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# Decolorization of Cationic Yellow X-Gl 200% from Textile Dyes by $TiO_2$ Films-Coated Rotor

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**Abstract**

Application of titanium dioxide ($TiO_2$) films-coated rotor for treatment of wastewater from textile dyes was investigated under photocatalytic activity. This study, $TiO_2$ films were prepared by sol-gel technique from titanium tetraisopropoxide and isopropanal of 1:15 and 1:20 (V/V) and adjusted to pH = 2 by using nitric acid. The $TiO_2$ films were coated on 6-paddles grade 304 stainless steel of rotor by dip coating of 10, 15 and 20 cycles. After deposition, $TiO_2$ films were treated at annealed temperature of 500 °C. All $TiO_2$ films showed anatase phase-structure. The experiments consist of two parts, in the part 1, the influence of titanium tetraisopropoxide and isopropanol ratio and number of $TiO_2$-coating cycles were investigated. In the part 2, efficiencies of decolorization by using coated $TiO_2$ samples and uncoated $TiO_2$ samples were investigated. Cationic yellow X-Gl 200% that had concentration 100 mg/L were used as wastewater from textile dyes. From, photocatalytic test by using Cationic yellow X-Gl 200% solution and immersed coated $TiO_2$ samples and uncoated $TiO_2$ samples in upon solution, showed that titanium tetraisopropoxide and isopropanal of 1:20 and number of $TiO_2$-coating cycles of 20 cycles was the best condition. Then, used the best condition to prepare the $TiO_2$ films-coated rotor. The $TiO_2$ films-coated rotor and Cationic yellow X-Gl 200% were irradiated under UV-A at middle wavelength of 365 nm with irradiation times at 1 2 and 3 days. The result showed that $TiO_2$ films-coated rotor had decolorization efficiencies of 95.53, 95.84 and 99.14% for irradiation times at 1, 2 and 3 days, respectively. The efficiency of decolorization is better than uncoated-$TiO_2$ surface about 90%. In this way, the photocatalytic degradation process by using coated rotor of $TiO_2$ film as a photocatalyst and UV-A light as an irradiation source showed potential application for the decolorization of wastewater from textile dyes.



*Keywords:* $TiO_2$; Film ; Photocatalytic activity; Decolorization; Textile Dye

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## 1. Introduction

The color in textile effluents has become a possible important environmental problem. These colors were used in dying process. Decolorization was industrial wastewater treatment practices. Therefore, in convention industrial wastewater treatment practices, dyes were usually removed by using adsorption or coagulation. However new environment laws may consider sludge from this treatment was hazardous wastes that require further treatment [1-2]. The well-known new technology of wastewater treatment in last decade is the photocatalysis process by using $TiO_2$. The detailed mechanism of the photocatalytic process on the $TiO_2$ surface is conversion organic compounds into the water. Hydroxyl radicals are formed on the surface of $TiO_2$ by reaction of holes in the valence band ($h^+_{vb}$) with adsorbed $H_2O$, hydroxide, or surface titanol groups (>TiOH). The photogenerated electrons are reduce enough to produce superoxide ($O^-_2$ ). $H_2O_2$ contributes to the degradation pathway by acting as an electron acceptor or as a direct source of hydroxyl radicals due to homolytic scission. Depending upon the reaction conditions, the holes, OH radicals, $O^-_2$, $H_2O_2$, and $O_2$ can play important roles in the photocatalytical reaction mechanism [3]. In general, the photocatalytic process used to form particles $TiO_2$. In this study, The $TiO_2$ films were coated on grade 304 stainless steel and 6-paddles grade 304 stainless steel of rotor by dip coating.

Nomenclature

| | | | |
|---|---|---|---|
| $A_0$ | initial absorbance | V/V | volume/volume |
| $A$ | absorbance after irradiated UV | UV | ultraviolet |
| °C | degree Celsius | hν | incident photon energy |
| H | high | $e^-_{cb}$ | electron in the conduction band |
| L | long | $h^+_{vb}$ | holes in the valence band |
| W | wide | $\lambda_{max}$ | maximum wavelength |

## 2. Experimental

### *2.1 Materials*

Dye was cation yellow X-Gl 200% ($\lambda_{max}$, 420 nm.) that had concentration 100 mg/L**.** The pH of the solution equivalent to 2 has been adjusted by using nitric acid ($HNO_3$).

### *2.2 Equipment*

In the part 1, grade 304 stainless steel plates of 2.2 cm × 2.2 cm (L×W) were coated $TiO_2$ to study the effects of titanium tetraisopropoxide and isopropanol ratio and number of $TiO_2$-coating cycles. Then, immersed coated-$TiO_2$ and uncoated-$TiO_2$ samples in cation yellow X-Gl 200% solution of 10 mL. The UV source was irradiated over 7 days to decolorize cation yellow X-Gl 200% solution.

In the part 2, used the best condition from the part 1 to prepare coated $TiO_2$ rotor. Fig. 1 showed the experimental setup for part 2 - study. The photocatalytic system were included: (a) the photocatalytic reactor (45 cm × 30 cm × 15 cm: L×W×H) that was approximately 20 L. (b) UV lamp (Black light lamp:

F10T8BL 10 W made in Japan) was as the irradiation source. The light intensity of 0.96 mW/cm$^2$ was measured by using a UV light meter (UV-340A) that could measure in the range of 290- 390nm. (c) The rotating speed of the motor was kept at 70 rpm during the experiment. (d) The rotor was coated by $TiO_2$ film, so $TiO_2$ film were prepared on stainless steel grade 304 (15 cm × 3 cm: L ×W) by sol-gel technique.

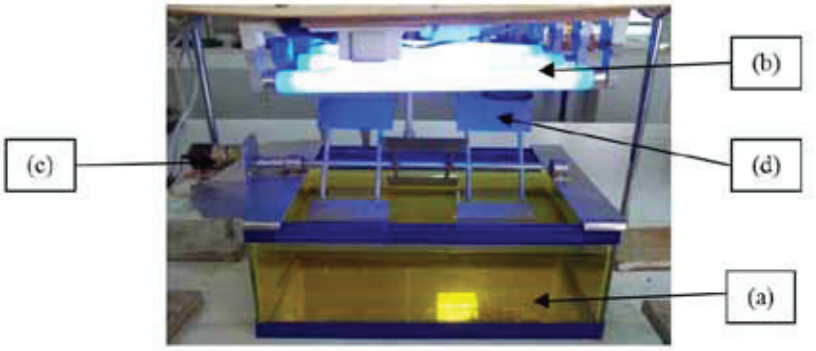


Fig. 1. The photocatalytic reactor used in this study

*2.3 Sol-gel technique*

The preparation steps for the sol–gel-derived $TiO_2$ composites and dip coat were shown in the Fig. 2.

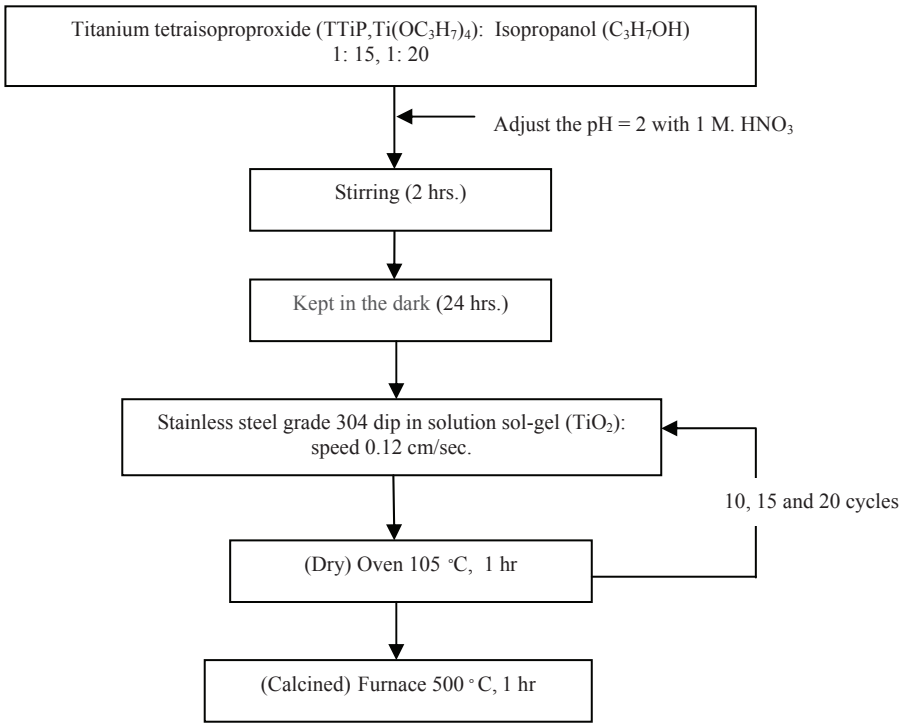


Fig. 2. The preparation steps for the sol–gel derived $TiO_2$ composites and dip coat

*2.4 Photocatalytic activity tests*

In the part 1, immersed coated-$TiO_2$ and uncoated-$TiO_2$ samples in cation yellow X-Gl 200% solution of 10 mL. Then, irradiate UV-A at middle wavelength of 365 nm over 7 days to decolorize cation yellow X-Gl 200% solution. Measurement the absorbance every day over 3 days by using UV Spectrophotometer (UV – 1100 Spectrophotomerter : Techcomp)

In the part 2, cation yellow dyes solution was volume 15 L. in the photocatalytic reactor. Then, irradiated UV light on the rotor coated $TiO_2$ film. The cation yellow dyes solution was measured absorbance every day over 3 days by using UV Spectrophotometer (UV – 1100 Spectrophotomerter : Techcomp)

## 3. Results and discussion

Table 1. Comparison ratio TTiP,$Ti(OC_3H_7)_4$ : $C_3H_7OH$ and cycle of $TiO_2$ film coated on stainless steel of rotor affect decolorization cation yellow X-Gl 200% to select the best condition

| Ratio | Decolorization (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| TTiP,$Ti(OC_3H_7)_4$ : $C_3H_7OH$ | 1 day | 2 days | 3 days | 4 days | 5 days | 6 days | 7 days |
| 1:15 (dip 10 cycles) | 20.50 | 32.96 | 46.79 | 61.00 | 71.00 | 79.83 | 84.39 |
| 1:15 (dip 15 cycles) | 15.57 | 29.39 | 42.54 | 57.25 | 69.56 | 81.02 | 87.99 |
| 1:15 (dip 20 cycles) | 26.15 | 43.60 | 53.00 | 69.02 | 78.14 | 85.07 | 88.77 |
| 1:20 (dip 10 cycles) | 15.11 | 23.87 | 29.69 | 36.38 | 44.02 | 54.44 | 62.45 |
| 1:20 (dip 15 cycles) | 16.77 | 27.89 | 39.81 | 47.67 | 54.48 | 63.03 | 66.77 |
| 1:20 (dip 20 cycles) | 22.34 | 40.84 | 58.68 | 76.08 | 86.78 | 91.83 | 92.79 |

The result from the part 1 showed that the ratio of TTiP,$Ti(OC_3H_7)_4$:$C_3H_7OH$ of 1:20 decolorize was better than 1:15 (decolorization efficiencies of 92.79 and 88.77 % for irradiation times at 7 days.) Because of $C_3H_7OH$ help in the distribution of $TiO_2$ film and reaction to increase the amount of oxygen to titanium dioxide film. Consider the cycle of $TiO_2$ film coated on stainless steel of rotor affect decolorization dyes, dip 20 cycles the best. The efficiencies of decolorization at irradiation time 7 day were 62.45, 66.77 and 92.79% for number of dip cycles of 10, 15 and 20 cycles respectively. Number of dipping involves the structure of anatase crystal effect of the amount of $TiO_2$.

So this experiment, $TiO_2$ films were prepared by sol-gel technique from TTiP,$Ti(OC_3H_7)_4$ : $C_3H_7OH$ of 1:20 (V/V) and adjusted to pH = 2 by using nitric acid. The $TiO_2$ films were coated on 6-paddles grade 304 stainless steel of rotor by dip coating of 20 cycles. $TiO_2$ films-coated rotor and cationic yellow X-Gl 200% were irradiated under UV-A at middle wavelength of 365 nm with irradiation times at 1, 2 and 3 days. Sample to be analysed by UV Spectrophotometer Fig. 3 showed the full spectrum scanning of cationic yellow dyes solution (maximum emission at $\lambda_{max}$ of 420 nm.) with time in 3 day of reaction. Absorbance of cationic yellow X-Gl 200% was treated $TiO_2$ films-coated rotor decrease continuously irradiated under UV irradiation times increase. Absorbance of cationic yellow X-Gl 200% was treated $TiO_2$ films uncoated rotor and control unchanged absorbance (Fig. 3).

The percentage of decolorization was calculated by using the equation given below:

$$Decolorization\,(\%) = \frac{A_0 - A}{A_0} \times 100 \qquad (1)$$

In which $A_0$ is the initial dye concentration and $A$ is the dye concentration after irradiated UV.

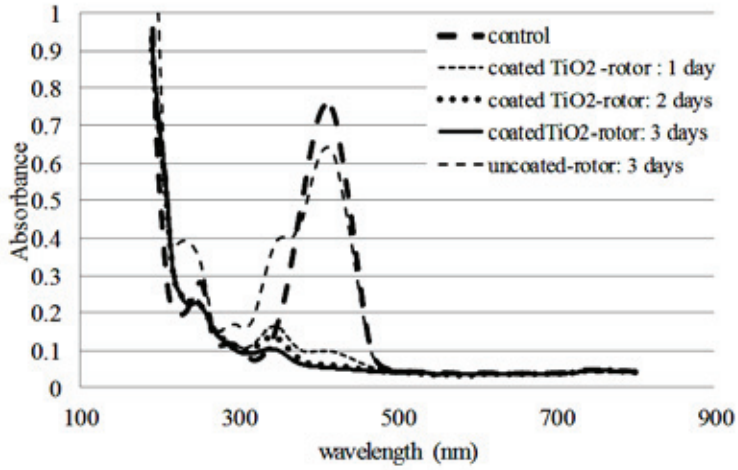


Fig. 3. Spectral changes that occur during the photocatalytic degradation of cationic yellow X-Gl 200% irradiated under UV irradiation times.

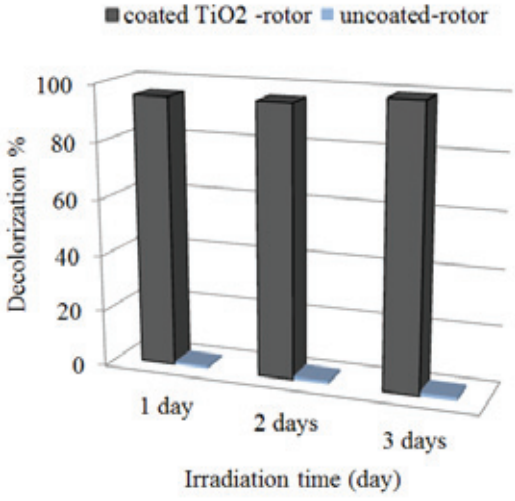


Fig. 4. Efficiencies of decolorization(%) of cationic yellow X-Gl 200% of $TiO_2$ films coated rotor and $TiO_2$ films uncoated rotor were irradiated by UV

From Fig. 4, the result showed that $TiO_2$ films coated rotor had decolorization efficiencies of 95.53, 95.84 and 99.14% respectively while $TiO_2$ films uncoated rotor had decolorization efficiencies of 0.90,

1.21 and 1.35% respectively for irradiation times at 1, 2 and 3 days. Comparison images of cationic yellow X-Gl 200% of $TiO_2$ films coated rotor with $TiO_2$ films uncoated rotor and control (in dark). In Fig. 5, comparison of cationic yellow X-Gl 200% images irradiated UV irradiation time of 24 hr. (1 day).

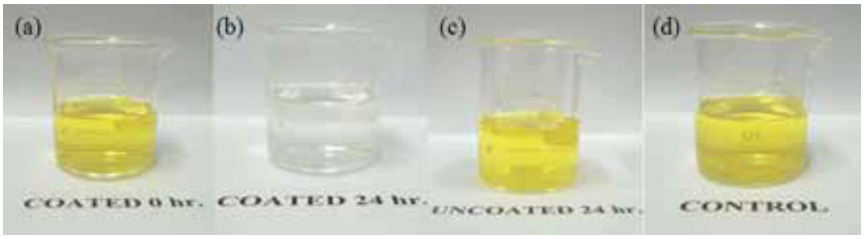


Fig. 5. Comparison of cationic yellow X-Gl 200% images of (a) initial UV irradiation time (b) $TiO_2$ film coated on rotor after UV irradiation time of 24 hr. (1 day) , (c) $TiO_2$ film uncoated on rotor after UV irradiation time of 24 hr. (1 day) and (d) control (in dark).

In the case of the sample photocatalytic reaction by UV light, the decoclorization of cationic yellow X-Gl 200% should go through the interaction with the electron hole pair ($e^-_{cb}$, $h^+_{vb}$) as usual. The recently proposed cationic yellow X-Gl 200% degradation mechanism for the irradiated $TiO_2$ system as follows (2) – (10) [2-5]

$$TiO_2 + h\upsilon \rightarrow TiO_2(e^-_{cb}, h^+_{vb}) \quad (2)$$

$$TiO_2(h^+_{vb}) + H_2O \rightarrow TiO_2 + H^+ + OH^\bullet \quad (3)$$

$$(H_2O \leftrightarrow H^+ + OH^-)_{(ads)} + h^+_{vb} \rightarrow H^+ + OH^\bullet \quad (4)$$

$$O_2^\bullet + H^+ \rightarrow HO_2^\bullet \quad (5)$$

$$2HO_2^\bullet \rightarrow H_2O_2 + O_2 \quad (6)$$

$$H_2O_2 + e^- \rightarrow OH^\bullet + OH \quad (7)$$

$$Dye + OH^\bullet \rightarrow degradation\ products \quad (8)$$

$$Dye + h^+_{vb} \rightarrow oxidation\ products \quad (9)$$

$$Dye + e^-_{cb} \rightarrow reduction\ products \quad (10)$$

The trapped holes may be regarded as surface-bound hydroxyl radicals. The bound radicals can also diffuse away from the surface toward the solution bulk and exist transiently as free $OH^\bullet$. This mechanism suggests that hydroxyl radicals and photogenerated holes ( $h^+_{vb}$) are the primary oxidizing species for the adsorbed or free dye molecules, while photogenerated electrons ($e^-_{cb}$) are the reducing species,[5-7] in photocatalytic reaction by UV light.

## 4. Conclusion

Application of coated- $TiO_2$ rotor under weakly-UVA of photocatalytic system has successfully improved the color degradation capability. The result showed that coated -$TiO_2$ rotor had decolorization efficiencies of 95.53, 95.84 and 99.14% for UV irradiation times of 1, 2 and 3 days, respectively. While, uncoated-rotor had decolorization efficiencies of 0.90, 1.21 and 1.35% for irradiation times at 1, 2 and 3 days, respectively. It clearly seen, under photocatalytic system of coated -$TiO_2$ rotor is rich decolorization for cationic yellow X-Gl 200%. It is better than uncoated-rotor system and immersed coated-$TiO_2$ systems.

## Acknowledgements

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## References

[1] Arslan I. and Balcioglu I.A. Degradation of commercial reactive dyestuffs by heterogeneous and homogennous advanced oxidation processes : a comparative study. *Dyes and Pigments* 1999; **43(2)**: 95-108.

[2] Kuo W.Sand, Ho P.H. Solar photocatalytic decolorization of dyes in solution with $TiO_2$ film. *Dyes and Pigments* 2006; **71**: 212-217.

[3] Carp O., Huisman C.L.and Reller A. Photoinduced reactivity of titanium dioxide. *Proress in Solid State Chemistry* 2004; **32**: 33-177.

[4] Randorn C., Wongnawa and Boonsin P. Bleaching of Methylene Blue by Hydrated Titanium Dioxide. *Science Asia* 2004; **30**: 149-156.

[5] Barakat M.A. Adsorption and photodegradation of Procion yellow H-EXL dye in textile wastewater over $TiO_2$ suspension. *Journal of Hydro-environment Research* 2011; **5**: 137-142.

[6] Tryba B., Piszac M.,Grzmil B., Pattek-Janczyk A. and Morawski A.W. Photodecomposition of dyes on Fe-C-$TiO_2$ photocatalyts under UV radiation supported by photo-Fenton process. *Journal of Hazardous Materials* 2009; **162**:111-119.

[7] Hathaisamit K., Pengmula., Wesamula T. and Pudwat S. Photocatalytic Decolorization of Dyes for Nano-structures of Titanium Dioxide ($TiO_2$) Films. *Advanced Materials Research* 2010; **93-94**: 603-606.