Z-scheme SiC/Ag_2CO_3 Composite as an Efficient Photocatalyst for Dye Degradation: Preparation and Experimentation

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Abstract: **Dyes are widely used in textile and color industries to impart color to different substances but such industries also produce a lot of colored waste water which is one of the sole reason for water pollution. Such polluted water decreases the dissolved oxygen in the water due to the presence of organic molecules. So it is mandatory to treat such polluted water before discharging. The conventional methods which are used have done limitations and thus this project focusses on some the principles of the latest advanced oxidation process called Photcatalysis. Z-scheme mechanism using visible light as a source of radiation is one of the latest technological development undergoing under photocatalysis. This paper includes preparation and experimentation of SiC/Ag2CO3 as one such composite catalyst working by Z-scheme mechanism.**

***Keywords*: Photocatalyst, Z-scheme, Absorbance, UV analysis**

I. INTRODUCTION

Industrial effluents always cause a major environmental issue. Dyes are extensively used in textile and printing industry. Ever increasing growth of industrialization and urbanization causes gigantic problem of environmental pollution. An industry consumes large quantity of water for their processes. The effluents from dye industry are highly colored, toxic and carcinogenic. The textile industries are responsible for pollution; large amount of waste water is released through cloth dyeing and washing processes. The effluents from these industries are highly organic and toxic in nature with non bio degradable properties. Removing color from wastes is often more important than other colorless and organic substances, because the presence of small amount of dyes (below 1 ppm) is clearly visible and influences the water environment considerably. Therefore, it is necessary to find an effective method of wastewater treatment in order to remove color from textile effluents. [1]

Z-scheme is one of the electron transfer mechanism through which the effectiveness of the catalyst can be increased.In this mechanism the photogenerated electron in the valence band of the semiconductor are transferred into the conduction band and annihilate the holes of the catalyst with lower valence band potential. Here again the charge separation take place and the electrons are transferred to the conduction band of that catalyst. Finally the holes are present in the catalyst whose valence band potential is relatively higher than the other and the electrons are present in the conduction band of the catalyst with more negative potential. Here the reactive radicals are generated and the dye molecule gets converted into simpler form.

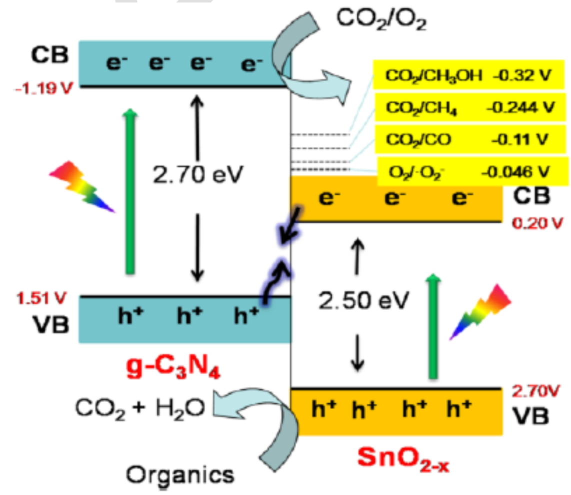


Figure 1 Z-scheme mechanism of $SnO_2/g\text{-}C_3N_4$[2]

II. COMPOSITE CATALYST

The catalyst SiC/Ag_2CO_3 will work according to the Z-scheme mechanism.

A. Synthesis of Photoctalyst

In order to prepare this composite photocatalyst, the two catalyst selected were SiC and Ag_2CO_3. The VB and CB potential of SiC are 1.5V, -1.5V and that of Ag_2CO_3 are 2.68V, 0.68V respectively and hence can effectively work in visible light as a photocatalyst for color removal of dye.

In order to understand the effect of concentration of both SiC and Ag_2CO_3 the catalyst were prepared in the varying proportion like 100% Ag_2CO_3, 75% Ag_2CO_3-25% SiC, 50% Ag_2CO_3-50% SiC, 25% Ag_2CO_3-75%SiC and 100%SiC.

B. Materials:

The materials used were Silver Nitrate ($AgNO_3$), sodium Carbonate (Na_2CO_3), SiC and distilled water. SiC was directly used without any further purification.

C. *Preparation of Ag_2CO_3:*

The Ag_2CO_3 sample was synthesized by a simple ion-exchange method. In a typical procedure for synthesing 100% Ag_2CO_3, $AgNO_3$solution (0.1N) was placed in a beaker and an aqueous solution of sodium carbonate (0.05N) was added dropwise using a burrete under constant stirring at room temperature. After this, a constant stirring for 24hrs was provided to obtain a yellowish green precipitate. The solution was filtered and washed several times with distilled water till showed neutral pH. The Ag_2CO_3 obtained was then driedin microwave oven for 15min. [3],[4]

D. Synthesis of Ag_2CO_3/SiC composite catalyst

For the synthesis of composite catalyst, the required amount of SiC powder was dissolved in water and ultrasonicated for 2hr at 175-180V. After this $AgNO_3$ was added to this solution and was added to this solution and was continuously stirred for 30min. Similar procedure of adding Na_2CO_3 to the solution was employed. After giving a constant stirring for about 24hr the solution was filtered and the precipitate obtained was washed with distilled water and then dried in microwave oven for about 15min. [3].For the preparation of different combination procedure remains same as above, only amount of raw material changes.

1. 100% Ag_2CO_3 : For this we took 4.93gm $AgNO_3$ (300ml) and 1.537gm Na_2CO_3 (300ml)
2. 75% Ag_2CO_3-25% SiC : For this we took 3.69gm $AgNO_3$ (225ml) and 1.153gm Na_2CO_3 (225ml)
3. 50% Ag_2CO_3-50% SiC : For this we took 2.46gm $AgNO_3$ (150ml) and 0.7688gm Na_2CO_3 (150ml)
4. 25% Ag_2CO_3-75%SiC : For this we took 1.23gm $AgNO_3$ (75ml) and 0.384gm Na_2CO_3 (75ml)
5. 100%SiC : Used as received

III. EXPERIMENT

The dye solution prepared for the experiment contained 70mg in 800 ml of distilled water which is equivalent to 90 ppm solution. We prepared such 4 samples of the dye solution and added 2 grams of the 100% SiC, 75% Ag_2CO_3-25% SiC, 50% Ag_2CO_3-50% SiC, 100%SiC respectively.

The 4 samples were first kept in dark with constant stirring for 1 hour. This was done to check the extent of adsorption. The first two readings were taken in the interval of 15 min and the last reading was taken after 1 hour from the initial time. The stirring was done at 750 rpm.

The samples were then kept in the sunlight. In order to prevent evaporation losses of the solution, the samples were kept in the chilling water bath maintained at 15°C. The stirring was done at 850 rpm. The initial intensity of the light at the time of placing the samples was recorded as 72 mW/cm^2. The first 4 readings were taken in the interval of 15 min and the intensity of light at that time was 62, 58, 44, 39 mW/cm^2 respectively and the last reading was taken after 2 hours from the initial time of placing the samples and the intensity was recorded as 30 mW/cm^2 The samples were placed in the sunlight at 2 pm and were withdrawn at 4:40 pm. The UV analysis for all the readings was done and recorded.

Figure. 2 Setup in Dark

Figure. 3 Setup in Sunlight

Figure. 4 100% SiC

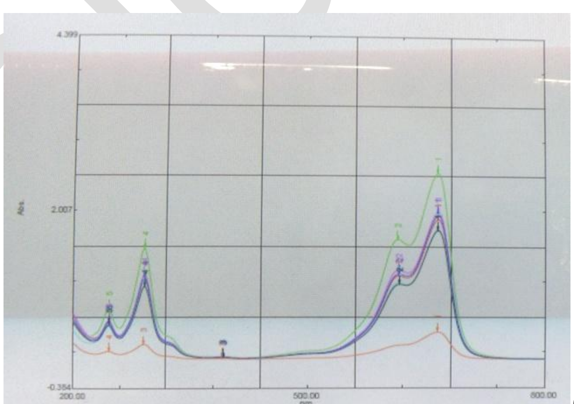
Figure. 5 50% Ag_2CO_3-50% SiC

Figure. 6 75% Ag_2CO_3-25% SiC

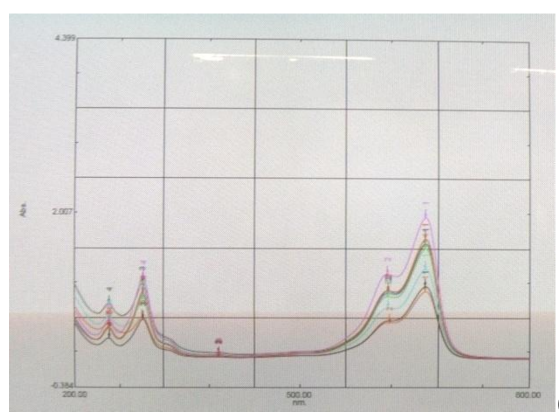
Figure. 7 100% Ag_2CO_3

IV. RESULTS

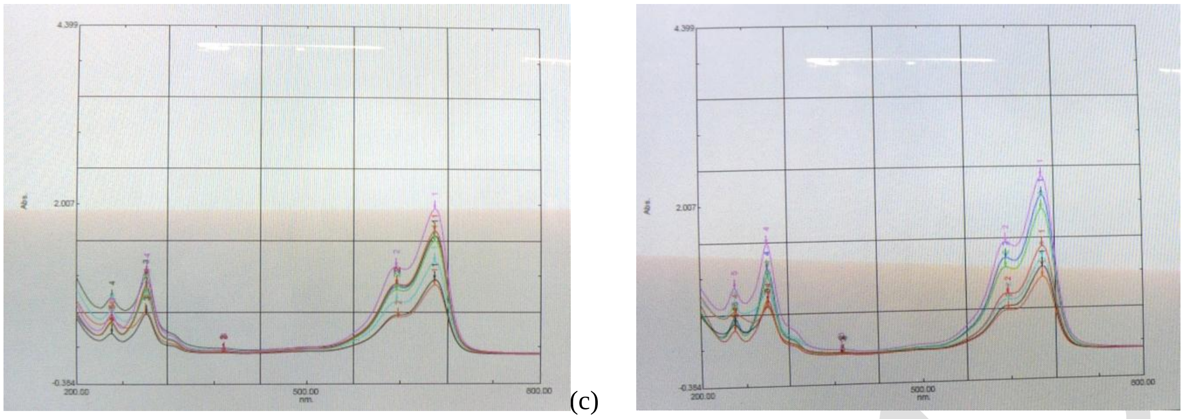
The following data of absorbance of the solution with respect to time was obtained from the UV analysis.



(a)



(b)



(c) (d)

Figure 8-9-10-11 UV Analysis of samples of (a)100% SiC, (b)75% Ag_2CO_3-25% SiC, (c)50% Ag_2CO_3-50% SiC and (d)100% Ag_2CO_3

Thus from the graph obtained, we can say that the concentration of the dye in the solution decreases as time passes when exposed to sunlight. The final concentrations for each sample were found from the calibration curve as

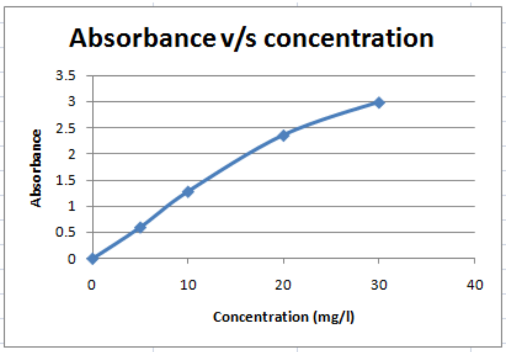


Figure. 12 Calibration Curve

TABLE 1

CONCENTRATION ANALYSIS OF DYE SAMPLES

Catalyst	Initial Concentration(ppm)	Final Concentration(ppm)
4S-0A	90	40
1S-3A	90	27.6
2S-2A	90	29
0S-4A	90	23.4

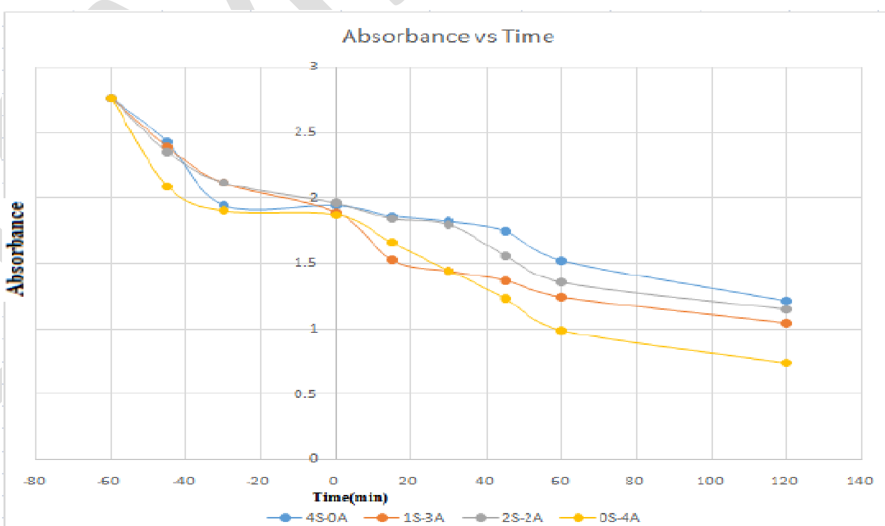


Figure. 13 Absorbance vs Time

TABLE 2

ABSORBANCE WITH RESPECT TO TIME FOR DIFFERENT CATALYST

Time (min)	Absorbance			
	4S-0A	1S-3A	2S-2A	0S-4A
-60	2.765	2.765	2.765	2.765
-30	2.396	2.396	2.358	2.095
-15	1.95	2.115	2.12	1.909
0	1.95	1.894	1.963	1.878
15	1.868	1.525	1.843	1.663
30	1.823	1.44	1.798	1.45
45	1.75	1.369	1.558	1.235
60	1.52	1.243	1.358	0.993
120	1.22	1.042	1.15	0.745

V. CONCLUSION

From the above results we can conclude that 100% Ag_2CO_3 has decreased the dye concentration to minimum as compared to other photocatalysts but amongst the composite combinations, 75% Ag_2CO_3-25% SiC is most effective though the color removal is visually not significant in any of the samples. The catalyst in the order of its effectiveness of color removal is as follows in the decreasing order-100% Ag_2CO_3, 75% Ag_2CO_3-25% SiC, 50% Ag_2CO_3-50% SiC, 100% SiC. This is particulary due to the small band gap ofAg_2CO_3which makes it more active than SiC. Also the order of the effectiveness of composite catalyst in different compositions also proves that they follow Z-scheme mechanism and such photocatalyst are more active than corresponding pure semiconductors.

The possible reasons for the color not getting completely removed may be:

- High concentration of the dye solution.
- Insufficient time of exposure of samples to the sunlight.
- The catalyst quantity was not sufficient for the complete color removal.

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