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Photocatalytic Degradation of Yellow-GCN dye using C-N-codoped TiO_2 Thin Film in Degradation Reactor Using Visible-Light Irradiation

Safni Safni[1*], Diana Vanda Weillia[2], Puti Sri Komala[3], Reza Audina Putri[1] and Deliza[1]

[1]*Laboratory of Applied Analytical-Chemistry, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Andalas University*
[2]*Laboratory of Material Chemistry, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Andalas University*
[3]*Laboratory of water, Department Enviroment-Engineering, Facuty of Engineering, Andalas University*

ABSTRACT

Yellow-GCN ($C_{28}H_{14}N_2O_2S_2$)textile dye was susessfully degraded by photolysis process undersolar and visible light irradiation using C-N-codoped TiO_2thin film photocatalyst.Yellow-GCN [120 mg/L]was irradiated by using 2 visible lamps (philips LED 7 watts 600 lumen and 14 watts 1400 lumen)and solar intensityaround 25.000 luxwith concentration and time variation. Degradation efficiency was measured byspectrophotometer UV-Vis (λ=300-800 nm). The optimum C-N-codoped TiO_2thin film used under solar irradiation was 5 coatings. From both diffrent light sources can be concluded that degradation under solar irradiation was better than visible light irradiation due to its degradation percentage during 120 minutes was 30,25%.

Key words : yellow-GCN, solar light, visible light, C-N-codoped TiO_2,thin film, photocatalyst.

INTRODUCTION

Yellow-GCN can be found in industrial wastewater which has carcinogenic effect. It is synthetic organic dye, stable with aromatic heterocyclic chains. Its stable structure can produce cotton with a longer lifetime dye, unfortunetelyeffluent consumption contribute negative impact to water ecosystem. The dye influences water characteristic just by impede solar, penetration and decrease photosystesis cycle process [1]. Thus, it is very important to degrade the dyes into enviromentally friendly simple compounds.

Technologies have been developed to reduce or even removalsynthetic dyesfrom wastewater, such as membrane filtration [2], absorption tecnique [3], coagulation-flouculation [4], biology technique by using microba or pure enzime [5,6]. As promising alternative, heterogeneous photocatalysis using semiconductor which one of AOPs (Advanced Oxidation Processes) method could be used for dyes wastewater treartment.

Titania (TiO_2) is one of semiconductor catalyst which has great potential in organic wastewater treatment [7,8] due to its high catalytic activity and high biological and chemical stability[9]. However, the main deficiency of TiO_2 that active only under UV light irradiation because of its large band gap (anatase ≈3,2 eV)[10]. To increase photocatalytic performance of TiO_2, doping TiO_2 with other elements is the best way.

TiO_2 doping with non metal elements (C, Nand S)is the most important method to raise utilization of visible light irradiation in dye wastewater degradation [11].TiO_2doped carbon and nitrogen show amazing photocatalytic activity than using another TiO_2 modification (N-doped TiO_2, La-doped TiO_2, Fe-doped TiO_2, Bi_2Wo_6/TiO_2) [12-15].Mostly, application of photocatalytic processes are widely carried out in slurry system operating using TiO_2 or TiO_2 modification powder. The major problem in these systems is needed much time and difficult process to separate and recyle the catalyst powder[16]. Thus, to solve this problem semiconductor catalyst powder are coated on supporting substrate to form thin film. Supporting substrate, including glass (2011, Fang Li), glass sphere (2015, V.Vaiano), hollow glass microsphere (2014, Lei sun), and stainless steel (2003)

C-N-*codoped* TiO_2wassynthesized by using peroxo sol-gel method.The advantage of this method are using water as solvent and lack of chemical which beneficialy low cost, environmental friendly, and simple steps [17]. Meanwhile, immobilization of C-N-codoped into glass substrate is formed by dip-coating method.

In previous research, powder of C-N-codoped TiO_2photocatalyst was used to degradate dyes in aquous medium and irradiated by solar light without degradator[18,19]. Based on its great photocatalytic activity under solar-light irradiation, in this research C-N-*codoped* TiO_2in two dimensional system as thin film which is mobilizated into glass substrate. With the result that, it could be applied to larger wastewater volume using degradation reactor which was planned. This application became effective, efficient, simple and low cost technology to solve environmental problems.

MATERIALS AND METHODS

Equipments

Spectrophotometer UV-Vis (S.1000 Secomam Sarcelles, French), Degradator reactor (SFN-Deg 001), Visible light (Phillips LED, 21 watt), analytical balance, and glasses equipments.

Materials

Yellow-GCN dyes ($C_{28}H_{14}N_2O_2S_2$, Mr = 474.56 g/mol from Silungkang Industry, distiled water, C-N-codoped TiO_2 thin film.

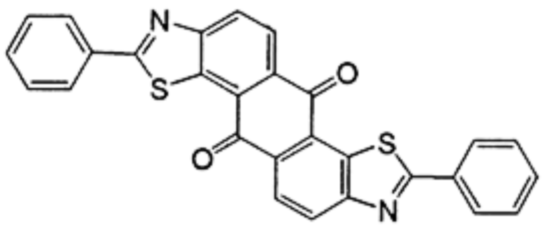


Figure 1. Structure of Yellow-GCNdyes

Photocatalytic Activity of C-N-codoped TiO_2 Thin Film

The photocatalytic activity was evaluated by the degradation of 120 mg/L yellow-GCN aqueous solution. The solution (40 mL) were put into beaker glass which is the container of the degradation reactor. Then, thin film catalyst is inserted into the solution and set spinning at constant speed by the reactor system. The reactor was enclosed in a cabinet during visible irradition to avaid interference from natural light. While, irradiation under solar light the reactor was open widely. The experiment was carried out under visibe light using 2 visible lamps (philips LED 7 watts 600 lumen and 14 watts 1400 lumen)and solar intensityaround 25.000 lux. Degradated dyes solution was analyzed at λ_{max} = 419 nm by spectrophotometer UV-Vis (S.1000 Secomam Sarcelles, French).

The degradation percentage of dye from solution at different time interval and condition is shown as :

$$\% \deg = \frac{Ao - At}{Ao} \, x \, 100\%$$

Where Ao is the initial absorbance of yellow-GCN and At is absorbance of yellow-GCN at different condition. The effect of C-N-codoped TiO2 amount on glass substrate and irradiation time on photodegradation of yellow-GCN was tested.

RESULTS AND DISCUSSION

Effect of C-N-codoped TiO_2amount on glass substrate

In order to define the best C-N-codoped TiO_2 amount deposited on glass substrate, number of coating was varied into 1, 3, and 5 coating and each was irradiated under solar light for an hour. Figure 2 shown the effect of C-N-codoped TiO_2 amount on glass substrate. The percentage removal of dyes with 1, 3, and 5 coatings about 8,42; 7,55; 11,24%, respectively. From 3 coatings into 5 coatings evidenced that up number of coating increased the amount of

C-N-codoped TiO2 deposited on glass substrate. Thus, photocatalytic activity increased and the dyes in aqueous solution will be moredegraded[19].

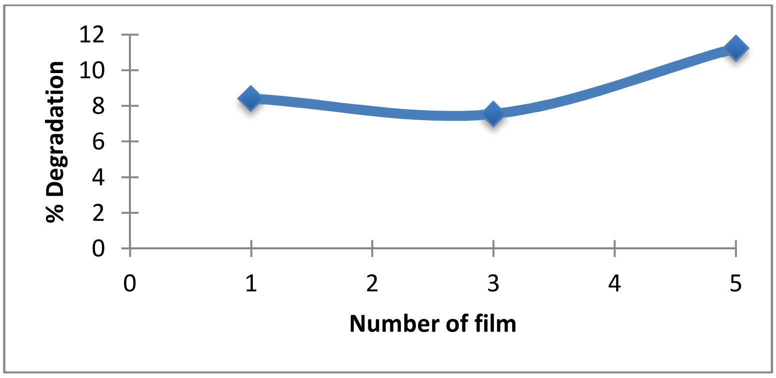
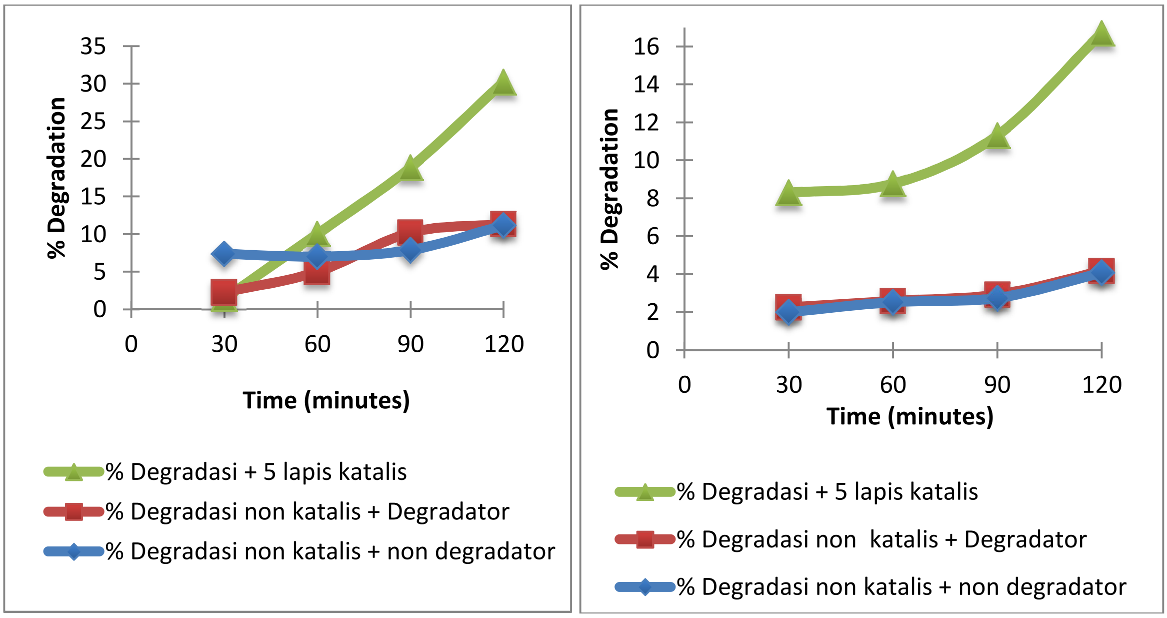


Figure 2. Effect of C-N-codoped TiO_2amount on glass substrate

Effect of irradiation time under visible and solar light



(a)

using 5 coatings of C-N-codoped TiO_2
using glass substrate
barely without catalyst

(b)

using 5 coatings of C-N-codoped TiO_2
using glass substrate
barely without catalyst

Figure3. Effect of irradition time under (a) solar light (b) visible light

Figure 3 shown the effect of irradition time under both of solar light and visible light irradiation. The percentage removal of dyes increasing by increment of irradiation time. During the photocatalytic reaction, C-N-codoped TiO_2 absorbs light to produce electron-hole pair which migrates to the catalyst surface to react with absorbed O_2 and H_2O, to produce strong oxidizing agents in the form of $O_2^{\bullet-}$ and HO• radicals, respectively, which are the main species responsible for the degradation of organic pollutants[20]. By increasing the irradition time, C-N-codoped thin film photocatalyst will more produce strong oxidizing agents. Thus, the photocatalytic degradation will increase. From figure 3, we can see that glass substrate has no photocatalytic activity due to its low degrdation percentage. The structure compound of yellow-GCN dyes is also very difficult to be degraded naturally. It is shown in figure 3 that degradation percentage without catalyst is only 4,07% and 11,15% under visible light and solar ligth irradiation, respectively. Higehst degradation percentage of yellow-GCN is achieved about 30.25% under solar light irradiation for 120 minutes.

Recyclability of C-N-codeped TiO_2 thin film 5 coating

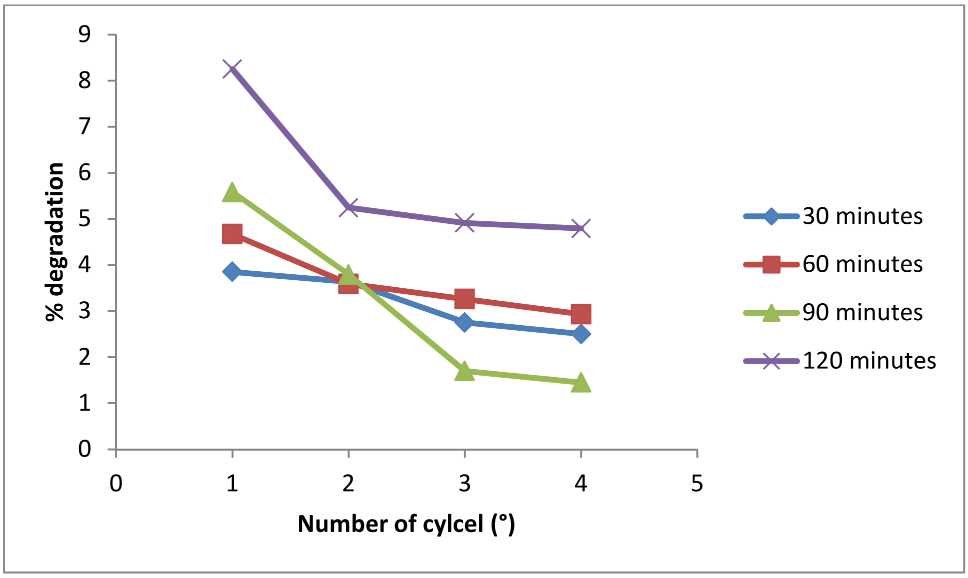


Figure 4. Recyclability of C-N-codoped TiO_2thin film after 4 recycling experiments

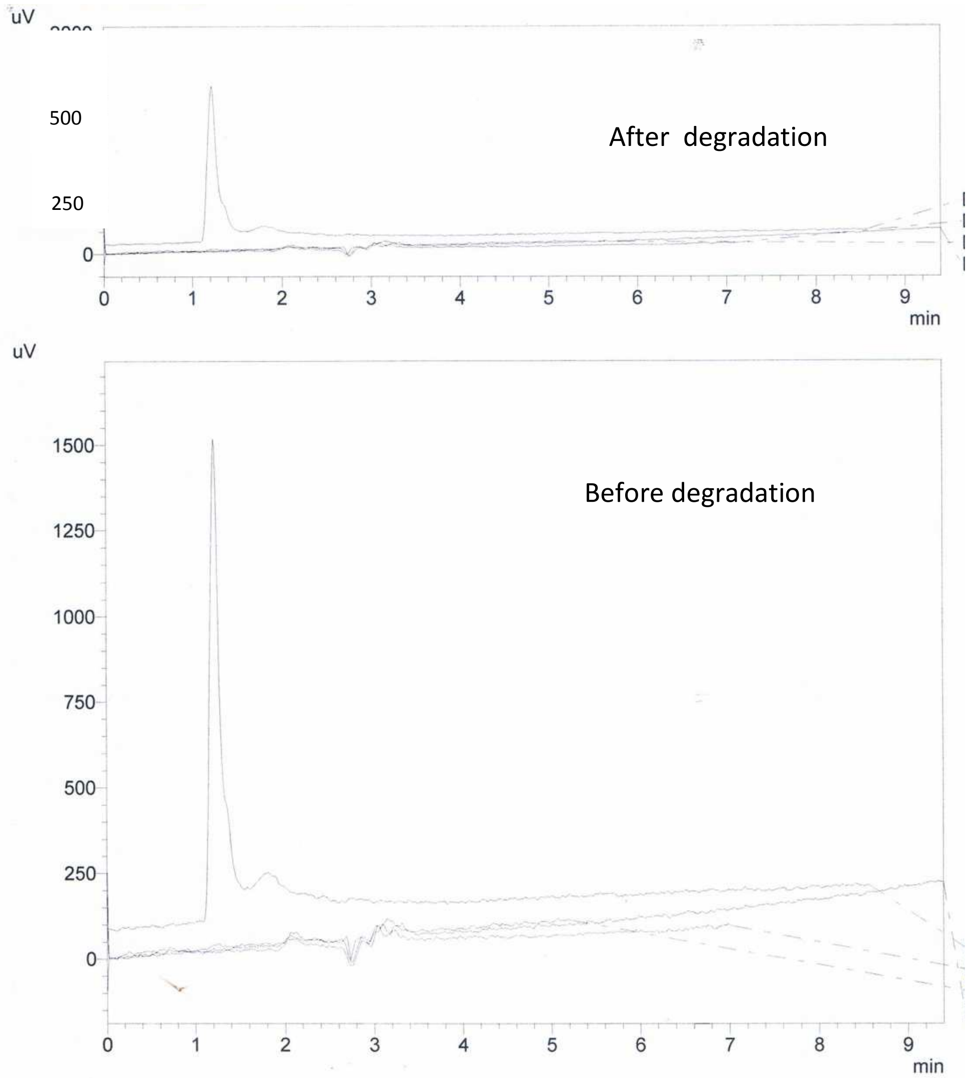


Figure 5. Analysis of Yellow GCN before and after degradation

Recyclability is one of the most important factor in catalysis research. To confirm the recyclability of C-N-codoped TiO_2 thin film with 5 coatings, the photocatalytic decolorization reaction was repeated up to four cycles in different irradiation time under visible light. The results is shown in figure 4. The results demonstrated that there was about 2% reduction of degradation percentage in 30, and 60 minutes of irradition and obout 4% in 90 and 120 minutes of irradiation after four cycles. These results confirm that there is no leaching of C-N-codoped TiO_2 from immobilized on glass substrate.

Analysis using High Performance Liquid Chromatography

Figure 5 describes that peak high and peak areas of Yellow-GCN decrease after degradation using C-N-codoped TiO_2thin film in degradation reactorunder solar-light irradiation, without other peaks appeared.

CONCLUSION

Yellow-GCN dyes in aqueous solution was successfully degraded by C-N-codoped TiO_2 immobilized on glass substrate. The degradation percentage of 120 mg/L yellow-GCN (40mL) is 4,07% and 11,15% without catalyst under visible and solar light irradtion fro 120 minutes, respectively. By the addition of C-N-codoped TiO2 thin film with 5 coatings and set constant spinning speed, the degradation percentage increase to 16,7% and 30,25% under visible and solar light irradtion, respectively. The C-N-codped TiO_2 thin film photocatalyst confirm that there is no leaching while mineralization of dyes occured. Photocatalytic degradaion of yellow-GCN dyes in aqueous solution is more effective under solar light irradtion.

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