



Photocatalytic activity of Ag-Ag₃PO₄/Cellulose aerogel composite for degradation of dye pollutants under visible light irradiation

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ABSTRACT

In this research, Ag-Ag₃PO₄/Cellulose aerogel composite was synthesized using hydrothermal reduction and freeze-drying methods. By combining the photocatalytic activity of the semiconductor Ag-Ag₃PO₄ and cellulose aerogel synthesized from agricultural waste sources, the synthesized Ag-Ag₃PO₄/Cellulose aerogel composite has overcome the disadvantages of pure Ag₃PO₄ and significantly improved the photocatalytic activity. Structural characteristics, morphology, surface area of the materials were analyzed by X-ray diffraction (XRD), scanning electron microscopy (SEM), N₂ adsorption-desorption and UV-vis diffuse reflectance spectroscopy (UV-vis DRS) methods. From the obtained results, composite has narrow bandgap energy (2.275 eV) and excellent catalytic performance in the photodegradation of dye pollutants (99% MB and 77% RY 145 degraded after 4 h, and only a minor change in the efficiency observed after four consecutive tests). It demonstrates the development of new catalysts made from agricultural waste sources that show high stability, ease of fabrication and can operate in natural light for environmental remediation.

Introduction

Industries are the primary sources of hazardous chemicals and wastewater such as drugs, dyes, pesticides, heavy metals and nitro compounds and their derivatives, thereby making water pollution a major problem for modern society [1]. According to a survey, about 10-15 % of the water environment is polluted by dyes during the production process. Some of them even have high stability and degrading difficulty, thus endanger human health, plants and animals [2]. Over the past few decades, research on semiconductor photocatalytic materials has grown

tremendously due to their potential to solve energy shortage and environmental degradation [3,4]. Scientists hope to develop semiconductor materials that operatable under a wide range of light, high electron separation ability and sufficient charge to degrade dyes and harmful substances [5].

Photocatalytic degradation under visible light attracts attention intending to degrade organic dyes wastes from chemical, textile, dyeing factories. Compared with the photochemical method using ultraviolet radiation, this method has advantages such as simple synthesis route, low cost and high efficiency [6-8]. In 2010, Ye *et al.* [9] first researched and proved the photo-oxidation

properties of Ag_3PO_4 with bandgap energy E_g of 2.36 eV. Then, this material was widely studied in water oxidation and degradation of organic compounds under irradiation. When the irradiated light wavelength is above 420 nm, Ag_3PO_4 has outstanding quantum separation and photocatalytic activity [10]. Many studies also reported that the surface plasmon resonance effect of Ag^0 could enhance the activity and stability of Ag_3PO_4 [11-13]. However, the nano-sized $\text{Ag}/\text{Ag}_3\text{PO}_4$ is easily agglomerated in an aqueous solution, thus significantly reducing photocatalytic activity. In practical applications, $\text{Ag}/\text{Ag}_3\text{PO}_4$ is also difficult to recover from the environment with simple methods and could lead to secondary pollution. The fixation of nano photocatalysts on supporting materials is considered one of the easiest and effective ways to overcome these limitations. Up to now, various materials have been developed as carriers, such as carbon materials [14,15], metal oxides [16,17] and organic compounds [18,19].

Currently, the most commonly used aerogel for photocatalytic applications is graphene aerogel. F. Chen *et al.* [20] synthesized graphene aerogel with 3D structure to support the $\text{Ag}@/\text{Ag}_3\text{PO}_4$ photocatalytic catalyst used for treating dyes in water. The results showed that the 3D $\text{Ag}@/\text{Ag}_3\text{PO}_4$ /graphene aerogel has good photoadsorption and photodegradation with both anionic and cationic dyes. S. Dong *et al.* [21] synthesized 3D Bi_2WO_6 /graphene aerogel composite with excellent photocatalytic performance. Using graphene aerogel with its 3D structure, the material has narrower bandgap energy, improved light absorbability, higher charge separation efficiency and better-contaminated adsorption than the original Bi_2WO_6 .

Cellulose aerogel is a form of gas-solid material produced from agricultural by-products (bagasse, straw, coffee beans,...). Since cellulose aerogel has most of the volume filled with air and gases, it resulted in a solid with extremely low density. However, the material still can withstand a weight of 500–2000 times its own [22]. Cellulose aerogel possesses excellent properties, suitable for applications in various fields: low density, high porosity, large specific surface area, good sound insulation, low heat transferability, good pollutant adsorbability, thermal and chemical stability, and biodegradability [23,24].

In this work, the $\text{Ag}-\text{Ag}_3\text{PO}_4$ /Cellulose aerogel photocatalysts were synthesized using cellulose aerogel as a carrier to reduce the recombination of the photogenerated electron-hole pairs. We proposed

bagasse, a cheap and abundantly available material in Vietnam, to synthesis cellulose. The degradation of Methylene Blue (MB) and Reactive Yellow 145 (RY 145) dyes was used to investigate the photocatalytic activity of $\text{Ag}-\text{Ag}_3\text{PO}_4$ /Cellulose aerogel composite.

Experimental

Materials

Polyvinyl alcohol (PVA), ethanol ($\text{C}_2\text{H}_5\text{OH}$ 99 %), sodium hydroxide (NaOH 99 %), hydrogen peroxide (H_2O_2 30 %), chloride acid (HCl 38 %), sodium hypochlorite (NaClO 99 %), silver nitrate (AgNO_3) and sodium phosphate ($\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$) were purchased from Sinopharm Chemical Reagent Co. Ltd., China. Methylene Blue (MB) and Reactive Yellow 145 (RY 145) were purchased from Merck, Germany. Sugarcane bagasse was used as the precursor of cellulose, collected from plantations located in Hoa Binh Province, Vietnam.

Synthesis of $\text{Ag}-\text{Ag}_3\text{PO}_4$ /Cellulose aerogel composite

Extraction of cellulose from sugarcane bagasse

The bagasse was washed thoroughly and cut into 1-2 cm pieces, then grind into powder. The powder of sugarcane bagasse was dewaxed using ethanol/water (1:1 v/v), stirred for 2 h at 60 °C, then washed with deionized water. After removing impurities, the sugarcane bagasse was further treated with 1M NaOH solution at 80 °C in 2 h to remove lignin. The product was washed with deionized water until the neutral pH was reached. Subsequently, the product was treated using 1% NaOH and 1% NaClO (w/v) water solution with a molar ratio of 2:1 at 80 °C for 1.5 h to remove hemicellulose. The product mixture was filtered, washed with deionized water and dried at 60 °C overnight. Finally, the extracted cellulose had the form of a white powder.

Synthesis of $\text{Ag}-\text{Ag}_3\text{PO}_4$ /Cellulose aerogel composite

A mixture of cellulose and PVA with a molar ratio of 100:1 was dispersed 50 mL of deionized water. Then, this mixture was ultrasonicated for 10 min. The sample was put into a mold with dimensions of 10 cm x 10 cm x 3 cm and freeze for 24 h. After freezing, the sample is taken out and left at room temperature within 2 hours then freeze again within 12 hours.

The reduction–hydrothermal reaction of AgNO_3 with hydrogel cellulose was proceeded by dispersing cellulose gel in AgNO_3 solution with the concentrations of 0.05, 0.1 and 0.4 mol/L. The mixture was put in an autoclave for aging at 80°C for 24 h. Hydrogel cellulose was washed with deionized water and dispersed into a 200 mL mixture of Na_2HPO_4 0.2 M and H_2O_2 30 % for 30 mins at room temperature. The mixture of hydrogel cellulose containing $\text{Ag-Ag}_3\text{PO}_4$ was washed three times with deionized water and then put into molds with dimensions of 10 cm x 10 cm x 3 cm, then frozen at -5°C for 24 h. Next, the sample was freeze-drying at -55°C and vacuum pressure

approximately at 10 μPa . $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel composites are denoted as 0.05 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, 0.1 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel và 0.4 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, respectively with the concentrations of AgNO_3 solution. Figure 1 shows (a) composite gel, (b-d) 0.05 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, 0.1 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel and 0.4 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, (e) cross-linking between cellulose from bagasse and PVA chain, hydrogen bonds were formed between different hydroxyl functional groups of cellulose and PVA [25], (f-g) mechanism of hydrothermal reduction to form Ag^0 and Ag_3PO_4 .

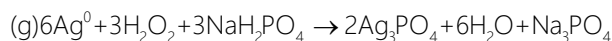
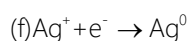
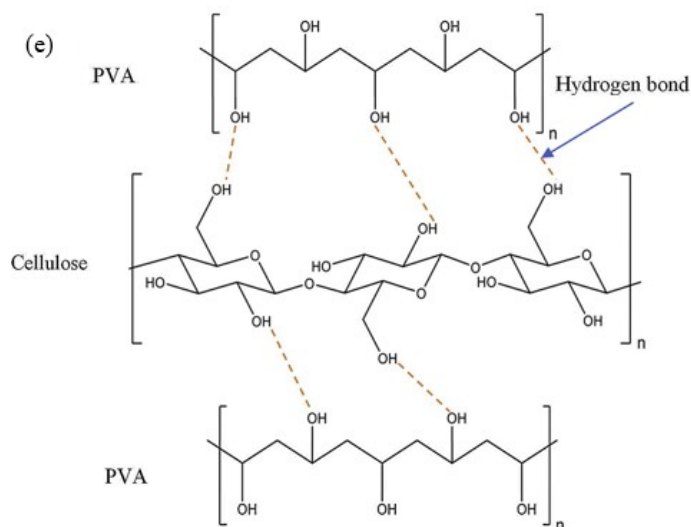
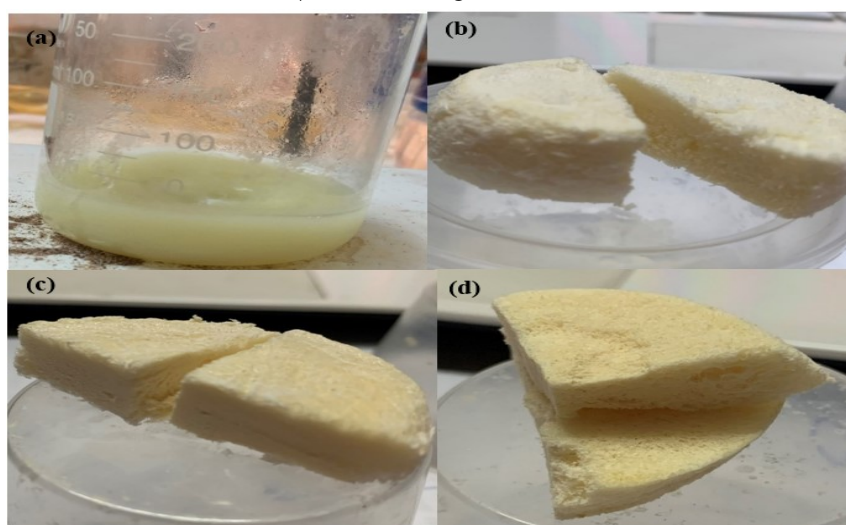


Figure 1: (a) the composite gel, (b-d) 0.05 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, 0.1 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel và 0.4 $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, (e) cross-linking between cellulose from bagasse and PVA chain, (f-g) mechanism of hydrothermal reduction to form Ag^0 and Ag_3PO_4 .

Characterization

X-ray diffraction spectrum (XRD) of the samples was measured on the Bruker D8 Advance diffractometer using Cu X-ray emission tube with wavelength $\lambda(\text{CuK}\alpha) = 0.15406 \text{ nm}$, capacity 30 kV, current 0.01 A were recorded in the 2θ range of 5-80°. All samples were ground into powder to avoid the influence of the crystalline orientation. The crystalline size (D) of the sample for the (210) plane of Ag_3PO_4 nanoparticle was calculated by the Scherrer formula [26]:

$$D = \frac{0.9\lambda}{\beta \times \cos\theta} \quad (1)$$

Where $\lambda = 0.15406 \text{ nm}$, β is the corrected integral width, and θ is the Bragg angle. Surface morphology was observed by scanning electron microscopy method (S-4800, Hitachi). Specific surface area Brunauer–Emmett–Teller (BET) was determined at 77 K by the N_2 adsorption-desorption method on ChemBET-3030. Ultraviolet-visible diffuse reflectance spectroscopy (UV-Vis DRS) was recorded on UV-2600 (Shimadzu) spectrophotometer.

The point of zero charge (pzc) of $\text{Ag-Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel was measured by salt addition method [27]. Typically, 50 mg of each sample was dispersed in 50 mL of KCl 0.1 M in 100 mL flasks and stirred magnetically for 30 min. The initial pH values (pH_0) of the suspension were then adjusted between 2 and 12 by adding either HCl 0.25 M or NaOH solution, measured by a calibrated Hach pH201 pH meter with accuracy = ± 0.02 . After stirring for 24 h in a revolving water bath to reach equilibrium, resulting pH values were measured and the difference between the initial and final pH values ($\Delta pH = pH -$

pH_0) against the initial pH was plotted. The pH value where ΔpH equals zero was denoted pH_{pzc} .

Catalytic activity test

The catalytic activity was evaluated through the degradation reaction of MB and RY 145 dyes under solar irradiation. Specifically, 50 mg of the photocatalyst was dispersed in 35 mL of an aqueous solution containing dyes (50 ppm). Before the reaction, the mixture was stirred magnetically at 300 rpm in the dark for 60 mins to achieve the adsorption-desorption equilibrium. The initial concentration (C_0) was taken at this point. Then, the mixture was illuminated under natural light for 4 h (from 10 A.M. to 2 P.M.). After every hour, a small quantity of the solution was taken and measured under UV-Vis spectrometer to record the concentration (C_t) (the absorption peaks of MB and RY 145 are at 664 nm and 541 nm, respectively). The dye degradation efficiency was calculated using Equation 2

$$H\% = \frac{C_0 - C_t}{C_0} \times 100 \quad (2)$$

Where: C_0 is the initial dye concentration (ppm)

C_t is the concentration of dye at time t (ppm)

Results and Discussion

The crystal structure and phase composition of the samples were characterized by X-ray diffraction. The results are shown in **Error! Reference source not found.**

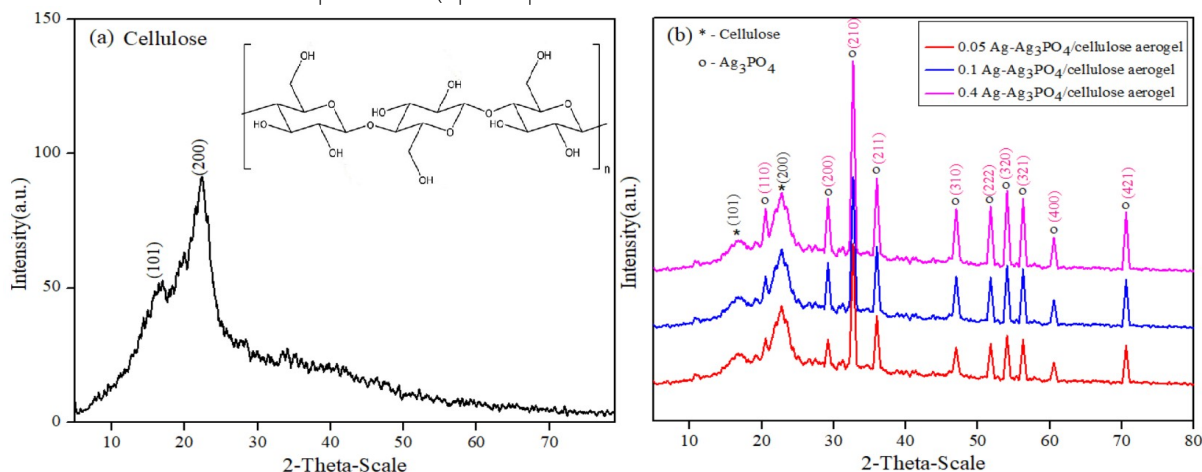


Figure 2: X-ray diffraction patterns of (a) cellulose, (b) 0.05Ag- $\text{Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, 0.1Ag- $\text{Ag}_3\text{PO}_4/\text{Cellulose}$ aerogel, 0.4Ag- $\text{Ag}_3\text{PO}_4/\text{cellulose}$ aerogel

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The characteristic diffraction peaks of cellulose aerogel were detected at $2\theta = 16-17^\circ$, corresponded to the (101) plane, $19-20^\circ$ angle for amorphous phase and 22° angle for reflectant (200) [28]. Typical diffraction peaks of Ag_3PO_4 were observed at $2\theta = 20.88^\circ, 29.70^\circ, 33.29^\circ, 36.59^\circ, 47.79^\circ, 52.70^\circ, 55.02^\circ, 57.28^\circ, 61.64^\circ$ and 71.90° , corresponded to (110), (200), (210), (211), (310), (222), (320), (321), (400) and (421) crystal planes, respectively. The diffraction peaks can be indexed to the pure body-centered cubic (bcc) structure of Ag_3PO_4 . The results were consistent with the standard data (JCPDS No. 06-0505). However, there were no visible diffraction peaks of Ag, which could be explained by either its small quantity or the small size of the particles. This phenomenon has been reported in previous papers of Ag/AgX (X: Cl, Br, I) [29,30]. All diffraction patterns of 0.05Ag- Ag_3PO_4 /Cellulose

aerogel, 0.1Ag- Ag_3PO_4 /Cellulose aerogel and 0.4Ag- Ag_3PO_4 /Cellulose aerogel samples appeared characteristic diffraction peaks of cellulose and Ag_3PO_4 . Additionally, peak intensities increased when the concentration of AgNO_3 increased from 0.05 to 0.4 M. This can be explained as the concentration of AgNO_3 increases, more nanoparticles form and agglomerate. Using Scherrer equation, the size of Ag_3PO_4 particles were estimated corresponding to (210) plane, approximately 17 nm for 0.05 Ag- Ag_3PO_4 /Cellulose aerogel sample and increased to 22 nm for 0.4 Ag- Ag_3PO_4 /Cellulose aerogel sample.

Scanning electron microscopy (SEM) was used to determine the surface morphology of 0.1Ag- Ag_3PO_4 /Cellulose aerogel composite (**Error! Reference source not found.**).

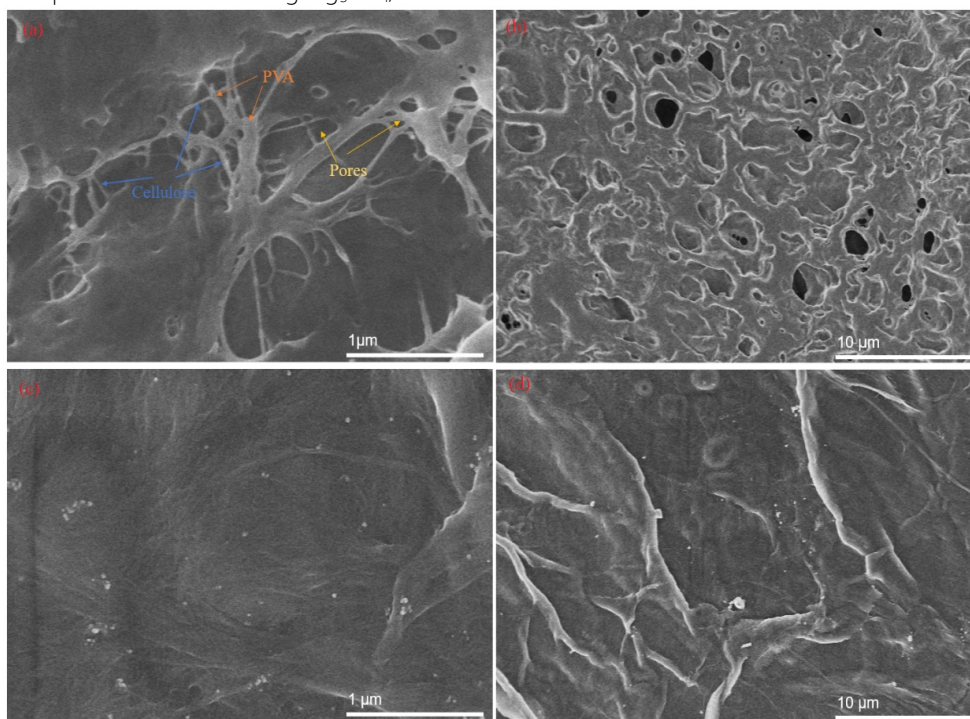


Figure 3: SEM images of (a-b) cellulose aerogel and (c-d) 0.1Ag- Ag_3PO_4 /cellulose aerogel

From the SEM images, after the freeze-drying process and solution evaporation, pores were formed with the size from nanometers to micrometers. Cellulose aerogel materials formed by random bonds between cellulose and PVA molecules created a 3-D network with high porosity. Figure 3 (c,d) show that silver and Ag_3PO_4 nanoparticles were synthesized in situ in cellulose aerogel and bonded directly to its frame by electrostatic interaction with the hydroxyl groups of

cellulose [31,32]. The porous structure of cellulose aerogel served both as cavities for the formation of the Ag- Ag_3PO_4 nanoparticles and shells to protect the nanostructure.

The surface area and pore size of cellulose aerogel and 0.1Ag- Ag_3PO_4 /Cellulose aerogel composite were determined by the N_2 adsorption-desorption method (**Error! Reference source not found.**).

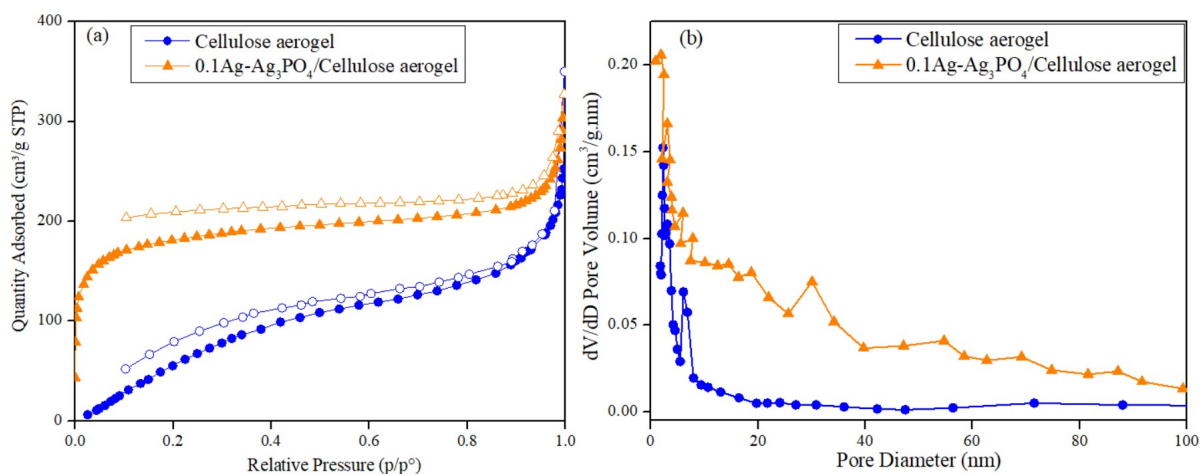


Figure 4: (a) N₂ adsorption-desorption isotherm curve (b) the corresponding pore size distribution of cellulose aerogel and 0.1Ag-Ag₃PO₄/Cellulose aerogel

The N₂ adsorption-desorption isotherm curve of cellulose aerogel and 0.1Ag-Ag₃PO₄/Cellulose aerogel composite (Figure 4a) have the type I hysteresis curve characteristic for capillary condensation and many defects in the sample. Based on Barrett-Joyner-Halenda (BJH) equation, the pore diameter of cellulose aerogel and 0.1Ag-Ag₃PO₄/Cellulose aerogel distributed widely in the range of 2–100 nm (Error! Reference source not found.). BET specific surface area of 0.1Ag-Ag₃PO₄/Cellulose aerogel composite materials increased compared to cellulose aerogel. Specifically, the surface area increased from 70 m²/g to

87.2 m²/g due to the formation of Ag₃PO₄ and their uniform pore distribution. The adsorption surface area increased with the cross-section area with the pollutants, thereby increasing the photocatalytic efficiency of the composite.

Optical properties have a significant impact on the photocatalytic activity of the catalyst. Therefore, the absorption property of samples was investigated by the UV-vis diffuse reflectance spectroscopy and the results are shown in Error! Reference source not found..

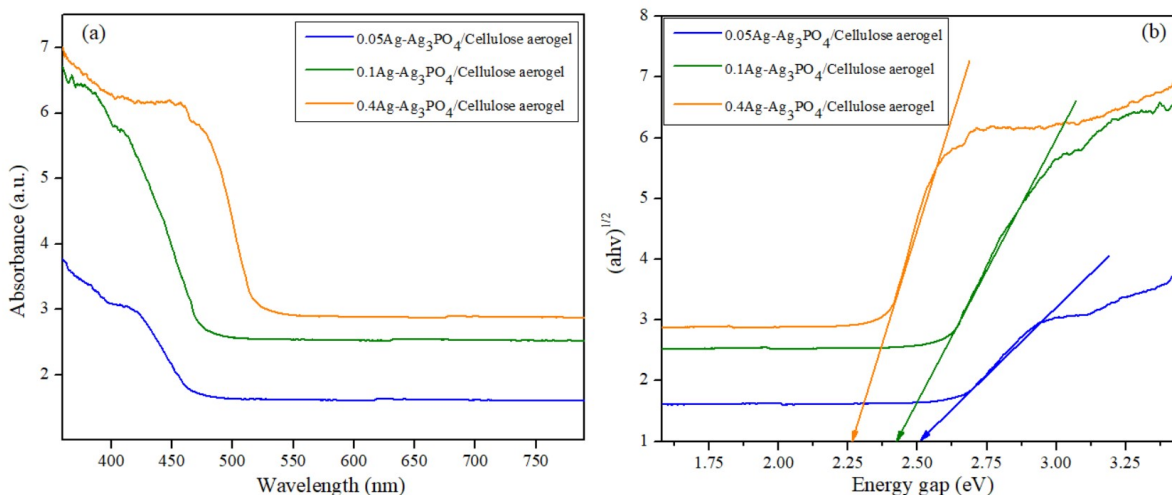


Figure 5: (a) UV-vis diffuse reflectance spectrum, (b) Kubelka-Munk equation of 0.05Ag-Ag₃PO₄/Cellulose aerogel, 0.1Ag-Ag₃PO₄/Cellulose aerogel and 0.4Ag-Ag₃PO₄/Cellulose aerogel

The absorption edge of the samples shifted to a greater wavelength region, from 495 to 540 nm as the concentration of AgNO₃ increased from 0.05 M to 0.4 M. The bandgap energies of the samples were also estimated using the Kubelka-Munk equation [33] :

$$\alpha h\nu = k(h\nu - E_g)^{\frac{n}{2}} \quad (3)$$

In which α , ν , k are the absorption coefficient, frequency of light and correction factor, respectively. The bandgap energy of 0.05Ag-Ag₃PO₄/Cellulose

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aerogel, 0.1Ag-Ag₃PO₄/Cellulose aerogel, 0.4Ag-Ag₃PO₄/Cellulose aerogel samples were 2.51, 2.385 and 2.275 eV, respectively. The reduced bandgap energy was related to the surface plasmon absorption of silver metal on Ag₃PO₄ surface [11]. Thus, increasing the content of active phase in composite materials has contributed to the bandgap energy reduction, while

increasing its photocatalytic efficiency. This result was entirely consistent with the previous report of Y. Liu *et al.* [12].

The photocatalytic activity of the samples was estimated by the degradation reaction of MB and RY 145 under visible light. The results are shown in **Error! Reference source not found.**

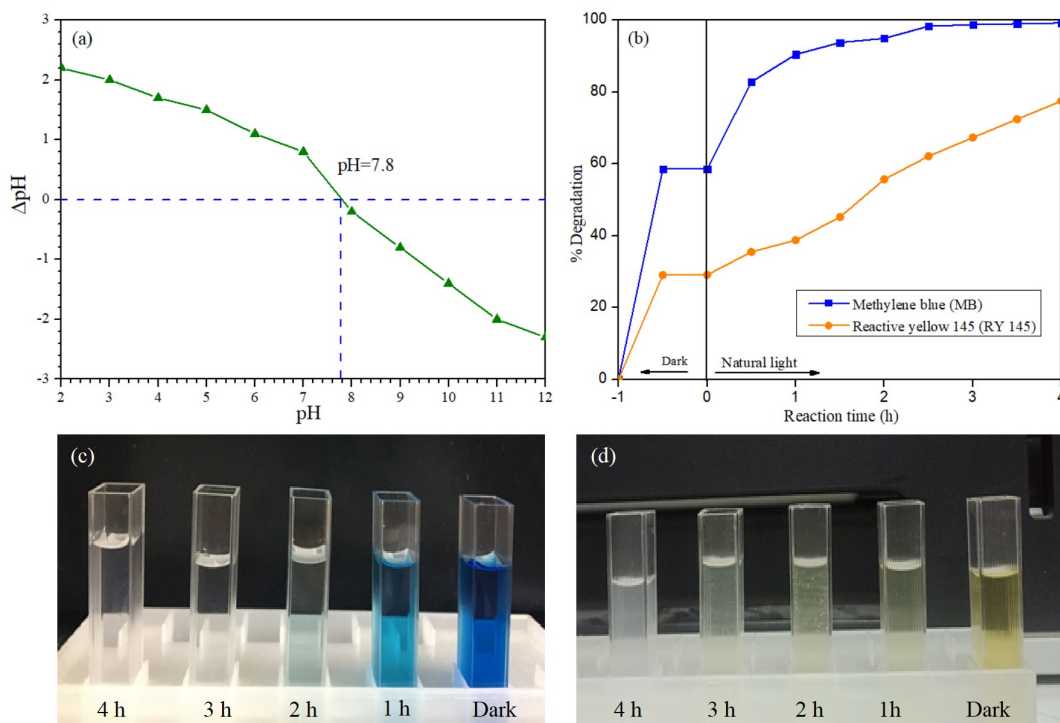


Figure 6: (a) Point of zero charge of 0.1Ag-Ag₃PO₄/Cellulose aerogel, (b-d) The photocatalytic efficiency of 0.1Ag-Ag₃PO₄/Cellulose aerogel degradation of MB and RY 145 dyes

The pH value of point zero charge (pH_{pzc}) was measured on 0.1Ag-Ag₃PO₄/Cellulose aerogel composite in various pH environments to survey the surface area. When the solids are dispersed in water with pH lower than pH_{pzc} , the surface of the material has positive charge and negative charge when pH higher than pH_{pzc} . In Fig.5a, the plot between ΔpH and initial pH value determined the point zero charge at $\text{pH} = 7.8$. The results showed Fig.5b that the 0.1Ag-Ag₃PO₄/Cellulose aerogel has good photodegradation for MB cationic dyes. Photodegradation reached 93.8 % after 1.5 h and reached 99 % after 3 h, while the degradation efficiency of anionic RY 145 dyes only reached 77 % after 4 h of irradiation with visible light. This may be due to the surface of aerogel material containing OH⁻ groups facilitating the binding of cation dyes. Hence, the dye ions binding to the

adsorbent mainly involved electrostatic interaction between cationic dyes and negatively charged OH⁻ groups. The mechanism of the adsorption process is physical adsorption depending on electrostatic interaction. Creating an interaction force with MB cation molecules [34] so the adsorbability of MB dye is better than anionic dye RY 145. The increasing interaction between pollutant and catalyst active sites led to increased photodegradation efficiency. Photodegradation of MB dye was selected to investigate the factors affecting the photocatalytic process of Ag-Ag₃PO₄/Cellulose aerogel materials.

Factors such as the contents of the active phase, dye concentration, H₂O₂ dosage and catalyst stability were also investigated to evaluate the photocatalytic efficiency of the composite materials. The results are shown in **Error! Reference source not found.**

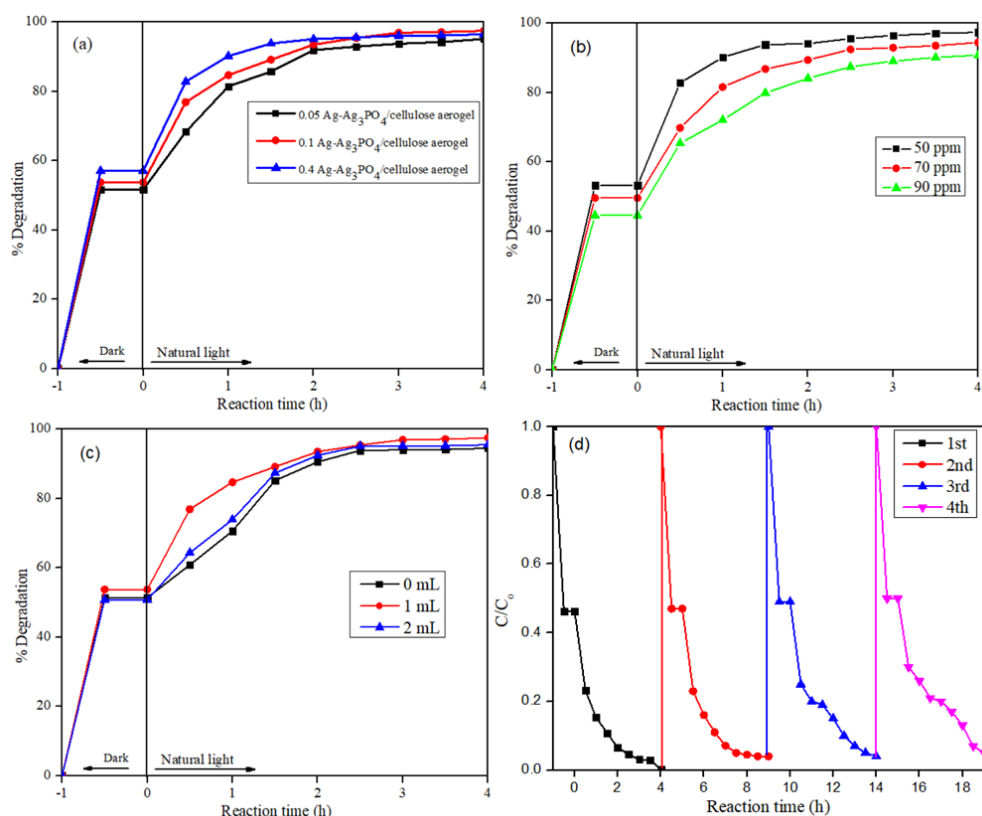


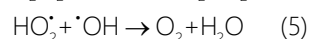
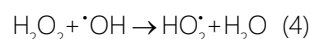
Figure 7: The degradation of MB dye under visible light using 0.1Ag-Ag₃PO₄/Cellulose aerogel catalyst under the conditions of (a) contents of the active phase, (b) dye concentration, (c) oxidant dosage (H₂O₂), (d) photocatalyst regenerability

The effect of Ag-Ag₃PO₄/Cellulose aerogel ratio on MB dye degradation efficiency is shown in **Error! Reference source not found.**a. Photocatalytic efficiency was approximately 97% after 4 h, corresponding to 0.1Ag-Ag₃PO₄/Cellulose aerogel catalyst. With 0.4Ag-Ag₃PO₄/Cellulose aerogel catalyst, the efficiency after 4 h reached 96.5 %. With a large amount of AgNO₃, the formation of active sites increased, but the interaction between the surface layers of the material occurred, thus reduced the formation of photo-produced electron-hole pairs of inside layers, led to a reduced photocatalytic efficiency.

To evaluate the effect of dye concentration on the photodegradation efficiency of Ag-Ag₃PO₄/Cellulose aerogel, the experiment was conducted with MB concentrations in the range of 50 to 90 ppm. The effect of initial concentration on the adsorption efficiency is shown in **Error! Reference source not found.**b. The results showed that when the concentration of MB increased from 50 ppm to 90 ppm, the adsorption efficiency in the absence of light of 0.1Ag-Ag₃PO₄/Cellulose aerogel decreased from 53 % to 44 %. This can be due to the adsorbability of

cellulose aerogel is inversely proportional to the dye concentration. After 4 h of illumination with visible light, the 50 ppm dye sample had a treatment efficiency of 97 %, decreased to 94 % and 90 % for 70 ppm and 90 ppm samples, respectively.

The dosage of oxidizing agent H₂O₂ also plays a large role in the degradation of MB dye by 0.1Ag-Ag₃PO₄/Cellulose aerogel composite (**Error! Reference source not found.**c). The MB dye degradation efficiency increased with increasing oxidizing agent dosage: from 92 % in the absence of an oxidizing agent to 97% when using 1 mL of H₂O₂. However, when the H₂O₂ content increased to 1.5 mL, the degradation efficiency decreased to 95 % after 4 h of illumination. This may be due to the presence of many free radicals $\cdot\text{OH}$ created from H₂O₂ promoted the reaction and led to faster degradation and higher efficiency. However, increasing the dosage of H₂O₂ too much will result in the reduction of free radicals, according to the equation:



Additionally, a high dosage of H₂O₂ also saturated the active sites of the catalyst, which decreased the reaction rate.

The regenerability of a photocatalyst is vital for its practical application. To evaluate these properties of 0.1Ag-Ag₃PO₄/Cellulose aerogel composite, the degradation of MB dye using 0.1Ag-Ag₃PO₄/Cellulose aerogel catalyst was repeated 4 times (**Error! Reference source not found.**d). The degradation efficiency of MB dye only decreased slightly (reached 95%) after 4 consecutive runs. This has demonstrated the stability of this catalyst in the photodegradation process.

From the survey results of affecting factors: reaction temperature 30 °C, 50 mg of the catalyst, pH = 6.5 were used to investigate the kinetics of MB

photodegradation. The assumption that the reaction is first-order was established based on the equation:

$$-\ln\left(\frac{C_t}{C_0}\right) = k_p t \quad (6)$$

In which C_t and C₀ are the concentration of the dye at time t and initial time (t=0), k_p is the first-order rate constant. Figure 8 shows that the linearity of the plot ln(C₀/C_t) compared to the irradiation time (t), proved that the first-order reaction is consistent with the photodegradation reaction. Specifically, the value of the regression coefficient R² > 0.98. The reaction rate constant decreased from 1.2893 min⁻¹ to 0.6978 min⁻¹ when the dye concentration increased from 50 ppm to 90 ppm.

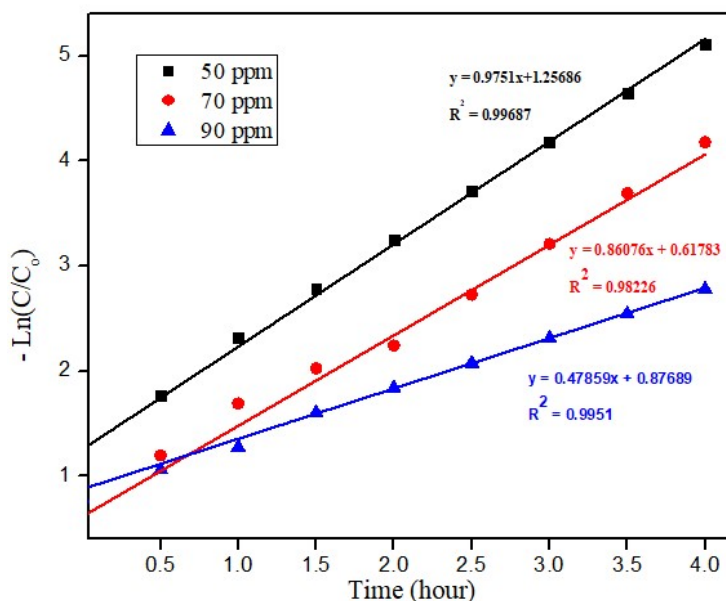
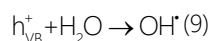
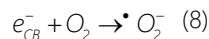


Figure 8: First-order kinetics model for 0.1Ag-Ag₃PO₄/Cellulose aerogel sample

The dye degradation mechanism of Ag-Ag₃PO₄/Cellulose aerogel composite could be similar to previous reports [35,36]. Ag and Ag₃PO₄ nanoparticles absorb visible light effectively. Silver nanoparticles have two main roles in photocatalytic reactions: (i) enhance the charge transfer and prevent the recombination of photogenerated electron – hole pairs and (ii) increase the efficiency of photodegradation due to electrons produce from the surface plasmon effect. Furthermore, a large quantity of electron - hole pairs generated inside Ag₃PO₄, electrons in the valance band will jump onto the conduction band of Ag₃PO₄ first and then to Ag particles. The remaining electrons trapped by O₂

molecules on the catalyst surface will create [•]O₂⁻ and holes react with H₂O or OH⁻ to create OH[•]. Those are the primary oxidants to degrade dye molecules into intermediate compounds along with CO₂ and H₂O.



Conclusions

In this study, Ag-Ag₃PO₄/Cellulose aerogel composite was synthesized successfully by hydrothermal reduction and freeze-drying method. The composite catalyst was studied systematically by MB and RY 145 degradation under visible light. Combining Ag₃PO₄ nanoparticles and cellulose resulted in the decrease of the bandgap energy, thus prevented the recombination of the photogenerated electron-hole pairs and greatly improved the photocatalytic efficiency. The photocatalyst is highly stable, the degradation efficiency of MB remained at 99% after 4 consecutive runs, and the photocatalytic process of Ag-Ag₃PO₄/Cellulose aerogel material consisted of the first-order reaction model. Using bagasse to synthesis cellulose will help to reduce environmental pollution and make agricultural waste economically valuable.

Acknowledgments

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