3500 µmol/L).

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