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FABRICATION AND INVESTIGATION OF PHOTOCATALYTIC CO₂ REDUCTION INTO CH₄ FUEL GAS OVER (N, Ta) CO-DOPED TiO₂ WITH VARYING NITROGEN WEIGHT PERCENTAGES VIA THE MICROWAVE METHOD**Summary**

The band gap of TiO₂ is relatively wide, approximately 3.2 eV; therefore, TiO₂ cannot absorb visible light, leading to poor solar energy conversion efficiency into hydrogen. To narrow the band gap, donor-acceptor alloy doping is applied to TiO₂ materials while simultaneously increasing the alloy concentration. This approach not only reduces the band gap energy but also enhances light absorption in the long-wavelength region and decreases the overall effective mass [1].

Previous studies on (N, Ta) co-doped TiO₂ synthesized via the hydrothermal method still face several limitations, including being time-consuming, the inability to adjust parameters mid-reaction, and the requirement for extensive equipment that is difficult to clean. Furthermore, these studies have been limited to fixed masses of N and Ta dopants. Notably, the dopant mass significantly influences the band gap alteration, crystal lattice transformation, and the variation in electron-hole pairs within the material system, thereby changing the optical properties of the material. Consequently, this study investigates the fabrication of modified TiO₂ nanoparticles through (N, Ta) co-doping with varying Nitrogen (N) content using the microwave method. This is a simple technique that allows for significantly shorter fabrication times compared to the hydrothermal method. We have obtained systematic research results regarding the photocatalytic CO₂ reduction capacity into CH₄ fuel gas of the synthesized materials [2, 3].

Keywords:

(N, Ta) co-doped TiO₂ , (N, Ta) co-doped TiO₂ with varying nitrogen weight percentages.

1. INTRODUCTION

To enhance the photocatalytic activity of TiO₂ in the visible light region, numerous studies have indicated that doping the TiO₂ matrix with non-metals, particularly nitrogen (N), effectively narrows its band gap. Consequently, N-doped TiO₂ not only exhibits absorption capabilities within the visible spectrum but also extends the lifetime of photogenerated electrons and holes. However, the substitution of N into the TiO₂ lattice can induce an increase in oxygen vacancies, which partially impairs the material's photocatalytic performance. To further bolster this activity, we conducted co-doping of N with a transition metal, specifically Tantalum (Ta). By incorporating both Ta and N at appropriate concentrations, charge neutrality between positive and negative charges is achieved, oxygen vacancies are suppressed, and the electron-hole lifetime is prolonged throughout the photocatalytic process [4].

2. MICROWAVE FABRICATION OF TiO₂:(N, Ta)

The (N, Ta) co-doped TiO₂ samples were designated as TN1Ta, TN2Ta, TN3Ta, and TN4Ta, corresponding to nitrogen (N) weight percentages of 6%, 7.5%, 9%, and 10.5%, respectively, while maintaining a constant Tantalum (Ta) content of 0.5 wt.%.

- **Step 1:** 11 mL of Tetraisopropyl orthotitanate (TPOT) was mixed with 20 mL of Isopropyl alcohol (IPA) and stirred for 10 minutes.

- **Step 2:** 25% ammonium hydroxide NH₄OH was added dropwise to the above mixture. The amount of N in NH₄OH was calculated relative to the theoretical mass of TiO₂ formed in the reaction to achieve weight percentages of 6%, 7.5%, 9%, and 10.5% (N/TiO₂). The resulting solutions were stirred for 1 hour at room temperature.

- **Step 3:** Tantalum (Ta) was dissolved in a mixture of HNO₃ and HF acids. This Ta-containing solution was then added dropwise into the four previously prepared solutions (containing TPOT, IPA, NH₄OH, and H₂O) such that the Ta/TiO₂ weight percentage in all four samples remained constant at 0.5%.