Study of Non-metals-doped Titanium Dioxide Nanotubes for Photocatalytic -Hydrogen Production and Dye degradation

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Abstract

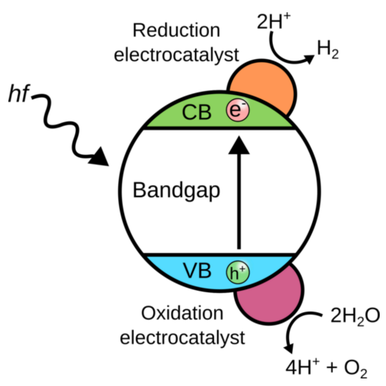
Photocatalysts are a class of catalysts that have attracted considerable attention as materials for alternative energy production and sustainable wastewater treatment, particularly rod-shaped titanium dioxide (TiO_2). However, TiO_2 still has a major limitation due to its high rate of charge recombination, which reduces its photocatalytic efficiency. Therefore, this study investigated the doping of TiO_2 with non-metals, including nitrogen (N), sulfur (S), and fluorine (F), in order to improve its performance and suppress charge recombination. TiO_2 was synthesized using a hydrothermal process at 180 °C for 36 hours, followed by calcination at 700 °C for 5 hours. The obtained TiO_2 was then ground with the respective non-metal dopants and further calcined at 450 °C for 1 hour. The effects of dopant concentrations at 5, 10, and 20 wt% were systematically studied. The structural and morphological properties of the prepared photocatalysts were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), and X-ray photoelectron spectroscopy (XPS). The results confirmed the successful incorporation of non-metal dopants into TiO_2. The catalysts exhibited a rod-like morphology with a rough surface, attributed to the presence of non-metal species on the TiO_2 rods. Photocatalytic dye degradation tests showed that TiO_2 doped with 5 wt% sulfur (S) achieved the highest degradation efficiency of 97.21%, while undoped TiO_2 showed a degradation efficiency of 94.50%. In hydrogen production experiments, TiO_2 doped with 10 wt% fluorine (F) demonstrated the highest hydrogen yield of 9191.90 μmol/g, whereas undoped TiO_2produced 9160.41 μmol/g under the same reaction time of 2 hours.

Introduction

Global energy demand has increased significantly, driving the search for renewable and environmentally friendly energy sources.

TiO_2 is a widely studied photocatalyst for hydrogen production, but its efficiency is limited by rapid electron–hole recombination.

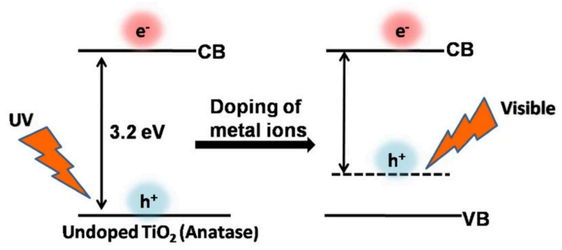
In this study, non-metal-doped TiO_2 nanotubes (N, S, and F) were synthesized to enhance photocatalytic hydrogen production and dye degradation.



VB Oxidation : $2H_2O + 4h^+_{vb} \rightarrow O_2 + 4H^+$

CB Reduction : $2H^+ + 2e^-_{cb} \rightarrow H_2$

Overall reaction : $2H_2O \rightarrow 2H_2 + O_2$

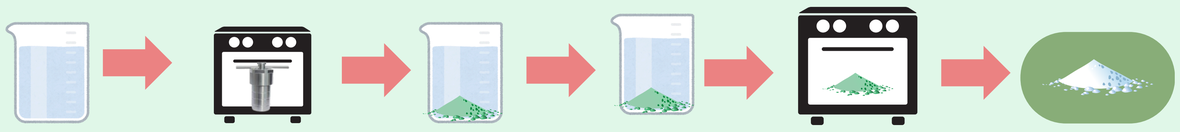


Objective

1. To study the synthesis and characteriz the non metal doped TiO_2 nanotubes via hydrothermal method
2. To study the photocatalytic performance of non-metal-doped TiO_2 in dye degradation and hydrogen production.

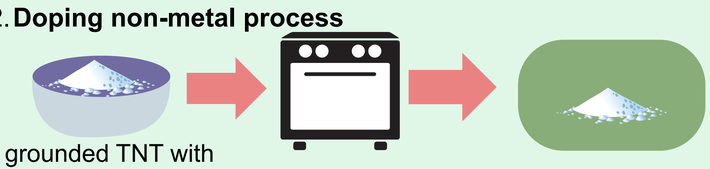
Experiment

1. Synthesis of Titanium Dioxide nanotubes (TiO_2) by Hydrothermal process



Adding P25 and mixing with 10M NaOH until homogeneous → hydrothermal process Heat at 180°C 36 hr. → washing DI water → Ion exchange via HNO_3 and washing by DI water → Calcine at 700°C 5 hr → TiO_2 nanotube anatase (TNT)

2. Doping non-metal process



grounded TNT with non-metals (urea, Na_2S, NaF) → Calcined at 450°C 1 hr → TNT doped non-metals

NTNT-05	N	5
NTNT-10	N	10
STNT-05	N	5
STNT-10	N	10
FTNT-05	N	5
FTNT-10	N	10

3. Photocatalytic Dye Degradation in 5ppm Rhodamine B 100 mL.

catalyst 100 mg

↓

while shaking Keep in dark 30 min

↓

photocatalysis 0-180 min with Light source take sample 5 mL. every 30 min

↓

Centrifuged and UV-vis measurement

4. Photocatalytic Hydrogen production

Sample dispersed onto a platinum (Pt) surface as a co-catalyst.

↓

Add prepared sample into reactor which contain methanol mixer

↓

substitute air with nitrogen

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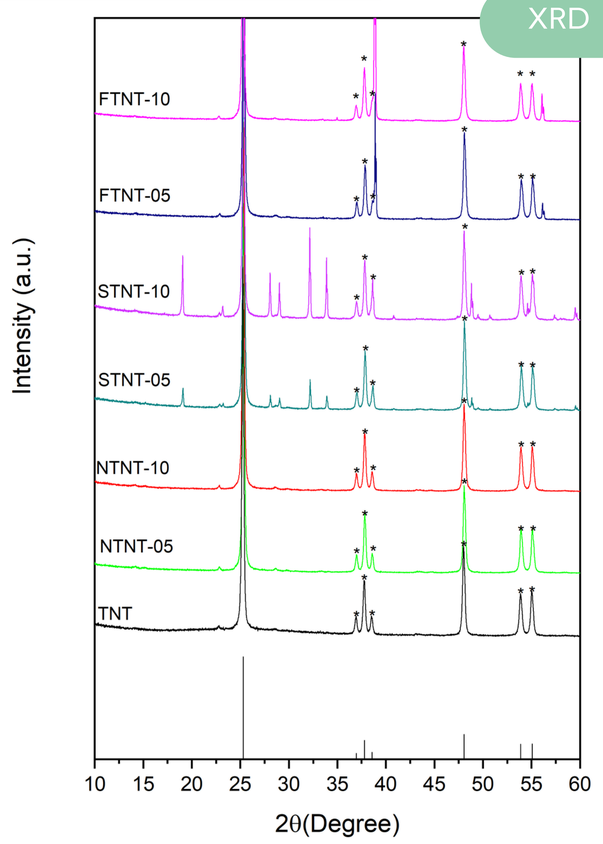
Start Hydrogen production turn on xenon lamp

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Measure producted hydrogen by Gas Chromatography

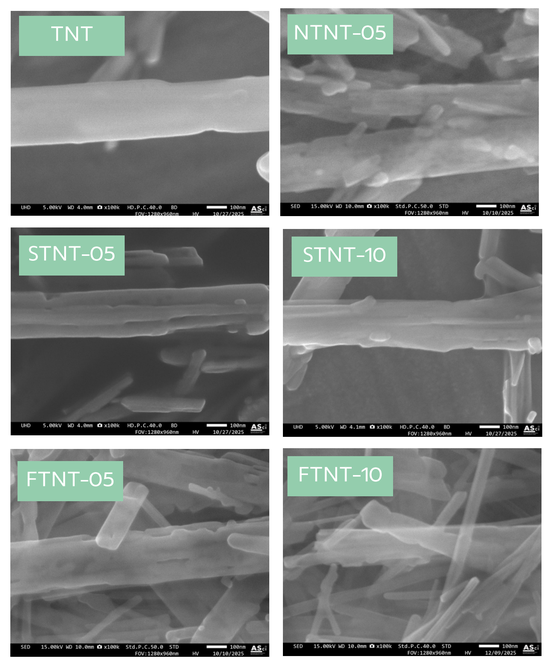
Results & Discussion

XRD



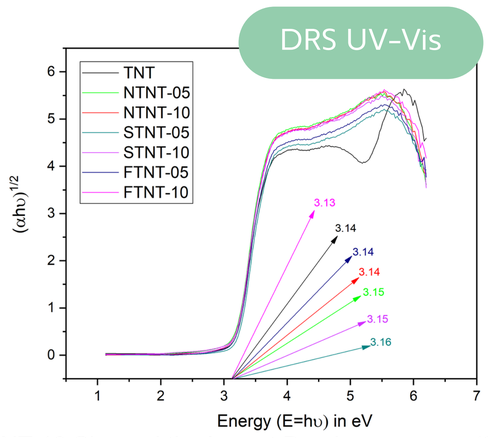
- XRD showed all sample's main structure is TiO_2 anatase

SEM



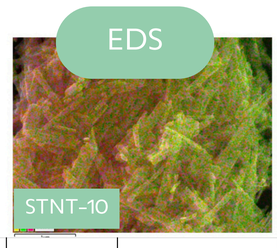
- SEM showed stucture like tube and found defect

DRS UV-Vis



- FTNT-10 Showed the lowest Band gap energy (3.13eV)

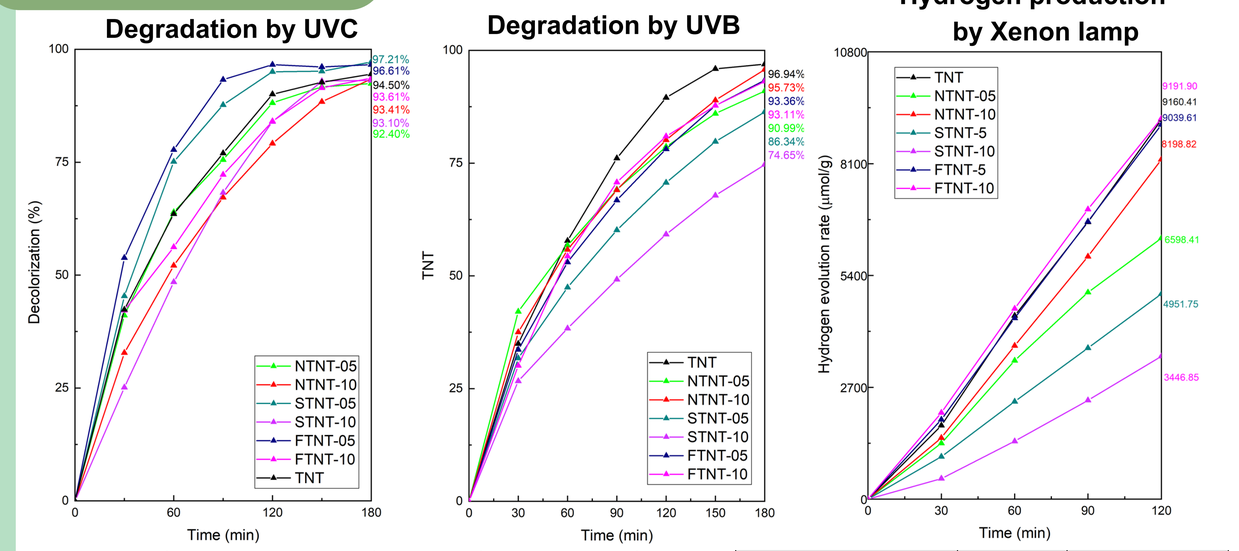
EDS



Element	Wt%	Wt% Sigma	Atomic %
O	52.48	0.2	76.61
F	0.93	0.03	0.68
Ti	46.59	0.19	22.72

- EDS found S

Photocalytic efficiency



bestperformance	Sample	%degradatio
UVC	STNT-05	97.21
UVC	TNT	96.94

bestperformance	Sample	μmol/g
XENON	FTNT-10	9191.9

Conclusion

- Successful synthesis non metal doped by XRD confirmed main structure is Anatase, SEM showed tube like structure and defect after doping, EDS found Sulfur in structure , and DRS Uv-Vis Sample have slightly different Band gap
- Some of non metal doped sample increase photocatalysis Dye degradation vai STNT-05 can decolerize for 97.21% showed highest rate for UVC and FTNT-10 can maximum product hydrogen for 9190.90 μmol/g

Acknowledments

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reference

Yadala Venkata Divyasri et al., Optimization of N-doping in TiO_2 nanotubes for enhanced solar-light mediated photocatalytic H_2 production and dye degradation. Environmental Pollution 2021, 269, 116170.