Vol. 2, No. 1, April 2023, pp. 65-73
p-ISSN: 2963-8577
e-ISSN: 2964-3511
DOI: 10.57102/jescee.v2i1.59

ONE STEP HYDROTHERMAL SYNTHESIS OF NICKEL DOPED TIO2 NANOTUBE

Eduardus Budi Nursanto[1,2,*], Resa Mayori Ridoi Sinaga[1], Dita Floresyona[1], Rinaldi Medali Rachman[1,2] Agung Nugroho[1,2]
[1]Chemical Engineering Department, Universitas Pertamina, Jakarta, Indonesia
[2]Center of Downstream Chemical Industry, Universitas Pertamina, Jakarta, Indonesia

Abstract
TiO_2 is one of the photocatalyst materials that is widely used and proven for environmental treatment. To increase the activity of TiO_2, TiO_2 has been modified into a nanotube shape with nickel metal doping. The TiO_2 nanotubes with Ni doping have been synthesized with one step hydrothermal process. In this research, it shows that nickel doped with TiO_2 led to a reduction of crystal size and band gap energy. The smaller crystalline size and lower band gap energy enhanced its photocatalytic activity. The best results for photocatalytic activity were TiO_2/Ni with a crystal size of 7.30 nm and a band gap energy value of 3.12 eV. The photocatalytic activity of TiO_2/Ni was tested by degrading methylene blue under mercury lamp radiation, with the best result of 92.73 % degradation of methylene blue, within 240 minutes of photocatalytic activity.

Keywords:
TiO_2 nanotubes; Ni-doping; hydrothermal process; photocatalytic methylene blue degradation

Article History:
Received: March 22nd, 2023
Revised: April 8th, 2023
Accepted: April 26th, 2023
Published: April 30th, 2023

Corresponding Author:
Eduardus Budi Nursanto
Department of Chemical Engineering, Universitas Pertamina, Indonesia
Email:
eduardus.bn@universitaspertamina.ac.id

1. Introduction

Indonesian textile industry is growing rapidly to fulfill the demand from society. Indonesia Central Bureau of Statistic [1] reports that the growth of the Indonesian textile industry continues to increase by around 2.8% per year. The growth also increases the usage of textile dyes. Indonesian textile industry uses around 10,000 types of dyes each year. About 10-15% of textile dyes used in the dyeing process will be dumped along with wastewater. This wastewater can pollute the environment and can cause health problems because some of the dyes used can decompose into toxic and carcinogenic compounds [2].

Several studies have been carried out to remove organic compounds and dyes contained in wastewater such as filtration, precipitation, coagulation, electrocoagulation, and adsorption using activated carbon. However, this method is considered inefficient due to high operational costs and can only transfer contaminants from one phase to another without any destruction [3]. Therefore, a better and more efficient way is needed to overcome this problem, such as photocatalysis process. The photocatalysis method is considered more effective in separating pollutants, decomposing wastewater and polluted air, and have ability to decompose of organic pollutants [4].

One of the proven materials for a photocatalyst is TiO_2. Titanium dioxide or TiO_2 is a semiconductor that has a wide band gap (3.2 eV-3.8 eV) which has photocatalytic efficiency around 5% of solar energy [5]. In addition, TiO_2 is relatively cheaper, stable, non-toxic, and can be used repeatedly [6, 26-28]. However, the wide band gap energy in TiO_2 limits its photocatalytic activity. The TiO_2 have higher activity in the UV region with a wavelength of 388 nm, while the desirable process will be in visible light region [7].

The photocatalytic activity of TiO_2 can be increased in various ways, including by adding doping, making composites using other semiconductors, or increasing TiO_2 active sites [8]. Nanostructured TiO_2 claimed have higher active sites compared to nanoparticle shaped. The well proven nanostructured shape of TiO_2 that has higher active sites such as nanotubes and nanowires. Doping acts as electron trapping which can increase the photocatalytic activity of TiO_2 by minimizing recombination between holes and electrons [9]. The addition of doping in the structure of TiO_2 led to change the electron structure of the TiO2 photocatalyst [10]. By changing the electron structure of TiO_2, the responsiveness to light absorption are changes. Several types of metals that are often used as doping on TiO_2 are platinum (Pt), nickel (Ni), molybdenum (Mo), and palladium (Pd), all the metals have high activity during photocatalysis process. However, due to the high prices of platinum, molybdenum, and palladium, the usage of Ni metal is preferred because it is abundant and cheaper compared to noble metals [11]. The use of Ni metal as doping on TiO_2 can increase its photocatalytic efficiency in the visible light region and reduce the energy band gap in TiO_2 [12].

The process to modify TiO_2 nanoparticles into TiO_2 nanotubes can be done by several methods such as anodization and hydrothermal methods. The nickel metal doping into TiO_2 can be done by various methods such as anodization, hydrothermal, and sol gel methods. In this research, we combine both the modification of TiO_2 nanoparticles into TiO_2 nanotubes and the Ni metal doping with one step hydrothermal process. The hydrothermal process is chosen since the process is simple, low cost and scalable. In this study, we fabricated Ni doped TiO_2 nanotubes catalysts via one step hydrothermal method. The effect of Ni doping has been investigated for photocatalytic reduction of methylene blue.

2. Experimental Section

A. Ni doped TIO_2 nanotubes synthesis

TiO_2/Ni was prepared by the hydrothermal process. The mixture of components TiO_2 (P25, Degussa) and $Ni(CH_3CO_2)2.4H_2O$ (Sigma Aldrich) was prepared according to Table 1. Then the mixture was placed into a 100 ml beaker then 60 ml of 10 M NaOH (Sigma Aldrich) was added. The mixtures were stirred for 1 hour on a hotplate. Then the mixture was put into an autoclave and then heated in an oven for 24 hours at a temperature of 120 °C. The results obtained in the form of solids were washed with 0.1 M HCl (Sigma Aldrich) until they reached a pH of 1-2. After pH 1-2 was reached, the samples were washed with distilled water by using a centrifuge until they reached a neutral pH. The solids from the centrifuge were dried in an oven at a temperature of 80 °C for 6 hours. The solids were then annealed in a furnace at a temperature of 450 °C for 2 hours.

Table 1. The molar ratio between TiO2 and Ni precursors

Samples Name	**Molar Ratio of TiO_2 (P25) and $Ni(CH_3CO_2)_2.4H_2O$**
A	20 : 0
B	20 : 0.5
C	20 : 1
D	20 : 1.5
E	20 : 2

B. Characterization

The synthesized of Ni doped TiO_2 nanotubes (TiO_2/Ni) was characterized by using X-Ray Diffraction (XRD) to analyze the crystal phase and degree of crystallinity. The Diffuse Reflectance Spectroscopy (DRS) has been used to analyze the band gap value of the material. UV Vis spectroscopy has been used to analyze the absorbance of the sample during photocatalyst degradation of methylene blue.

C. Photocatalyst activity on methylene blue degradation

A total of 0.1 grams of solid TiO_2/Ni were weighed and put into a glass container whose surface was covered with aluminum foil. Then 100 ml of 20 ppm methylene blue solution was added and stirred for 1 hour. After stirring, 2 ml of the sample was taken, then put into a centrifuge tube and recorded as the 0^{th} time. The hotplate and glass container containing the sample and stirrer were placed into the photocatalyst reactor.

For the methylene blue degradation, the experiment for arrange calibration curve has been done. UV-Vis Spectroscopy is used for the absorbance value of sample. Based on calibration curve, the concentration of methylene blue can be calculated from equation (1). The Y axis is absorbance value and X axis is concentration of methylene blue.

$$y = 0{,}1853x + 0{,}0052 \quad (1)$$

The photocatalyst test was carried out in the photocatalyst reactor for 4 hours (mercury lamp, blower, and hotplate were turned on). The 2 mL of samples were taken during time interval at 15, 30, 60, 120, 150, 180, and 240 minutes. All samples were centrifuged at 7000 rpm for 10 minutes. After centrifugation, 1 ml of liquid was pipetted and then 2 ml of distilled water was added for the measurement of methylene blue contents by using absorbance method on UV-Vis spectrophotometer.

p-ISSN: 2963-8577
e-ISSN: 2964-3511

3. Result and Discussion

The synthesized TiO2/Ni was characterized using XRD to determine the crystallinity of samples. The TiO2/Ni diffraction pattern for each sample that has been characterized using XRD is shown in Fig 1. Based on the TiO2/Ni diffraction pattern (Fig. 1), all samples were only in the anatase phase. The rutile phase was not detected in the TiO2/Ni diffraction pattern in each sample because the formation of rutile phase began at a calcination temperature of more than 800 ˚C, while in this study the calcination temperature is 450 ˚C. Nickel diffraction peaks that did not appear during XRD characterization indicated that nickel atoms had entered the TiO2 lattice [13, 14]. From the Fig. 1, it was processed using the Scherrer equation to determine the crystallite size.

$$D = \frac{0{,}89\,\lambda}{\beta \cos \theta} \tag{2}$$

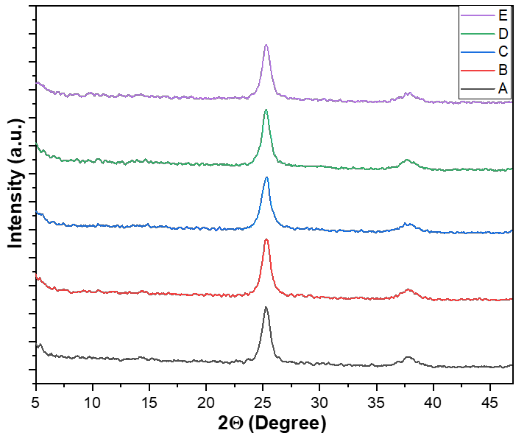

Figure 1. X-Ray diffractometer result of TiO_2/Ni samples

Table 2. Crystallites size of TiO2/Ni sample

Samples	Molar Ratio of TiO_2 and Ni	2θ (˚)	D (nm)
A	20 : 0	25.36	8.09
B	20 : 0.5	25.36	7.88
C	20 : 1	25.26	7.30
D	20 : 1.5	25.19	7.84
E	20 : 2	25.27	8.17

Table 2 shows the crystallite size decreased when nickel doping was added. From Table. II, sample A without nickel doping had a crystal size of 8.09nm, while samples B, C, and D with nickel doped addition has lower crystallite sizes. The addition of doping can affect the physical properties of TiO_2 nanotubes, one of which is to produce a small crystallite size [15]. Photocatalysts with small crystal sizes can induce a larger band gap due to the increased reduction-oxidation ability so as to increase the photocatalytic activity. Materials with nano size (1-100 nm) can provide high photocatalytic activity. The smaller crystal size led to the larger the crystal surface area [16]. The large surface area of the crystal enhances the rate of the photocatalytic reaction, due to the increased availability of active sites in the photocatalyst [15].

The characterization of the synthesized TiO_2/Ni using a DRS spectrophotometer was carried out to determine the light absorption area to calculate the band gap energy value. The band gap energy values will affect during electron excitation process of TiO_2/Ni [17]. In addition, the band gap energy value will also affect the absorption of the required light energy [18,19]. A small band gap energy value will only require a small amount of light energy. Fig. 2 shows the absorbance spectra of the synthesized material at a wavelength of 200-800 nm. From Fig.2, an increase in absorbance begins to occur at a wavelength of 400 nm for all samples. On the curve it can be seen that all samples absorb well in the UV light region where the wavelength is less than 380 nm.

From Fig.2, further analysis was carried out using the Kubelka-munk theory approach to determine the absorption properties of the synthesized material. The relationship between optical absorption coefficients is derived mathematically through the equation F(R) = (1-R)2/2R whose value is proportional to the value of the absorption coefficient per scattering or the value of k/s, where F(R) is the Kubelka-munk factor. The relationship between the Kubelka-munk factor and photon energy is shown in Fig. 3.

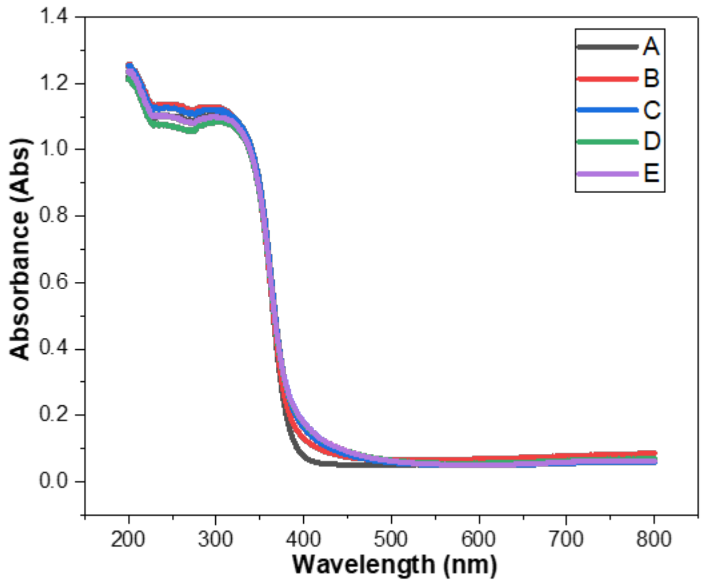

Figure 2. Diffuse reflectance spectroscopy (DRS) of TiO_2/Ni samples

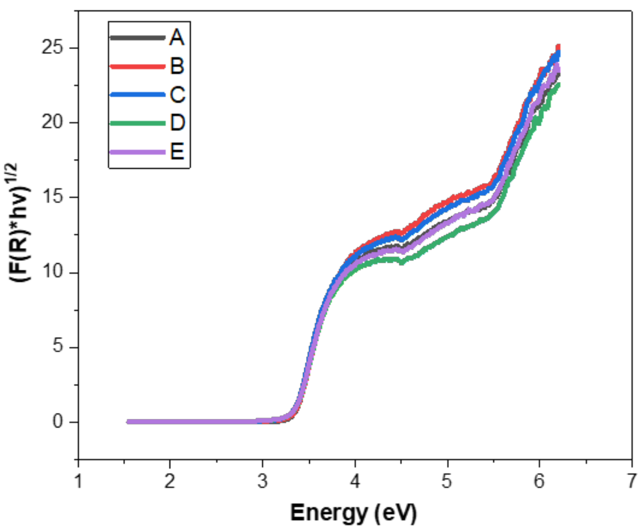

Figure 3. The relationship between Kubelka-munk factor and photon energy for TiO_2/Ni Samples

Based on Fig. 3, the band gap energy value for each sample can be determined by linear extrapolation on the area of the graph that has the highest slope. The results of the linear extrapolation performed on each sample are shown in Table III.

Table 3. Band gap energy of TiO_2/Ni samples

Samples	Band Gap Energy (eV)
A	3.16
B	3.15
C	3.12
D	3.14
E	3.20

Based on Table 3, sample A which was not added with nickel doped had a higher band gap energy value than samples B, C, and D were added with nickel doped. This evidence proves that the addition of nickel doping can

p-ISSN: 2963-8577
e-ISSN: 2964-3511

reduce the band gap energy value of the synthesized material. The decrease in the energy value of the band gap is due to the formation of new energy levels by nickel doping, so the distance between the valence band and the conduction band is reduced. The smaller the band gap energy value led to the increase of photocatalyst activity to capture the light with lower energy levels such as visible light. Angel et.al mentioned that lower band gap TiO_2 has higher photocatalytic activity for water treatment [29]. The band gap value is increasing again after sample C. This phenomenon happens since there is a possibility of agglomeration of doped metal that led to increasing band gap value.

The photocatalytic activity of TiO_2/Ni was analyzed based on its ability to degrade the pollutant methylene blue. The degradation reaction of methylene blue is shown in Equation 3 below.

$$C_{16}H_{18}N_3SCl + 25{,}5O_2 \rightarrow HCl + H_2SO_4 + 3HNO_3 + 16CO_2 + 6H_2O \quad (3)$$

The solution of TiO_2/Ni degradation in methylene blue was tested by using a UV-Vis spectrophotometer at a wavelength of 660 nm. This wavelength is the wavelength used to detect methylene blue.

Testing of the photocatalytic activity of TiO_2/Ni was carried out with an initial concentration of 20 ppm methylene blue solution. The selection of this initial concentration is based on the content of dye in the waste produced in the textile industry, which is around 20 to 30 ppm [20]. In the photoreactor, each mixture of TiO_2/Ni and methylene blue will be irradiated using a mercury lamp for a certain time. Prior to irradiation, the sample was dispersed for 1 hour in the dark (without light). It aims to achieve equilibrium conditions for the adsorption of reactants on the surface of the catalyst. During this process there was no degradation of methylene blue which was indicated by the unchanged concentration of methylene blue before and after the dispersion took place.

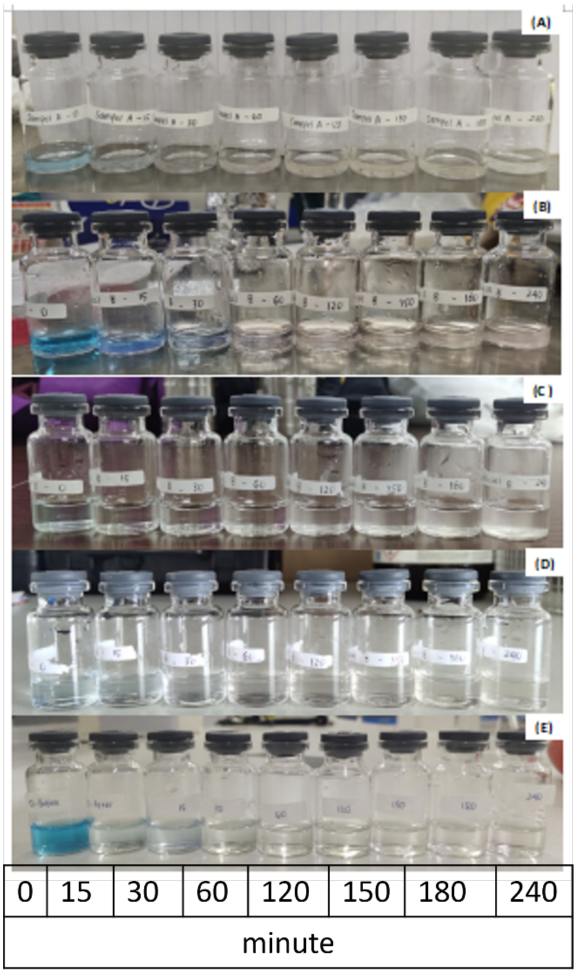

Figure 4. The photocatalytic activity results of TIO_2/Ni samples on methylene blue degradation

 p-ISSN: 2963-8577
e-ISSN: 2964-3511

Fig. 4 shows a solution of methylene blue that has been degraded by TiO_2/Ni at test times of 0, 15, 30, 60, 120, 150, 180, and 240 minutes for all samples. The left side samples on Fig.5 are samples at 0 minute. From the visual analysis, there is a decrease in color intensity over time. After being examined using a UV-Vis spectrophotometer at a wavelength of 660 nm, the absorbance value of each sample decreased. The longer the time of irradiation by a mercury lamp to a mixture of TiO_2/Ni with methylene blue, the smaller the absorbance value.

The results of the degradation of methylene blue at 240 minutes for each sample are shown in Table IV and Fig. 5. From Table IV, it shows that samples B, C, and D have a higher percentage of degradation compared to sample A. This indicates that nickel doped samples has higher photocatalytic activity on methylene blue degradation. The smaller crystallite size and lower band gap value had the important effect on photocatalytic activity. This conclusion has been proved by Tan [15] ,where the addition of doping was able to increase the photocatalytic activity of the synthesized material. Tan [15] also study the relation between crystallite size and active surface area, smaller crystallite size led to larger active surface area. The large surface area of the photocatalyst will increase the rate of photocatalytic degradation of organic pollutants because the availability of active sites in the photocatalyst increases [15].

From several research, TiO_2 with the addition of metal doping in the form of iron (Fe), fluorine (F), and boron (B) can degrade methylene blue in the UV light region by 72%, 92%, and 98% [21-25]. Meanwhile, in this study, the addition of nickel (Ni) doping on TiO_2 was able to degrade methylene blue under UV light by 92.73% (sample C). This shows that the use of nickel metal as doping in TiO_2 semiconductors is better than iron and fluorine metals[21-25]. The highest photocatalytic activity of sample C shows that low band gap has effect for photocatlytic activity, as it is proven also by several study [29-30]..

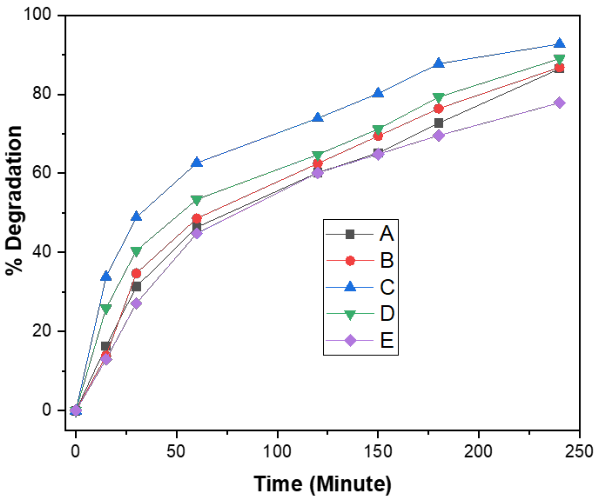

Figure 5. The photocatalytic activity of TiO2/Ni samples during methylene blue degradation

Table 4. The Degradation of methylene blue for TiO_2/Ni samples after 240 minutes

Samples	Degradation of Methylene Blue (%)
A	86. 47
B	86.81
C	92.73
D	88.99
E	77.83

4. Conclusion

The TiO_2/Ni photocatalyst can be synthesized from TiO_2 (P25) and $Ni(CH_3CO_2)_2.4H_2O$ by using one step hydrothermal method in an autoclave at 120 ˚C for 24 hours. From the analysis using X-Ray Diffraction (XRD) the crystal sizes for samples A, B, C, D, and E were obtained, was 8.09, 7.88, 7.30, 7.83, and 8.16 nm. From the analysis using the DRS spectrophotometer, the band gap energy for samples A, B, C, D, and E was obtained, was

3.16, 3.15, 3.12, 3.14, and 3.20 eV. The results of XRD and DRS showed that the addition of nickel doping on the TiO_2 lattice has effect on reduction of crystallite size and the band gap energy value, that led to increasing of its photocatalytic activity. Sample C with a molar ratio of TiO_2 and Ni of 20:1 was able to degrade 92.73% of methylene blue in 240 minutes. While samples A, B, D, and E were able to degrade 86.47%, 86.81%, 88.99%, and 77.83% methylene blue.

Acknowledgment

This work was supported by Universitas Pertamina UPSkilling research grant.

References

[1] Statistik, B. P., "Manufacturing Industrial Statistics Indonesia—Production 2014 [Report:Report]", Badan Pusat Statistik, 2016.
[2] Widjajanti, E., Regina T.P., and Utomo, M. P., "Pola Adsorpsi Zeolit Terhadap Pewarna Azo Metil Merah dan Metil Jingga". Proceedings of the National Research Seminar-Science Education and Application, 2011, pp. K115-K122.
[3] Elias M. S., "Penyingkiran Fenol Terlarut dalam Air Melalui Fotodegradasi Menggunakan Titanium Dioksida (TiO_2)", Malaysian Journal of Analytical Science, 2001, Vol. 7, No.1, pp. 1-6.
[4] Aliah, A. Sawitri, M. P. Aji, A. Setiawan, E. Sustini, M. Budiman, and M. Abdullah, Pelapisan Partikel TiO_2 pada Polimer Polipropilena dan Aplikasinya sebagai Reusable Photocatalyst. Bandung : SNM Proceeding, 2015.
[5] Effendi, Mukhtar, Analisis Sifat Optik Lapisan Tipis TiO_2 Doping Nitrogen yang Disiapkan dengan Metode Spin Coating. Scientific Meeting Proceedings, ISSN : 0853-0823, 2012.
[6] Herrmann, J. M., Heterogeneous photocatalysis: fundamentals and applications to the removal of various types of aqueous pollutants. Catalysis Today, 1999, pp.115-129.
[7] Lestari, D.N., Studi Preparasi dan Karakterisasi N-Doped TiO_2 dengan Metode Sol-Gel Mengunakan Prekursor Titanium Iso Propoksida (TTIP) dan Diethylamine (DEA). Depok : Universtas Indonesia,2009.
[8] Liu, N., Chen, X., Zhang, J., and Schwank, J. W., A review on TiO_2-based nanotubes synthesized via hydrothermal method: Formation mechanism, structure modification, and photocatalytic applications. Science Direct, 2013.
[9] Afrozi, A, S., Sintesis dan Karakterisasi Katalis Non Komposit Berbasis Titania untuk Produksi Hidrogen Dari Gliseol dan Air. Jakarta : Faculty of Engineering Department of Chemical Engineering Indonesia University, 2010.
[10] Chen, X., and Mao S.S., "Titanium Dioxide Nanomaterials : synthesis, properties, modifications, and applications". Chem Rev. vol.107, pp. 2891-2959, 2007.
[11] Yao, Zhongping, fangzhou Jia, and Shujun Tian, Microporus Ni-doped Film Photocatalyst by Plasma Electrolytic Oxidation. School of Chemical Engineering and echnology No. 92, 2010.
[12] Takashi, H,.Y sunagawa, S Myagmarjav, K Yamamoto, N sato, and Muramatsu, "Reductive Deposition of Ni-Zn Nanopartikel selectively on TiO_2 Fine Particles in the Liquid Phase". Materials Transactions, vol. 44, No. 11, 2003.
[13] Omrani, A. Dakhlaoui, Bousnina, MA., Smiri, LS.,Taibi, M., Leone, P., Schoenstein, F., and Joulini, N., "Elaboration of Nickel Nanoparticles by Modified Polyol and Their Spark Plasma Sintering, Characterization and Magnetic Properties of the Nanoparticles and Dense Nano-structured Material", Elsevier, pp. 821-828, 2010.
[14] Wu, J. C. S. and Chen, C. H., "A Visible Light Response Vanadium Doped Titanias Nanocatalyst by Sol Gel Method". Journal of Photochemistry and Photobiology : Chemistry, vol. 163 pp. 509-515, 2004.
[15] Tan, Y. N., Wong, C. L., and Mohamed, A. R., An Overview on the Photocatalytic Activity of Nano-Doped-TiO_2 in the Degradation of Organic Pollutants. ISRN Materials Science, 2011.

[16] Naimah, S., and Ermawati, “Efek fotokatalis nano TiO_2 terhadap mekanisme anti mikroba E. Coli dan Salmonela”. Jurnal Riset Industri, vol. 5, pp.113-120, 2011.

[17] Lestari, Mastuti Widi, “Sintesis dan Karaktrisasi Nanokatalis CuO/TiO_2 yang Dialikasikan pada Proses Degradasi Limbah Fenol”. Indo. J Chem 2, 2012.

[18] Gunlazuardi, J., “Fotoelektrokatalis untuk Detoksifikasi Air”, Proceedings of the National Electrochemistry Seminar, pp.1-21, 2001.

[19] Wardiyati, S., Adel F., and Saeul Y., Sintesis Nanokatalis TiO_2 Anatase dalam Larutan Elektrolit dengan Metode Sol Gel. Serpong : Pusat Sains dan Teknologi Bahan Maju, 2014.

[20] Kustiningsih, Indar and Denni Kartika Sari. “Uji Adsorpsi Zeolit Alam Bayah dan Pengaruh Sinar Ultraviolet terhadap Degradasi Limbah Methylene Blue”. Jurnal TEKNIKA, vol.13 No.1 pp. 25-32, 2017.

[21] Xiao, Q., Zhang, J., Xiao, C., Si, Z., and Tan, X., “Solar photocatalytic degradation of methylene blue in carbon-doped TiO_2 nanoparticles suspension”. Solar Energy, vol. 82, no. 8, pp. 706–713, 2008.

[22] Wen, C., Zhu, YJ., Kanbara, T., Zhu, HZ., and Xiao, C. F.,”Effects of I and F codoped TiO_2 on the photocatalytic degradation of methylene blue”. Desalination, vol. 249, no.2, pp. 621-625, 2009.

[23] Hamadanian, M., Reisi-Vanani, A., and Majedi, A., “Synthesis, characterization and effect of calcination temperature on phase transformation and photocatalytic activity of Cu, S codoped TiO_2 nanoparticles”, Applied Surface Science, vol. 256, no. 6, pp. 1837-1844, 2010.

[24] Yu, CL., Yu, JC., and. Chan, M., “Sonochemical fabrication of fluorinated mesoporous titanium dioxide microspheres”. Journal of Solid State Chemistry, vol. 182, no. 5, pp. 1061–1069, 2009.

[25] Li, Z., Shen, W., He, W., and Zu, X., “Effect of Fe-doped TiO_2 nanoparticle derived from modified hydrothermal process on the photocatalytic degradation performance on methylene blue”. Journal of Hazardous Materials, vol. 155, no. 3, pp. 590–594, 2008.

[26] Nursanto, EB., Park, SJ., Jeon, HS., Hwang.YJ., Kim, J., and Min, BK., “Uniform Deposition of ternary chalcogenide nanoparticles onto mesoporous TiO2 film using liquid carbon dioxide-based coating”. Thin Solid Films, vol 565, pp 122-127, 2014

[27] Handojo, L., Nursanto, EB., and Indarto,A., “Progress of nanomaterials application in environmental concerns” in Book “Nanohybrids in Environmental & Biomedical Applications, CRC Press, pp 189-205, 2019

[28] Nursanto, EB., Kim, J., and Min, BK., “Fabrication of TiO2-CuInS2 nanocomposite on ITO substrate via liquid carbon dioxide coating” J.Phys: Conf.Ser., 1349, 012138, 2019

[29] Angel, R.D., Alvarez, J.C.D., and Zanella, R., “TiO2 Low Band Gap Semiconductor Heterostructures for Water Treatment using Sunlight Driven Photocatlyst” in Book “Titanium Dioxide-Material for Sustainable Environment”, Intechopen,76501, 2018

[30] Cervantes, O.R.F., Larios, A.P., Arellano, V.H.R., Rangel, B.R., and Gonzalez., C.A.G., ‘Effect in Band Gap for Photocatalysis in TiO2 support by Adding Gold and Ruthenium.” Processes, Vol 8, 1032, 2020.

Biographies of Authors

Eduardus Budi Nursanto graduated his doctoral degree education majoring in clean energy and chemical engineering from Korea University of Science and Technology, South Korea. Currently, he is active faculty member at Chemical Engineering Department, Universitas Pertamina, Indonesia.

Reisa M.R Sinaga graduated her bachelor's degree from Chemical Engineering Department, Universitas Pertamina, Indonesia.

Dita Floresyona graduated her doctoral degree majoring in chemistry from Université Paris sud-Université Paris saclay, France. Currently, she is active faculty member at Chemical Engineering Department, Universitas Pertamina, Indonesia.

Rinaldi Medali Rachman graduated his master's degree majoring in chemical engineering from King Abdullah University of Science and Technology, Kingdom of Saudi Arabia. Currently, he is active faculty member at Chemical Engineering Department, Universitas Pertamina, Indonesia.

Agung Nugroho graduated his doctoral degree education majoring in clean energy and chemical engineering from Korea University of Science and Technology, South Korea. Currently, he is active faculty member at Chemical Engineering Department, Universitas Pertamina, Indonesia.