# DAFTAR PUSTAKA

Abbad, M. M., Takriff, M. S., & Mohammad, A. W. 2015. Enhancement of 2-chlorophenol photocatalytic degradation in the presence $Co^{2+}$ doped ZnO nanoparticles under direct solar radiation. *Research on Chemical Intermediates*, **42**(6),1-18.

Abbasi, S., Hasanpour, M., Ahmadpoor, F., Sillanpaa, M., Dastan, D., & Achour, A. 2019. Application of the statistical analysis methodology for photodegradation of methyl orange using a new nanocomposite containing modified $TiO_2$ semiconductor with $SnO_2$. *International Journal of Environmental Analytical Chemistry*, **101**(2),1-17.

Abdullah, H., Khan, M., Ong, H., & Yaakob, Z. 2017. Modified $TiO_2$ photocatalyst for $CO_2$ photocatalytic reduction : An overview. *Journal of $CO_2$ Utilization*, **22**, 15-32.

Abdullah, M., Khairurrijal, Nurhasanah, I., Sriyanti, I., & Marully, A. R. 2009. Nanopartikel Ceria yang Didop Neodimium untuk Aplikasi Solid Oxide Fuel Cell (SOFC). *Jurnal Nanosains & Nanoteknologi*, **2**(1), 21-26.

Aberoumand, A. 2011. A review article on edible pigments properties and sources as natural biocolorants in foodstuff and food industry. *Journal of Dairy & Food Sciences*, **6**(1), 71-78.

Aboud, N. A. A., Alkayat, W. M. S., & Hussain, D. H. 2020. Simple chemical synthesis of zinc oxide and copper oxide nanoparticles for biological protection. *Systematic Reviews in Pharmacy*, **11**(6), 1188-1195.

Akpan, U. G., & Hameed, B. H. 2010. The advancements in sol-gel method of doped-$TiO_2$ photocatalysts. *Applied Catalysis A: General*, **375***(1)*, 1-11.

Akrami, A., & Niazi, A. 2016. Synthesis of maghemite nanoparticles and its application for removal of Titan yellow from aqueous solutions using full factorial design. *Desalination and Water Treatment*, **57**(47),1-14.

Ali, T., Ahmed, A., Alam, U., Uddin, I., Tripathi, P., & Muneer, M. 2018. Enhanced photocatalytic and antibacterial activities of Ag-doped $TiO_2$ nanoparticles under visible light. *Materials Chemistry and Physics*, **212**, 325-335.

Alsharaeh, E. H., Bora, T., Soliman, A., Ahmed, F., Bharath, G., Ghoniem, M. G., Salah, K. M., & Dutta, J. 2017. Sol-gel-assisted microwave-derived synthesis of anatase Ag/$TiO_2$/Go nanohybrids toward efficient visible light phenol degradation. *Catalysts*, **7**(5), 1-10.

André, R. S., Zamperini, C. A., Mima, E. G., Longo, V. M., Albuquerque, A.

R., Sambrano, J. R., Machado, A. L., Vergani, C. E., Hernandes, A. C., Varela, J. A., & Longo, E. 2015. Antimicrobial activity of $TiO_2$:Ag nanocrystalline heterostructures: Experimental and theoretical insights. *Chemical Physics*, **459**, 87-95.

Ansari, S. A., Ansari, S. G., Foaud, H., & Cho, M. H. 2017. Facile and sustainable synthesis of carbon-doped ZnO nanostructures towards the superior visible light photocatalytic performance. *New Journal of Chemistry*, **41**(17),1-23.

Anwar, B. 2016. Biodegradasi Poli (Hidroksibutirat Co Caprolakton) dengan Menggunakan Lumpur Aktif. *Jurnal Pengajaran MIPA*, **12**(2), 68-78.

Aritonang, A. B., Krisnandi, Y. K., & Gunlazuardi, J. 2018. Modification of $TiO_2$ nanotube arrays with N doping and Ag decorating for enhanced visible light photoelectrocatalytic degradation of methylene blue. *International Journal on Advanced Science,Engineering and Information Technology*, **8**(1), 234-241.

Avci, N., Smet, Æ. P. F., Poelman, Æ. H., Driessche, I. Van, & Poelman, Æ. D. 2009. Characterization of $TiO_2$ powders and thin films prepared by non-aqueous sol-gel techniques. *Journal Sol-Gel Sci Technol*, **52**(3), 424-431.

Ayed, L., Chaieb, Æ. K., & Cheref, Æ. A. 2009. Biodegradation of triphenylmethane dye Malachite Green by Sphingomonas paucimobilis. *World Journal of Microbiology and Biotechnology*, **25**(4), 705-711.

Azad, K., & Gajanan, P. 2017. Photodegradation of Methyl Orange in Aqueous Solution by the Visible Light Active Co:La :$TiO_2$ Nanocomposite. *Chemical Sciences Journal*, **8**(3), 1-9.

Azazy, M., Dimassi, S. N., El-shafie, A. S., & Issa, A. A. 2019. Applied sciences Bio-Waste Aloe vera Leaves as an Efficient Adsorbent for Titan Yellow from Wastewater : Structuring of a Novel Adsorbent Using Plackett-Burman Factorial Design. *Applied Sciences,* **9**(22),1-20.

Azmi, W., Sani, R. K., & Banerjee, U. C. 1998. Biodegradation of triphenylmethane dyes. *Enzyme and Microbial Technology*, **22**(3), 185-191.

Baban, A., Yediler, A., Lienert, D., Kemerdere, N., & Kettrup, A. 2003. Ozonation of high strength segregated effluents from a woollen textile dyeing and finishing plant. *Dyes and Pigments*, **58**(2), 93-98.

Bai, Z., & Zhang, Y. (2016). Self-powered UV-visible photodetectors based on ZnO/$Cu_2O$ nanowire/electrolyte heterojunctions. *Journal of Alloys and Compounds*, **675**, 325-330.

Barakat, M. A., & Kumar, R. 2016. *Photocatalytic Activity Enhancement of*

*Titanium Dioxide Nanoparticles*. 1-29.

Baylor, S. ., & Hollingworth, C. 1990. Absorbance Signals from Resting Frog Skeletal Muscle Fibers Injected with the pH Indicator Dye , Phenol Red. *Journal Of General Physiology*, **96**(3), 449-471.

Benkhaya, S., Harfi, S. El, & Harfi, A. El. 2017. Classifications , properties and applications of textile dyes : A review. *Applied Journal of Environmental Engineering Science*, ***3***(3), 311-320.

Bharat, T. C., Shubham, Mondal, S., Gupta, H. S., kumarvidya, P. K., & Das, A. K. 2019. Synthesis of doped zinc oxide nanoparticles: A review. *Materials Today: Proceedings*, **11**, 767-775.

Bharti, D. B., & Bharati, A. V. 2016. Synthesis of ZnO nanoparticles using a hydrothermal method and a study its optical activity. *Luminescence*, **32**(3),1-4.

Bhermana, B. G., Safni, & Syukri. 2015. Degradasi zat warna Metanil Yellow secara fotolisis dan penyinaran matahari dengan penambahan katalis $TiO_2$ Anatase dan $SnO_2$. *Journal of Islamic Science and Technology*, **1**(1), 49-62.

Bonanni, A. 2007. Ferromagnetic nitride-based semiconductors doped with transition metals and rare earths. *Semiconductor Science and Technology*, **22**(9), 41-56.

Byrne, C., Moran, L., Hermosilla, D., Merayo, N., Blanco, Á., Rhatigan, S., Hinder, S., Ganguly, P., Nolan, M., & Pillai, S. C. 2019. Effect of Cu doping on the anatase-to-rutile phase transition in $TiO_2$ photocatalysts: Theory and experiments. *Applied Catalysis B: Environmental*, **246**, 266-276.

Cahino, A. M., Loureiro, R. G., Dantas, J., Madeira, V. S., & Ribeiro Fernandes, P. C. 2019. Characterization and Evaluation of ZnO/CuO Catalyst in the Degradation of Methylene Blue Using Solar Radiation. *Ceramics International*, **45**(11), 13628-13636.

Carp, O., Huisman, C. L., & Reller, A. 2004. Photoinduced reactivity of titanium dioxide. *Progres in Solid State Chemistry*, **32**(3), 33-177.

Chandekar, Shkir, M., Al-Shehri, B. M., AlFaify, S., Halor, R. G., Khan, A., Al-Namshah, K. S., & Hamdy, M. S. 2020. Visible light sensitive Cu doped ZnO: Facile synthesis, characterization and high photocatalytic response. *Materials Characterization*, **165**, 1-11.

Chaudhary, B. 2020. Chemistry of synthetic dyes : A Review. *Journal of Interdisciplinary Cycle Research*, ***7***(11), 390-396.

Cheng, Q., Benipal, M., Liu, Q., Wang, X., Crozier, P., Chan, C., & Nemanich, R. 2017. $Al_2O_3$ and $SiO_2$ Atomic Layer Deposition Layers on ZnO Photoanodes and Degradation Mechanisms. *ACS Applied Materials & Interfaces*, **9**(19), 1-7.

Chong, M. N., Jin, B., Chow, C. W. K., & Saint, C. 2010. Recent developments in photocatalytic water treatment technology: A review. *Water Research*, **44**(10), 2997-3027.

Coleman, H. M., Vimonses, V., Leslie, G., & Amal, R. 2007. Degradation of 1,4-dioxane in water using $TiO_2$ based photocatalytic and $H_2O_2$/UV processes. *Journal of Hazardous Materials*, **146**(3), 496-501.

Colon, G., Maicu, M., Hidalgo, M. C., & Navı, J. A. 2006. Cu-doped $TiO_2$ systems with improved photocatalytic activity. *Applied Catalysis*, **67**, 41-51.

Daghrir, R., Drogui, P., & Robert, D. 2013. Modified $TiO_2$ for environmental photocatalytic applications: A review. *Industrial and Engineering Chemistry Research*, **52**(10), 3581-3599.

Dewi, T., Mahdi;, & Novriyansyah, T. 2016. Pengaruh Rasio Reaktan Pada Impregnasi Dan Suhu Reduksi Terhadap Karakter Katalis Kobalt/Zeolit Alam Aktif. *Jurnal Teknik Kimia*, **22**(3), 34-42.

Ebrahimi, R., Hossienzadeh, K., Maleki, A., Ghanbari, R., Rezaee, R., & Safari, M. 2019. Effects of doping zinc oxide nanoparticles with transition metals ( Ag , Cu , Mn ) on photocatalytic degradation of Direct Blue 15 dye under UV and visible light irradiation. *Journal of Environmental Health Science and Engineering*, **17**(1), 1-14.

Elkamel, I., Hamdaoui, N., Mezni, A., Ajjel, R., & Beji, L. 2019. Synthesis and characterization of Cu doped ZnO nanoparticles for stable and fast response UV photodetector at low noise current. *Journal of Materials Science: Materials in Electronics*, **30**(10), 1-11.

Eyison, A. A., Tetteh, S., & Zugle, R. 2020. Frontiers in Chemical Research Photocatalytic degradation of azo reactive dyes with ultraviolet and sunlight. *Frontiers in Chemical Research*, **2**(1), 26-32.

Farhan, S., Sharafee, M., Ismail, S., Bonilla-petriciolet, A., Ben, A., & Erto, A. 2018. Synthesis and characterization of a novel amphoteric adsorbent coating for anionic and cationic dyes adsorption : Experimental investigation and statistical physics modelling. *Chemical Engineering Journal*, **351**, 221-229.

Fenoll, J., Ruiz, E., Hellín, P., Flores, P., & Navarro, S. 2011. Chemosphere Heterogeneous photocatalytic oxidation of cyprodinil and fludioxonil in leaching water under solar irradiation. *Chemosphere*, **85**(8), 1262-1268.

Forgacs, E., Cserháti, T., & Oros, G. 2004. Removal of synthetic dyes from wastewaters: A review. *Environment International*, **30**(7), 953-971.

Gaya, U. I., & Abdullah, A. H. 2008. Heterogeneous photocatalytic degradation of organic contaminants over titanium dioxide: A review of fundamentals, progress and problems. *Journal of Photochemistry and Photobiology C: Photochemistry Reviews*, **9**(1), 1-12.

Gratzel, M. 2003. Dye-sensitized solar cells. *Journal of Photochemistry and Photobiology C: Photochemistry Reviews*, **4**(2), 145-153.

Gupta, K., Singh, R. P., Pandey, A., & Pandey, A. 2013. Photocatalytic antibacterial performance of $TiO_2$ and Ag-doped $TiO_2$ against S. Aureus. P. Aeruginosa and E. Coli. *Beilstein Journal of Nanotechnology*, **4**(1), 345-351.

Gupta, S. M., & Tripathi, M. 2011. A review of $TiO_2$ nanoparticles. *Chinese Science Bulletin*, **56**(16), 1639-1657.

Gupta, V. K., Mittal, A., Kurup, L., & Mittal, J. 2006. Adsorption of a hazardous dye, erythrosine, over hen feathers. *Journal of Colloid and Interface Science*, **304**(1), 52-57.

Harisha, S., Keshavayya, J., Kumara Swamy, B. E., & Viswanath, C. C. 2017. Synthesis, characterization and electrochemical studies of azo dyes derived from barbituric acid. *Dyes and Pigments*, **136**, 1-46.

Hassaan, M. A., & Nemr, A. El. 2017. Health and Environmental Impacts of Dyes : Mini Review. *American Journal of Environmental Science and Engineering*, **1**(3), 64-67.

Hikmawati, Watoni, A. H., Wibowo, D., Maulidiyah, & Nurdin, M. 2017. Synthesis of Nano-Ilmenite ($FeTiO_3$) doped $TiO_2$/Ti Electrode for Photoelectrocatalytic System. *IOP Conference Series: Materials Science and Engineering*, **267**(1), 1-9.

Hiremath, S., Antony Raj, M. A. L., Chandra Prabha, M. N., & Vidya, C. 2018. Tamarindus indica mediated biosynthesis of nano $TiO_2$ and its application in photocatalytic degradation of Titan yellow. *Journal of Environmental Chemical Engineering*, **6**(6), 1-30.

Hsu, M. H., & Chang, C. J. 2014. Ag-doped ZnO nanorods coated metal wire meshes as hierarchical photocatalysts with high visible-light driven photoactivity and photostability. *Journal of Hazardous Materials*, **278**, 444-453.

Ismael, M. 2020. A review and recent advances in solar-to-hydrogen energy conversion based on photocatalytic water splitting over doped-$TiO_2$ nanoparticles. *Solar Energy*, **211**, 522-546.

Janaki, A. C., Sailatha, E., & Gunasekaran, S. 2015. Synthesis, characteristics and antimicrobial activity of ZnO nanoparticles. *Spectrochimica Acta Part, A: Molecular and Biomolecular Spectroscopy*,**144**, 17-22.

Janczyk, A., Krakowska, E., Stochel, G., & Macyk, W. 2006. Singlet oxygen photogeneration at surface modified titanium dioxide. *Journal of the American Chemical Society*, **128**(49), 15574-15575.

Jayabharathi, J., Karunakaran, C., Kalaiarasi, V., & Ramanathan, P. 2014. Nano ZnO, Cu-doped ZnO, and Ag-doped ZnO assisted generation of light from imidazole. *Journal of Photochemistry and Photobiology A: Chemistry*, **295**, 1-10.

Kacus, H., Sahin, Y., Aydogan, S., Incekara, U., & Yilmaz, M. 2020. Phenol red based hybrid photodiode for optical detector applications. *Solid State Electronics*, **171**, 1-7.

Kant, R. 2012. Textile dyeing industry an environmental hazard. *Natural Science*, **4**(1), 22-26.

Kausar, A., Iqbal, M., Javed, A., Aftab, K.,Nazli, Z., Bhatti, H. N., & Nouren, S. 2018. Dyes adsorption using clay and modified clay: A review. *Journal of Molecular Liquids*, **256**,1-48.

Koohestani, H., & Ezoji, R. 2021. Synthesis and Characterization of $TiO_2/CuO/WO_3$ Ternary Composite and its Application as Photocatalyst. *International Journal of Engineering*, **34**(3), 721-727.

Kormann, C., Bahnemann, D. W., & Hoffmann, M. R. 1988. Photocatalytic production of H2O2 and organic peroxides in aqueous suspensions of $TiO_2$, ZnO, and desert sand. *Environmental Science and Technology*, **22**(7), 798-806.

Kumar, A., & Pandey, G. 2017. A review on the factors affecting the photocatalytic degradation of hazardous materials. *Material Science & Engineering International Journal*, **1**(3), 106-114.

Kumar, H., & Rani, R. 2013. Structural and Optical Characterization of ZnO Nanoparticles Synthesized by Microemulsion Route. *International Letters of Chemistry, Physics and Astronomy*, **14**, 26-36.

Kumar, R., & Gnanavel, B. 2017. High performance catalytic activity of pure and silver (Ag) doped $TiO_2$ nanoparticles by a novel microwave irradiation technique. *Journal of Materials Science: Materials in Electronics*, **28**(5), 1-7.

Kumaresan, S., Vallalperuman, K., Sathishkumar, S., Karthik, M., & SivaKarthik, P. 2017. Synthesis and systematic investigations of Al and Cu-doped ZnO nanoparticles and its structural, optical and photocatalytic properties. *Journal of Materials Science: Materials in Electronics*, **28**(3), 1-8.

Kuriakose, S., Satpati, B., & Mohapatra, S. 2015. Highly efficient photocatalytic degradation of organic dyes by Cu doped ZnO nanostructures. *Physical Chemistry Chemical Physics*, **17**(38),1-23.

Labhane, P. K., Huse, V. R., Patle, L. B., Chaudhari, A. L., & Sonawane, G. H. 2015. Synthesis of Cu Doped ZnO Nanoparticles: Crystallographic, Optical, FTIR, Morphological and Photocatalytic Study. *Journal of Materials Science and Chemical Engineering*, **3**(7), 39-51.

Lam, S. M., Sin, J. C., Abdullah, A. Z., & Mohamed, A. R. 2012. Degradation of wastewaters containing organic dyes photocatalysed by zinc oxide: A review. *Desalination and Water Treatment*, **41**(3), 131-169.

Lee, K., Akmal Saipolbahri, Z., Hoe Guan, B., & Soleimani, H. 2014. Organic sol-gel method in the synthesis and characterization of zinc oxide nanoparticles. *American Journal of Applied Sciences*, **11**(6), 959-962.

Lei, X. F., Xue, X. X., & Yang, H. 2014. Preparation and characterization of Ag-doped $TiO_2$ nanomaterials and their photocatalytic reduction of Cr(VI) under visible light. *Applied Surface Science*, **321**, 396-403.

Linsebigler, A. L., Lu, G., & Yates, J. T. 1995. Photocatalysis on $TiO_2$ Surfaces: Principles, Mechanisms, and Selected Results. *Chemical Reviews*, **95**(3), 735-758.

Listiorini, Fahyuan, H. D., & Ngatijo. 2018. Pengaruh Doping Al Terhadap *Band Gap Energy* Lapisan Tipis ZnO. *Journal Of Physic*, **4**(1), 24-29.

Madadi, M., Ghorbanpour, M., & Feizi, A. 2018. Antibacterial and photocatalytic activity of anatase phase Ag-doped $TiO_2$ nanoparticles. *Micro and Nano Letters*, **13**(11), 1590-1593.

Maddhinni, V. L., Vurimindi, H. B., & Yerramilli, A. 2006. Degradation of azo dye with horse radish peroxidase (HRP). *Journal of the Indian Institute of Science*, **86**(5), 507-514.

Maensiri, S., Laokul, P., & Promarak, V. 2006. Synthesis and optical properties of nanocrystalline ZnO powders by a simple method using zinc acetate dihydrate and poly(vinyl pyrrolidone). *Journal of Crystal Growth*, **289**(1), 102-106.

Mamun, K., Asw, R., & Fahmida, K. 2017. Parameters affecting the photocatalytic degradation of dyes using $TiO_2$ : a review. *Applied Water Science*, **7**(4), 1569-1578.

Masoudian, N. 2018. Highly efficient adsorption of Naphthol Green B and Phenol Red dye by Combination of Ultrasound wave and Copper-Doped Zinc Sulfide Nanoparticles Loaded on Pistachio - Nut. *Applied Organometallic Chemistry*, **32**(8), 1-13.

Meshram, S. P., Adhyapak, P. V., Amalnerkar, D. P., & Mulla, I. S. 2016. Cu doped ZnO microballs as effective sunlight driven photocatalyst. *Ceramics International*, **42**(6),1-27.

Misriyani, Wahab, A. W., Taba, P., & Gunlazuardi, J. 2017. Effect of anodizing time and annealing temperature on photoelectrochemical properties of anodized $TiO_2$ nanotube for corrosion prevention application. *Indonesian Journal of Chemistry*, **17**(2), 219-227.

Mittal, A., Kaur, D., Malviya, A., Mittal, J., & Gupta, V. K. 2009. Adsorption studies on the removal of coloring agent phenol red from wastewater using waste materials as adsorbents. *Journal of Colloid And Interface Science*, **337**(2), 345-354.

Mittal, M., Sharma, M., & Pandey, O. P. 2014. UV-Visible light induced photocatalytic studies of Cu doped ZnO nanoparticles prepared by coprecipitation method. *Solar Energy*, **110**, 386-397.

Mo, J., Yang, Q., Zhang, N., Zhang, W., Zheng, Y., & Zhang, Z. 2018. A review on agro-industrial waste (AIW) derived adsorbents for water and wastewater treatment. *Journal of Environmental Management*, **227**, 395-405.

Mo, S. Di, & Ching, W. Y. 1995. Electronic and optical properties of three phases of titanium dioxide: Rutile, anatase, and brookite. *Physical Review B*, **51**(19), 13023-13032.

Modwi, A., Abbo, M. A., Hassan, E. A., Al-Duaij, O. K., & Houas, A. 2017. Adsorption kinetics and photocatalytic degradation of malachite green (MG) via Cu/ZnO nanocomposites. *Journal of Environmental Chemical Engineering*, **5**(6), 5954-5960.

Muhammad, W., Ullah, N., Haroon, M., & Abbasi, B. H. 2019. Optical, morphological and biological analysis of zinc oxide nanoparticles (ZnO NPs) using: Papaver somniferum L. *RSC Advances*, **9**(51), 29541-29548.

Munnik, P., De Jongh, P. E., & De Jong, K. P. 2015. Recent Developments in the Synthesis of Supported Catalysts. *Chemical Reviews*, **115**(14), 6687-6718.

Nagarkar, M. G., Chitodakar, V. D., & Mandake, M. B. 2017. Catalytic Ozonation: A Rising Advanced Oxidation Technology for Textile Dyes. *International Journal of Innovative Research in Science, Engineering and Technology*, **6**(4), 6789-6796.

Naldoni, A., Riboni, F., Guler, U., Boltasseva, A., Shalaev, V. M., & Kildishev, A. V. 2016. Solar-Powered Plasmon-Enhanced Heterogeneous Catalysis. *Nanophotonics*, **5**(1), 112-133.

Narayan, M. R. 2012. Review: Dye sensitized solar cells based on natural photosensitizers. *Renewable and Sustainable Energy Reviews*, **16**(1), 208-215.

Narayanan, A. L., Dhamodaran, M., & Solomon, J. S. 2015. Thermodynamics and kinetics of adsorption of azo dye titan yellow from aqueous solutions on natural plant material Saccharum spontaneum. *Der Pharma Chemica*, **7**(8), 36-45.

Natarajan, S., Bajaj, H. C., & Tayade, R. J. 2017. Recent advances based on the synergetic effect of adsorption for removal of dyes from waste water using photocatalytic process. *Journal of Environmental Sciences*, **65**, 1-22.

Nguyen, C. H., Tran, M. L., Tran, T. T. Van, & Juang, R. S. 2020. Enhanced removal of various dyes from aqueous solutions by UV and simulated solar photocatalysis over $TiO_2$/ZnO/rGO composites. *Separation and Purification Technology*, **232**, 1-14.

Nguyen, S. T., Feng, J., Ng, S. K., Wong, J. P. W., Tan, V. B. C., & Duong, H. M. 2014. Advanced thermal insulation and absorption properties of recycled cellulose aerogels. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **445**, 128-134.

Nie, C., Du, H., Li, Q., Ni, J., Yuan, D., Chen, Y., Wang, B., & Wang, X. 2020. Solar-driven highly thermal electrochemical oxidation in the temperature of more than 100 °C for sustainable treatment of organic pollutants in wastewater. *Renewable Energy*, **147**, 2171-2178.

Nigussie, G. Y., Tesfamariam, G. M., Tegegne, B. M., Weldemichel, Y. A., Gebreab, T. W., Gebrehiwot, D. G., & Gebremichel, G. E. 2018. Antibacterial activity of Ag-Doped $TiO_2$ and Ag-Doped ZnO nanoparticles. *International Journal of Photoenergy*, **23**, 1-7.

Nurdin, M., Muzakkar, M. Z., Maulidiyah, M., Maulidiyah, N., & Wibowo, D. 2016. Plasmonic Silver N/$TiO_2$ Effect on Photoelectrocatalytic Oxidation Reaction. *Journal Mater Environ*, **7**(9), 3334-3343.

Olimpiani, I., & Astuti. 2016. Efek Doping Senyawa Alkali Terhadap Celah Pita Energi Nanopartikel ZnO. *Jurnal Fisika Unand*, **5**(2), 115-121.

Ong, C. B., Ng, L. Y., & Mohammad, A. W. 2018. A review of ZnO nanoparticles as solar photocatalysts: Synthesis, mechanisms and applications. *Renewable and Sustainable Energy Reviews*, **81**, 536-551.

Pal, S., Mondal, S., Maity, J., & Mukherjee, R. 2018. Synthesis and characterization of zno nanoparticles using Moringa Oleifera leaf extract: Investigation of photocatalytic and antibacterial activity. *International Journal of Nanoscience and Nanotechnology*, **14**(2), 111-119.

Parra, M. R., & Haque, F. Z. 2014. Aqueous chemical route synthesis and the effect of calcination temperature on the structural and optical properties of ZnO nanoparticles. *Journal of Materials Research and Technology*, **3**(4), 363-369.

Peng, T., Zhao, D., Dai, K., Shi, W., & Hirao, K. 2005. Synthesis of titanium dioxide nanoparticles with mesoporous anatase wall and high photocatalytic activity. *Journal of Physical Chemistry B*, **109**(11), 4947-4952.

Prabhu, R., Hewitt, F., Georgieva, G., Lawton, L. A., Meenakshi, H. N., & Robertson, P. K. J. 2017. Energy efficient operation of photocatalytic reactors based on UV LEDs for pollution remediation in water. *Aberdeen*, **12**, 1-5.

Purwanto, A., & Kwartiningsih, E. 2012. Pembuatan Zat Warna Alami dalam Bentuk Serbuk untuk Mendukung Industri Batik di Indonesia. *Jurnal Rekayasa Proses*, **6**(1), 26-29.

Raganata, T. C., Aritonang, H., & Suryanto, E. 2019. Sintesis Fotokatalis Nanopartikel Zno Untuk Mendegradasi Zat Warna Methylene Blue. *Chemistry Progress*, **12**(2), 54-58.

Ramirez, M., Remirez, H., & Trevino, M. 2015. Synthesis Methods for Photocatalytic Material. In *Springer International Publishing Switzerland*, 69-102.

Reddy, A. J., Kokila, M. K., Nagabhushana, H., Chakradhar, R. P. S., Shivakumara, C., Rao, J. L., & Nagabhushana, B. M. 2011. Structural, optical and EPR studies on ZnO:Cu nanopowders prepared via low temperature solution combustion synthesis. *Journal of Alloys and Compounds*, **509,** 5349–5355.

Reddy, K. M. 2018. Photocatalytic Degradation of Organic Dyes Using Ag-$TiO_2$ Nanomaterials. *Journal of Chemical and Pharmaceutical Research*, **10**(2), 128-133.

Reza, K. M., Kurny, A., & Gulshan, F. 2017. Parameters affecting the photocatalytic degradation of dyes using $TiO_2$: a review. *Applied Water Science*, **7**(4),1-10.

Rishikesan, S., & Basha, M. A. M. 2020. Synthesis, characterization and evaluation of antimicrobial, antioxidant & anticancer activities of copper doped zinc oxide nanoparticles. *Acta Chimica Slovenica*, **67**(1), 235-245.

Riyani, K., Setyaningtyas, T., & Dwiasih, D. W. 2012. Pengolahan Limbah Cair Batik menggunakan Fotokatalis $TiO_2$-Dopan-N dengan Bantuan Sinar Matahari. *Jurnal Kimia Valensi*, **2**(5), 581-587.

Sahoo, C., Gupta, A. K., & Pal, A. 2005. Photocatalytic degradation of Crystal Violet (C . I . Basic Violet 3) on silver ion doped $TiO_2$. *Dyes and Pigments*, **66**(3), 189-196.

Sakthivel, S., Neppolian, B., Shankar, M. V., Arabindoo, B., Palanichamy, M., & Murugesan, V. 2003. Solar photocatalytic degradation of azo dye:

Comparison of photocatalytic efficiency of ZnO and $TiO_2$. *Solar Energy Materials and Solar Cells*, **77**(1), 65-82.

Samanta, K., & Agarwal, P. 2009. Application of natural dyes on diverse textile materials. *Indian Journal of Fibre & Textile Research*, **34**, 384-399.

Samavati, A., Ismail, A. F., Nur, H., Othaman, Z., & Mustafa, M. K. 2016. Spectral features and antibacterial properties of Cu-doped ZnO nanoparticles prepared by sol-gel method. *Chinese Physics Society*, **25**(7), 1-7.

Santhi, T., Manonmani, S., Vasantha, V. S., & Chang, Y. T. 2016. A new alternative adsorbent for the removal of cationic dyes from aqueous solution. *Arabian Journal of Chemistry*, **9**, 1-9.

Sapawe, N., Jalil, A. A., Triwahyono, S., Sah, R. N. R. A., Jusoh, N. W. C., Hairom, N. H. H., & Efendi, J. 2013. Electrochemical strategy for grown ZnO nanoparticles deposited onto HY zeolite with enhanced photodecolorization of methylene blue: Effect of the formation of SiOZn bonds. *Applied Catalysis A: General*, **456**, 144-158.

Saravanan, R., Gracia, F., Mansoob, M., Poornima, V., Kumar, V., Narayanan, V., & Stephen, A. 2015. ZnO/CdO nanocomposites for textile ef fl uent degradation and electrochemical detection. *Journal of Molecular Liquids*, **209**, 374-380.

Sarwono, R., & Tursiloadi, S. 2015. Morfologi Dan Aktifitas Katalis Logam Cu Dengan Penyangga Mono Dan Bimetalik Oksida Cara Kerja Impregnasi Ko-Presipitasi. *Jurnal Sains Materi Indonesia*, **16**(2), 76-82.

Sathishkumar, P., Sweena, R., Wu, J. J., & Anandan, S. 2011. Synthesis of CuO-ZnO nanophotocatalyst for visible light assisted degradation of a textile dye in aqueous solution. *Chemical Engineering Journal*, **171**(1), 136-140.

Savitri, S., Nugraha, A. S., & Aziz, I. 2016. Pembuatan Katalis Asam (Ni/γ-$Al_2O_3$) dan Katalis Basa (Mg/γ-$Al_2O_3$) untuk Aplikasi Pembuatan Biodiesel dari Bahan Baku Minyak Jelantah. *Jurnal Penelitian Dan Pengembangan*, ***2***(1), 1-10.

Scanlon, D. O., Dunnill, C. W., Buckeridge, J., Shevlin, S. A., Logsdail, A. J., Woodley, S. M., Catlow, C. R. A., Powell, M. J., Palgrave, R. G., Parkin, I. P., Watson, G. W., Keal, T. W., Sherwood, P., Walsh, A., & Sokol, A. A. 2013. Band alignment of rutile and anatase $TiO_2$. *Nature Materials*, **12**(9), 1-4.

Schumann, J., Eichelbaum, M., Lunkenbein, T., Thomas, N., Álvarez Galván, M. C., Schlögl, R., & Behrens, M. 2015. Promoting strong metal support interaction: Doping ZnO for enhanced activity of Cu/ZnO:M

(M = Al, Ga, Mg) catalysts. *ACS Catalysis*, **5**(6), 3260-3270.

Shahpal, A., Aziz Choudhary, M., & Ahmad, Z. 2017. An investigation on the synthesis and catalytic activities of pure and Cu-doped zinc oxide nanoparticles. *Cogent Chemistry*, **3**(1), 1-12.

Shanmugam, V., & Jeyaperumal, K. S. 2017. Investigations of visible light driven Sn and Cu doped ZnO hybrid nanoparticles for photocatalytic performance and antibacterial activity. *Applied Surface Science*, **449**, 1-45.

Sharma, K., Dalai, A. K., & Vyas, R. K. 2017. Removal of synthetic dyes from multicomponent industrial wastewaters. *Reviews in Chemical Engineering*, **34**(1), 1-29.

Shedbalkar, U., Dhanve, R., & Jadhav, J. 2008. Biodegradation of triphenylmethane dye cotton blue by Penicillium ochrochloron MTCC 517. *Journal of Hazardous Materials*, **157**(3), 472-479.

Silveira, E., Marques, P. P., Silva, S. S., Lima-Filho, J. L., Porto, A. L. F., & Tambourgi, E. B. 2009. Selection of Pseudomonas for industrial textile dyes decolourization. *International Biodeterioration and Biodegradation*, **63**(2), 230-235.

Singh, K., & Arora, S. 2011. Removal of synthetic textile dyes from wastewaters: A critical review on present treatment technologies. *Critical Reviews in Environmental Science and Technology*, **41**(9), 807-878.

Singh, R., Singh, P., & Singh, R. 2014. Bacterial decolorization of textile azo dye acid orange by staphylococcus hominis RMLRT03. *Toxicology International*, **21**(2), 160-166.

Sobana, N., Muruganadham, M., & Swaminathan, M. 2006. Nano-Ag particles doped $TiO_2$ for efficient photodegradation of Direct azo dyes. *Journal of Molecular Catalysis A: Chemical*, **258**(2), 124-132.

Sood, S., Umar, A., Mehta, S. K., & Kansal, S. K. 2015. Highly effective Fe-doped $TiO_2$ nanoparticles photocatalysts for visible-light driven photocatalytic degradation of toxic organic compounds. *Journal of Colloid and Interface Science*, **450**, 213-223.

Sucahya, T. N., Permatasari, N., Bayu, A., & Nandiyanto, D. 2016. Fotoktalisis untuk Pengolahan Limbah Cair. *Jurnal Integrasi Proses*, **6**(1), 1-15.

Supriyanto, E., & Holikin, A. 2007. Pengaruh Thermal Annealing terhadap Struktur Kristal dan Morfologi Bubuk Titanium Dioksida ($TiO_2$) The Thermal Annealing Effect on Crystal Structure and Morphology of Titanium Dioxide ($TiO_2$) Powder. *Jurnal Ilmu Dasar*, **15**(1), 37-41.

Tarkwa, J. B., Oturan, N., Acayanka, E., Laminsi, S., & Oturan, M. A. 2019. Photo-Fenton oxidation of Orange G azo dye: process optimization and mineralization mechanism. *Environmental Chemistry Letters*, **17**(1), 473-479.

Toback, F. G., Margaret, M., & Phe-, F. G. T. 2019. Phenol red inhibits growth of renal epithelial. *American Journal of Physiology-Renal Physiology*, **11**, 687-691.

Türkyılmaz, Ş. Ş., Güy, N., & Özacar, M. 2017. Photocatalytic efficiencies of Ni , Mn , Fe and Ag doped ZnO nanostructures synthesized by hydrothermal method : The synergistic / antagonistic effect between ZnO and metals. *Journal of Photochemistry & Photobiology*, **341**, 1-42.

Vidya, C., Manjunatha, C., Sudeep, M., Ashoka, S., & Lourdu Antony Raj, M. A. 2020. Photo-assisted mineralisation of titan yellow dye using ZnO nanorods synthesised via environmental benign route. *SN Applied Sciences*, **2**(4), 1-15.

Wahab, H. S., & Hussain, A. A. 2016. Photocatalytic oxidation of phenol red onto nanocrystalline $TiO_2$ particles. *Journal of Nanostructure in Chemistry*, **6**(3), 261-274.

Wang, P., Wang, D., Li, H., Xie, T., Wang, H., & Du, Z. 2007. A facile solution-phase synthesis of high quality water-soluble anatase TiO2 nanocrystals. *Journal of Colloid and Interface Science*, **314**(1), 337-340.

Wang, X. B., Li, D. M., Zeng, F., & Pan, F. 2005. Microstructure and properties of Cu-doped ZnO films prepared by dc reactive magnetron sputtering. *Journal of Physics D: Applied Physics*, **38**(22), 4104-4108.

Wang, Y., Yan, L., He, X., Li, J., & Wang, D. 2016. Controlled fabrication of Ag/$TiO_2$ nanofibers with enhanced stability of photocatalytic activity. *Journal of Materials Science: Materials in Electronics*, **27**(5), 1-7.

Weldegebrieal, G. K. 2020. Synthesis method, antibacterial and photocatalytic activity of ZnO nanoparticles for azo dyes in wastewater treatment: A review. *Inorganic Chemistry Communications*, **120**, 1-29.

Xu, C.-L., Qin, D.-H., Li, H., Guo, Y., Xu, T., & Li, H.-L. 2004. Low-temperature growth and optical properties of radial ZnO nanowires. *Materials Letters*, **58**(30), 3976-3979.

Yan, X., Yuan, K., Lu, N., Xu, H., Zhang, S., Takeuchi, N., Kobayashi, H., & Li, R. 2017. The interplay of sulfur doping and surface hydroxyl in band gap engineering: Mesoporous sulfur-doped $TiO_2$ coupled with magnetite as a recyclable, efficient, visible light active photocatalyst for water purification. *Applied Catalysis B: Environmental*, **218**, 1-34.

Yaseen, D. A., & Scholz, M. (2019). Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. *International journal of environmental science and technology*, **16**(2), 1193-1226.

Yaseen, Dina A., & Scholz, M. 2018. Treatment of synthetic textile wastewater containing dye mixtures with microcosms. *Environmental Science and Pollution Research*, **25**(2), 1980-1997.

Zhang, F., Cheng, Z., Kang, L., Cui, L., Liu, W., Xu, X., Hou, G., & Yang, H. 2015. A novel preparation of Ag-doped $TiO_2$ nanofibers with enhanced stability of photocatalytic activity. *RSC Advances*, **5**(41), 32088-32091.

Zhao, H., Deng, W., & Li, Y. 2017. Atomic layer deposited $TiO_2$ ultrathin layer on Ag_ZnO nanorods for stable and efficient photocatalytic degradation of RhB. *Advanced Composites and Hybrid Materials*, **1**(2), 404-413.

Zhao, Z., Wang, L., Fan, J., Song, Y., Chu, G., & Shao, L. 2020. Degradation of indigo carmine by coupling Fe(II)-activated sodium persulfate and ozone in a rotor-stator reactor. *Chemical Engineering and Processing-Process Intensification*, **148**, 1-6.

Zhou, S., Fu, Z., Xia, L., Mao, Y., Zhao, W., & Wang, A. 2021. In situ synthesis of ternary hybrid nanocomposites on natural Juncus effusus fiber for adsorption and photodegradation of organic dyes. *Separation and Purification Technology*, **255**, 1-10.

Zhu, C., Wang, L., Kong, L., Yang, X., Wang, L., Zheng, S., Chen, F., Maizhi, F., & Zong, H. 2000. Photocatalytic degradation of AZO dyes by supported $TiO_2^+$ UV in aqueous solution. *Chemosphere*, **41**(3), 303-309.

Zhu, K. R., Zhang, M. S., Hong, J. M., & Yin, Z. 2005. Size effect on phase transition sequence of $TiO_2$ nanocrystal. *Materials Science and Engineering A*, **403**(2), 87-93.

Zong, X., & Wang, L. 2014. Ion-exchangeable semiconductor materials for visible light-induced photocatalysis. *Journal of Photochemistry and Photobiology*, **18**, 1-62.

**LAMPIRAN 1.** Skema Prosedur Kerja

**1. Aktivasi semikonduktor**

**a. Seng Oksida (ZnO)**

ZnO

- diaktivasi selama 6 jam pada suhu 110$^{o}$C

Serbuk ZnO

**2. Sintesis Katalis Cu/ZnO**

**a. Seng Oksida (ZnO)**

30 g ZnO

- dilarutkan dengan 100 mL $CH_3COOH$ 30%
- diaduk sampai larut

Larutan ZnO

**b. Tembaga Nitrat Cu $(NO_3)_2$**

7,5 g $Cu(NO_3)_2$

- dilarutkan dengan 50 mL isopropanol
- diaduk sampai larut

Larutan $Cu(NO_3)_2$

**c. Sintesis Katalis Cu/ZnO**

Larutan ZnO

Larutan $Cu(NO_3)_2$

- dicampurkan dalam gelas kimia 500 mL
- diaduk menggunakan pengaduk magnetik selama 6 jam pada suhu ruang
- dipanaskan pada suhu 60-70$^oC$ sampai terbentuk pasta

Pasta Cu/ZnO

- diukur pH pasta
- ditambahkan akuades hingga pH netral
- dipanaskan pada suhu 120 $^oC$ hingga terbentuk pasta
- didinginkan pada suhu ruang

Padatan Cu/ZnO

- dihaluskan menggunakan mortar
- dikeringkan pada suhu 120 $^oC$ dalam oven selama 24 jam.
- dikalsinasi menggunakan tanur pada suhu 500$^oC$ selama 5 jam

Serbuk Cu/ZnO

- dikarakterisasi dengan FTIR, XRD, UV-VIS DRS, SEM

Hasil Karakterisasi

**3. Aktivasi semikonduktor**

**a. Titanium Dioksida ($TiO_2$)**

$TiO_2$

- diaktivasi selama 6 jam pada suhu110$^oC$

Serbuk

**4. Sintesis Katalis Ag/$TiO_2$**

**a. Titanium dioksida ($TiO_2$)**

50 g $TiO_2$

- dilarutkan dengan 250 mL HCl
- diaduk sampai larut

Larutan $TiO_2$

**b. Perak nitrat ($AgNO_3$)**

12,5 g ($AgNO_3$)

- dilarutkan dengan 150 mL akuades
- diaduk sampai larut

Larutan ($AgNO_3$)

**c. Sintesis Katalis Ag/$TiO_2$**

Larutan $TiO_2$ + Larutan $AgNO_3$

- dicampurkan dalam gelas kimia 1000 mL
- diaduk menggunakan pengaduk magnetik selama 6 jam pada suhu ruang
- dipanaskan pada suhu 60-70$^oC$ sampai terbentuk pasta

Pasta Ag/$TiO_2$

- diukur pH pasta
- ditambahkan NaOH 10 % hingga pH netral
- dipanaskan pada suhu 120 $^oC$ hingga terbentuk pasta
- didinginkan pada suhu ruang

Padatan Ag/$TiO_2$

- dihaluskan menggunakan mortar
- dikeringkan pada suhu 120$^oC$ dalam oven selama 24 jam.
- dikalsinasi menggunakan tanur pada suhu 450 $^oC$ selama 4 jam

Serbuk Ag/$TiO_2$

- dikarakterisasi dengan FTIR, XRD, UV-VIS DRS, SEM

Hasil Karakterisasi

**5. Penentuan panjang gelombang maksimum titan kuning dan fenol merah**

Larutan zat warna
TK dan FM

- Larutan zat warna TK diukur pada rentang panjang gelombang 390-415 nm dan FM 400-436 nm menggunakan spektrofotometer UV-Vis
- dicatat absorbansi zat warna
- ditentukan panjang gelombang maksimum zat warna dengan menggunakan absorbansi maksimum.

$\lambda_{max}$ TK dan FM

**6. Pembuatan kurva kalibrasi titan kuning dan fenol merah**

Larutan baku zat warna
TK dan FM

- dibuat deret konsentrasi 2, 4, 6, 8 dan 10, 12, 14 dan 16 ppm
- diukur absorbansi masing-masing larutan pada $\lambda_{max}$
- dibuat kurva hubungan konsentrasi dan absorbansi

Kurva standar zat warna
TK dan FM

**7. Penentuan Kondisi Optimum Fotodegradasi**

**a. Penentuan bobot optimum**

0,05; 0,10; 0,15; 0,20; 0,25; 0,50; 0,75; dan 1,0 g katalis Cu/ZnO, Ag/$TiO_2$

- diinteraksikan masing-masing ke dalam 50 mL larutan zat warna TK dan FM dengan konsentrasi 50 ppm
- diletakkan dibawah lampu UV-A $\lambda$ = 356 nm
- diaduk menggunakan *shaker* selama 60 menit untuk zat warna TK dan FM
- disaring

Residu

Filtrat

- diukur absorbansinya dengan spektrofotometer UV-Vis pada panjang gelombang $\lambda_{max}$ TK dan FM

Data

- dihitung setiap absorbansi pada variasi bobot

Bobot optimum

**b. Penentuan waktu kontak optimum**

Bobot Optimum Katalis Cu/ZnO dan Ag/$TiO_2$

- diinteraksikan masing-masing ke dalam 50 mL larutan zat warna TK dan FM dengan konsentrasi 50 ppm
- diletakkan dibawah lampu UV-A λ = 356 nm
- diaduk menggunakan *shaker* selama 5, 10, 20, 30, 45, 60, 90, 120, 150, dan 210 menit.
- disaring

Residu

Filtrat

- diukur absorbansinya dengan spektrofotometer UV-Vis pada panjang gelombang $\lambda_{max}$ TK dan FM

Data

- dihitung setiap absorbansi pada variasi waktu kontak

Waktu kontak optimum

**c. Penentuan konsentrasi optimum**

Bobot Optimum Katalis Cu/ZnO dan Ag/$TiO_2$

- diinteraksikan masing-masing dengan 50 mL zat warna TK dengan 65, 75, 100, 125, 150, 200, 250, dan 300 ppm. Variasi konsentrasi FM 60, 70, 80, 90, 100, 110, 120, dan 150 ppm.
- diletakkan dibawah lampu UV-A $\lambda$ = 356 nm
- diaduk menggunakan *shaker* menggunakan waktu optimum

Residu | Filtrat

Filtrat

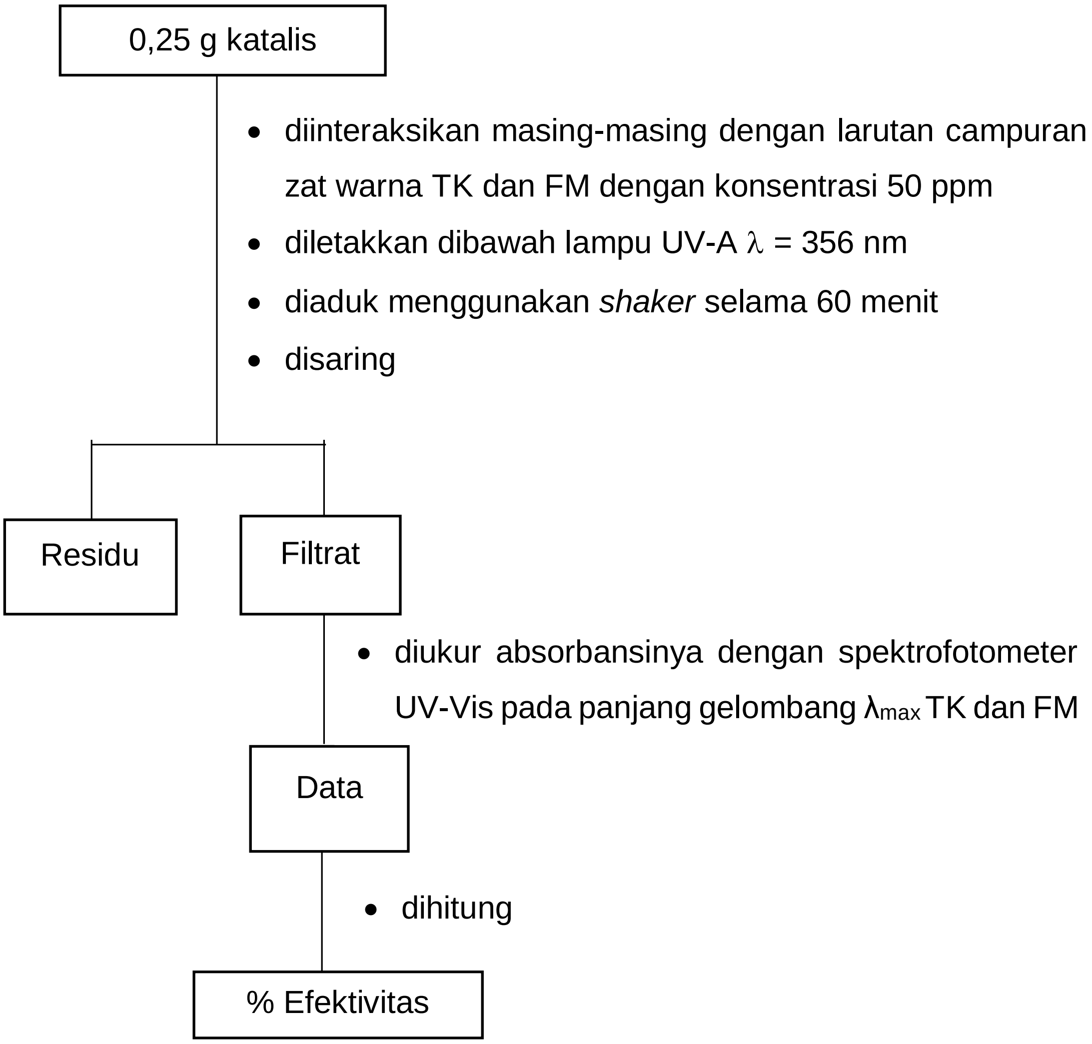
- diukur absorbansinya dengan spektrofotometer UV-Vis

Data

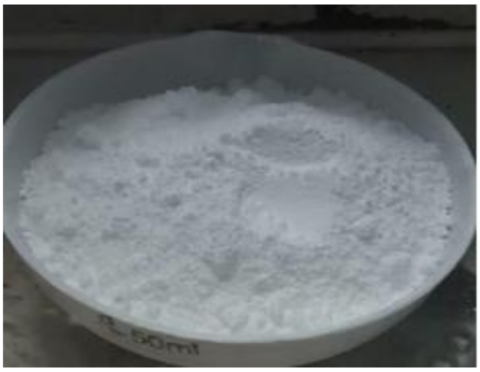
- dihitung setiap absorbansi pada variasi konsentrasi

Konsentrasi 0ptimum

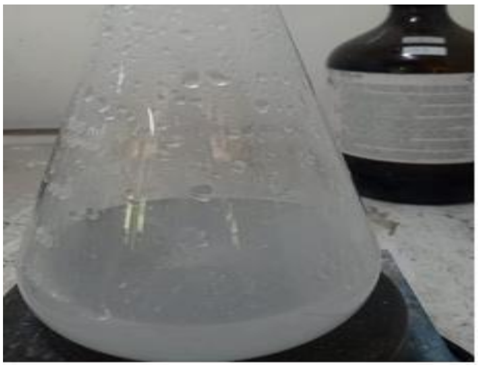
**d. Penentuan efektivitas campuran zat warna TK dan FM**



**Lampiran 2.** Dokumentasi Kegiatan Penelitian

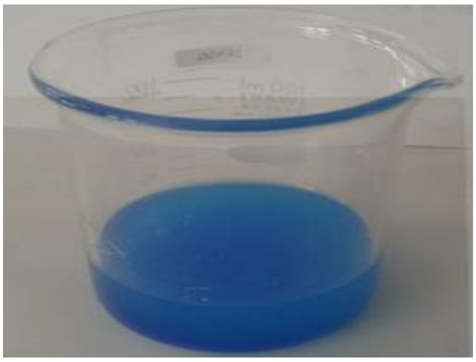


Bubuk ZnO

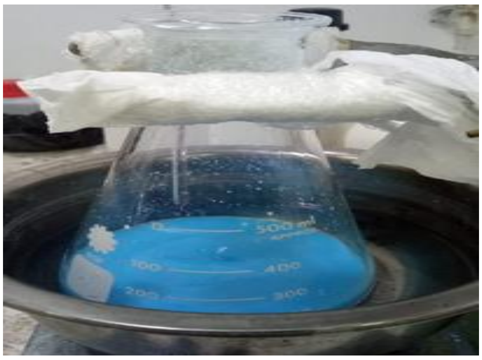


Larutan ZnO (Larutan I)

Tembaga nitrat



Larutan tembaga nitrat (Larutan II)



Larutan I dan Larutan II

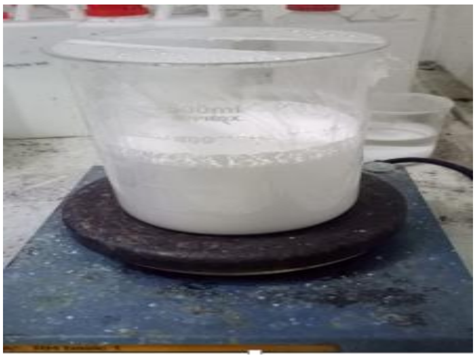
Cu/ZnO sebelum kalsinasi

Proses kalsinasi

Cu/ZnO setelah kalsinasi

Serbuk $TiO_2$

Larutan $TiO_2$ dan Perak nitrat

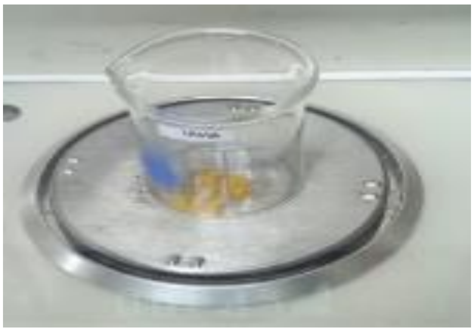


Proses penetralan

Proses penghalusan

Ag/$TiO_2$ sebelum kalsinasi

Ag/$TiO_2$ setelah kalsinasi



Titan kuning

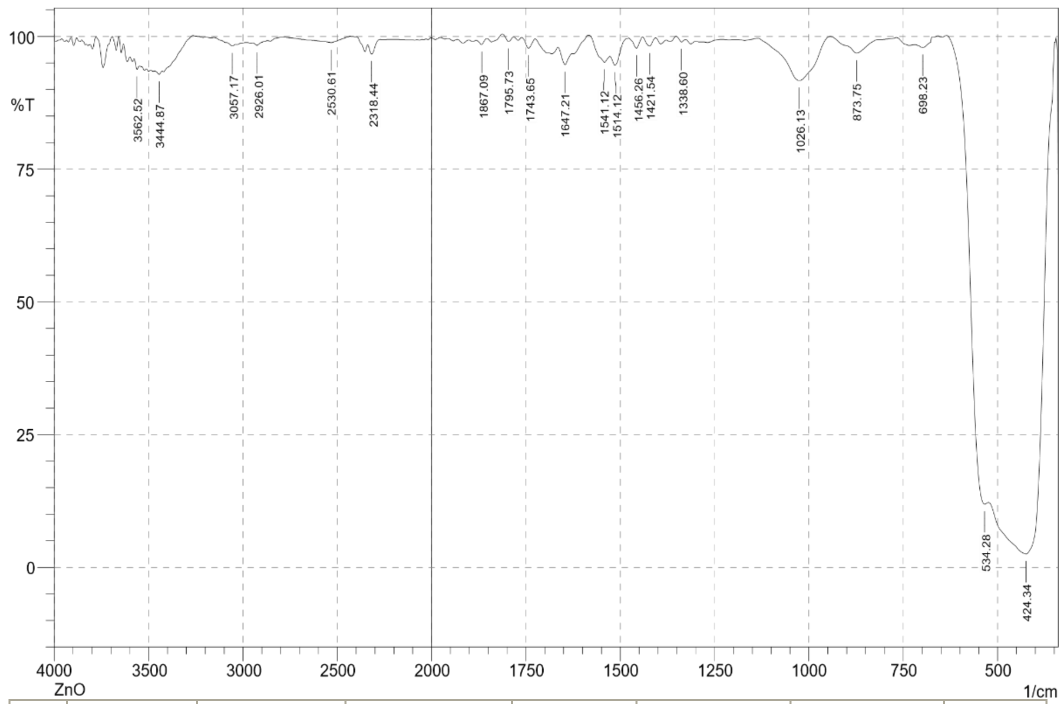
Fenol merah

Larutan titan kuning

Larutan fenol merah

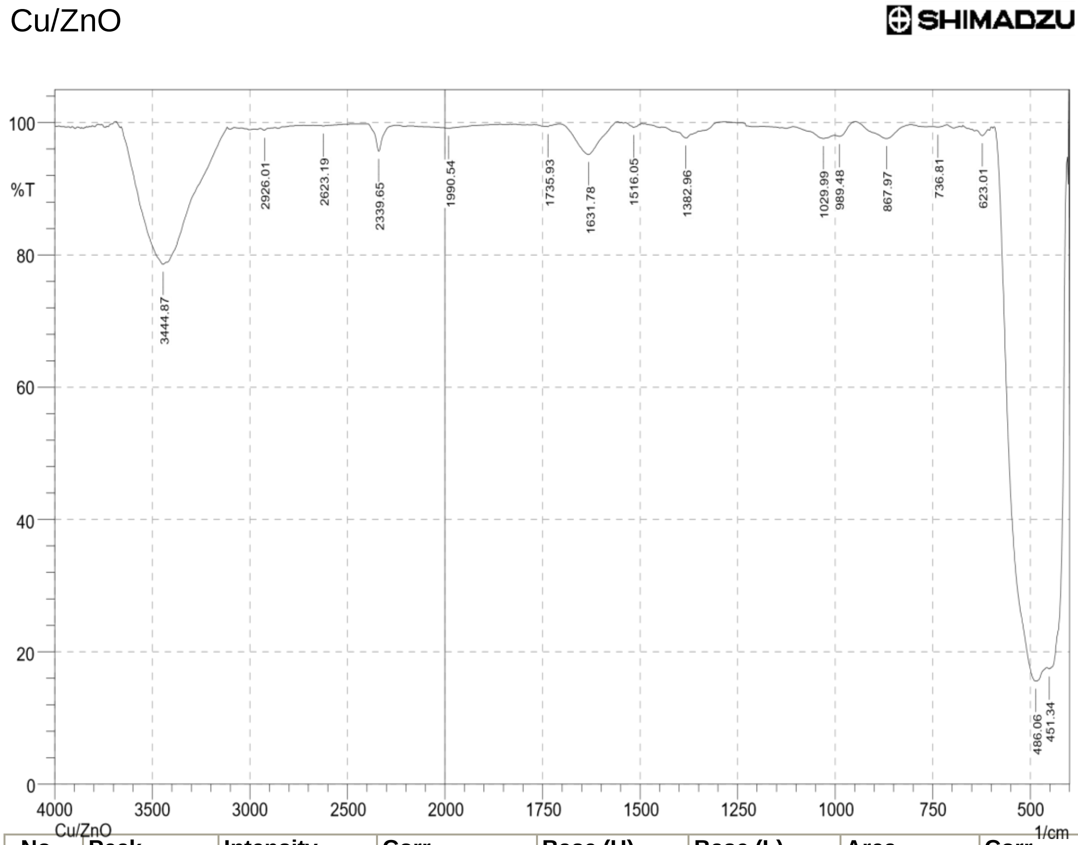
**Lampiran 3.** Hasil FTIR

ZnO



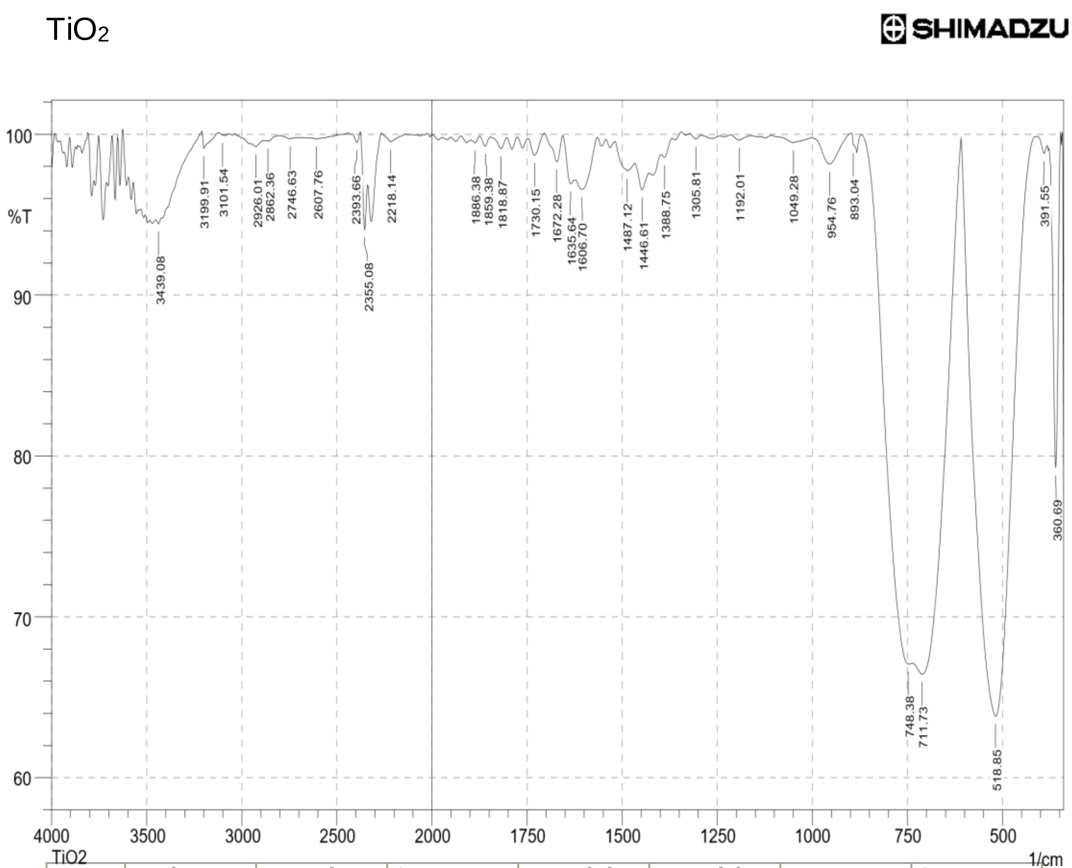

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 424.34 | 2.487 | 58.84 | 522.71 | 349.12 | 177.927 | 99.108 |
| 2 | 534.28 | 11.887 | 8.058 | 634.58 | 524.64 | 38.974 | 2.39 |
| 3 | 698.23 | 97.907 | 1.099 | 719.45 | 657.73 | 0.33 | 0.132 |
| 4 | 873.75 | 96.843 | 2.841 | 943.19 | 812.03 | 0.92 | 0.749 |
| 5 | 1026.13 | 91.686 | 8.151 | 1132.21 | 945.12 | 3.466 | 3.317 |
| 6 | 1338.6 | 98.922 | 0.768 | 1352.1 | 1327.03 | 0.069 | 0.038 |
| 7 | 1421.54 | 98.17 | 1.656 | 1440.83 | 1406.11 | 0.159 | 0.135 |
| 8 | 1456.26 | 97.755 | 2.066 | 1477.47 | 1440.83 | 0.187 | 0.156 |
| 9 | 1514.12 | 94.547 | 2.631 | 1527.62 | 1477.47 | 0.651 | 0.202 |
| 10 | 1541.12 | 95.083 | 2.098 | 1585.49 | 1527.62 | 0.734 | 0.284 |
| 11 | 1647.21 | 94.681 | 2.704 | 1664.57 | 1627.92 | 0.642 | 0.214 |
| 12 | 1743.65 | 97.77 | 1.908 | 1761.01 | 1726.29 | 0.194 | 0.146 |
| 13 | 1795.73 | 99.033 | 1.081 | 1813.09 | 1782.23 | 0.048 | 0.068 |
| 14 | 1867.09 | 98.46 | 0.983 | 1882.52 | 1853.59 | 0.127 | 0.055 |
| 15 | 2318.44 | 96.663 | 2.059 | 2339.65 | 2272.15 | 0.581 | 0.259 |
| 16 | 2530.61 | 98.817 | 1.178 | 2792.93 | 2434.17 | 0.966 | 0.911 |
| 17 | 2926.01 | 98.317 | 0.57 | 2947.23 | 2870.08 | 0.415 | 0.071 |
| 18 | 3057.17 | 98.189 | 0.474 | 3153.61 | 3039.81 | 0.52 | 0.081 |
| 19 | 3444.87 | 92.858 | 0.589 | 3466.08 | 3429.43 | 1.126 | 0.048 |
| 20 | 3562.52 | 93.777 | 1.257 | 3577.95 | 3549.02 | 0.71 | 0.076 |

Cu/ZnO



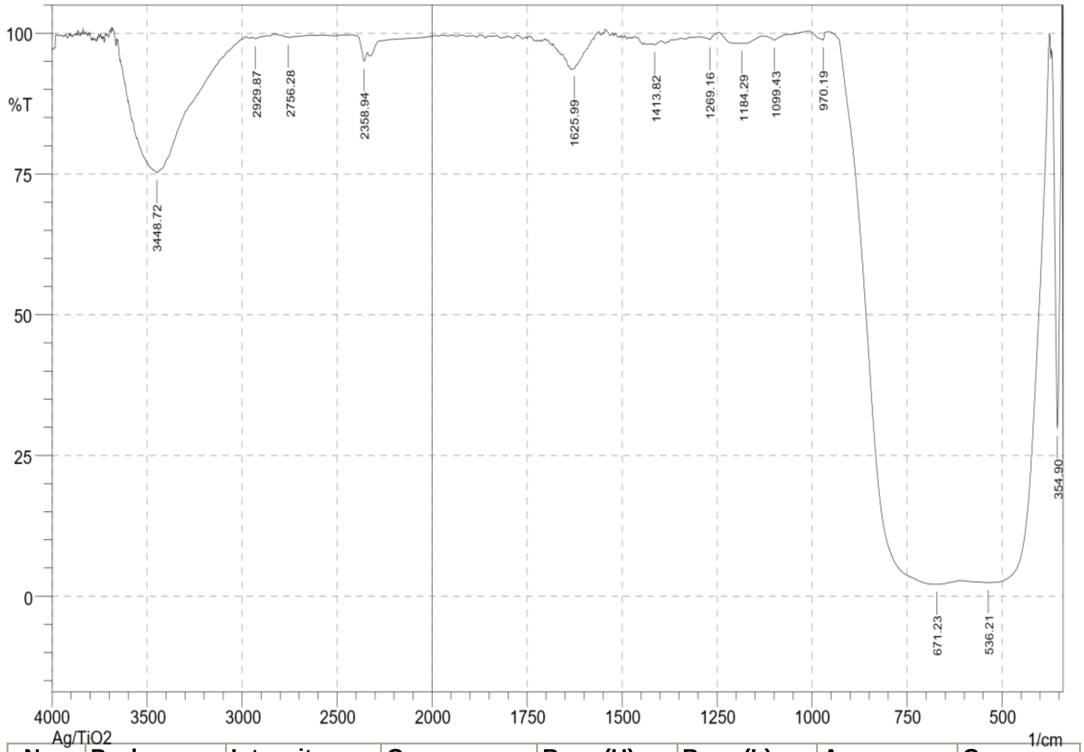

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 451.34 | 17.392 | 9.03 | 457.13 | 406.98 | 27.837 | 8.976 |
| 2 | 486.06 | 15.553 | 18.612 | 592.15 | 459.06 | 67.471 | 16.86 |
| 3 | 623.01 | 98.037 | 0.839 | 636.51 | 609.51 | 0.188 | 0.056 |
| 4 | 736.81 | 99.311 | 0.239 | 756.1 | 713.66 | 0.103 | 0.022 |
| 5 | 867.97 | 97.592 | 2.317 | 948.98 | 806.25 | 0.752 | 0.715 |
| 6 | 989.48 | 97.929 | 0.682 | 1002.98 | 948.98 | 0.28 | 0.075 |
| 7 | 1029.99 | 97.621 | 0.808 | 1107.14 | 1002.98 | 0.729 | 0.156 |
| 8 | 1382.96 | 97.689 | 1.921 | 1438.9 | 1282.66 | 0.75 | 0.564 |
| 9 | 1516.05 | 99.29 | 0.309 | 1521.84 | 1494.83 | 0.055 | 0.02 |
| 10 | 1631.78 | 95.21 | 4.753 | 1703.14 | 1558.48 | 1.475 | 1.455 |
| 11 | 1735.93 | 99.429 | 0.051 | 1737.86 | 1720.5 | 0.034 | 0.002 |
| 12 | 1990.54 | 99.164 | 0.131 | 2005.97 | 1930.74 | 0.226 | 0.024 |
| 13 | 2339.65 | 95.679 | 4.047 | 2395.59 | 2247.07 | 0.969 | 0.772 |
| 14 | 2623.19 | 99.503 | 0.047 | 2636.69 | 2468.88 | 0.244 | -0.004 |
| 15 | 2926.01 | 98.868 | 0.272 | 2947.23 | 2904.8 | 0.183 | 0.024 |
| 16 | 3444.87 | 78.589 | 1.841 | 3658.96 | 3427.51 | 14.747 | 2.417 |

TiO$_2$



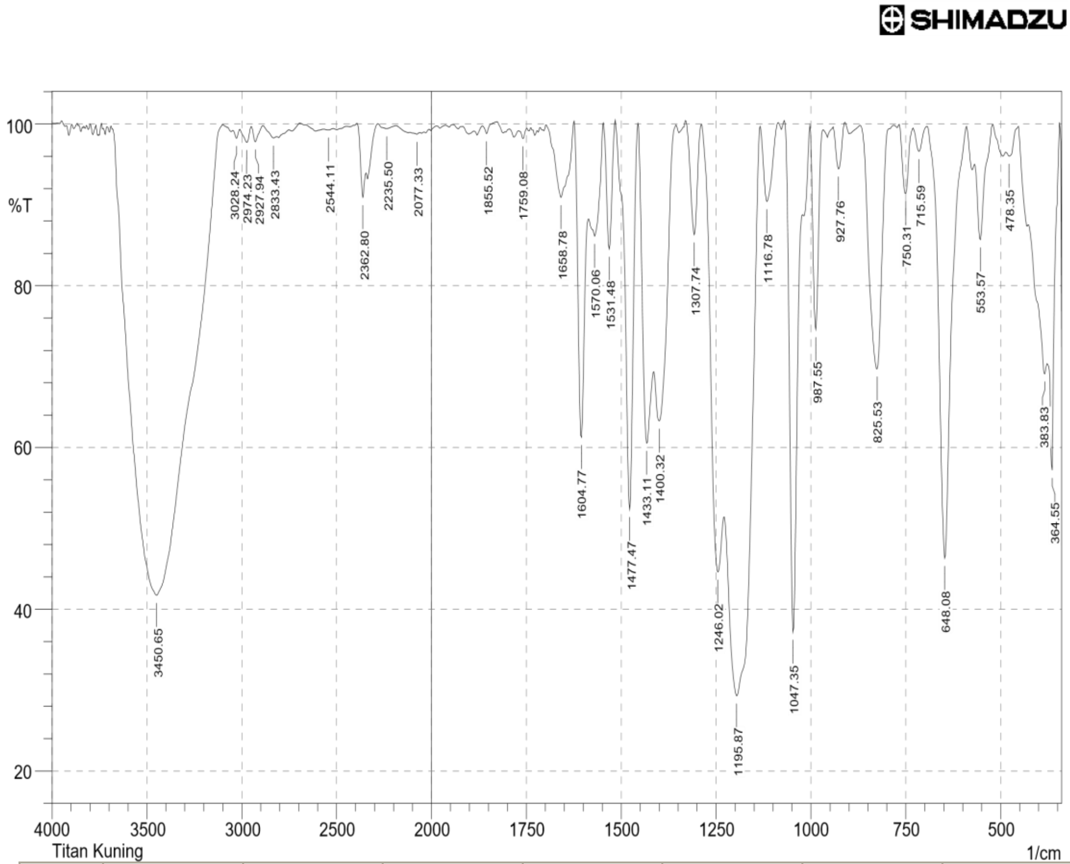

| | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 360.69 | 79.263 | 19.915 | 381.91 | 349.12 | 1.451 | 1.336 |
| 2 | 391.55 | 98.806 | 0.656 | 408.91 | 383.83 | 0.074 | 0.028 |
| 3 | 518.85 | 63.824 | 35.715 | 607.58 | 416.62 | 19.695 | 19.33 |
| 4 | 711.73 | 66.431 | 7.111 | 736.81 | 609.51 | 15.142 | 4.214 |
| 5 | 748.38 | 67.065 | 2.469 | 869.9 | 738.74 | 12.199 | 1.403 |
| 6 | 893.04 | 99.331 | 0.189 | 898.83 | 891.11 | 0.008 | -0.002 |
| 7 | 954.76 | 98.155 | 1.761 | 1001.06 | 898.83 | 0.404 | 0.373 |
| 8 | 1049.28 | 99.496 | 0.352 | 1107.14 | 1001.06 | 0.144 | 0.077 |
| 9 | 1192.01 | 99.637 | 0.304 | 1215.15 | 1159.22 | 0.049 | 0.034 |
| 10 | 1305.81 | 99.706 | 0.281 | 1323.17 | 1292.31 | 0.019 | 0.019 |
| 11 | 1388.75 | 98.555 | 0.506 | 1398.39 | 1367.53 | 0.131 | 0.03 |
| 12 | 1446.61 | 96.548 | 1.321 | 1467.83 | 1429.25 | 0.464 | 0.108 |
| 13 | 1487.12 | 97.717 | 1.003 | 1517.98 | 1467.83 | 0.399 | 0.152 |
| 14 | 1606.7 | 96.571 | 1.446 | 1625.99 | 1566.2 | 0.653 | 0.254 |
| 15 | 1635.64 | 96.92 | 1.103 | 1656.85 | 1625.99 | 0.278 | 0.079 |
| 16 | 1672.28 | 98.288 | 1.668 | 1705.07 | 1656.85 | 0.172 | 0.169 |
| 17 | 1730.15 | 98.687 | 1.175 | 1747.51 | 1705.07 | 0.13 | 0.11 |
| 18 | 2218.14 | 99.519 | 0.54 | 2264.43 | 2140.99 | 0.113 | 0.139 |
| 19 | 2355.08 | 94.07 | 4.2 | 2378.23 | 2337.72 | 0.598 | 0.331 |
| 20 | 2393.66 | 99.497 | 0.613 | 2420.66 | 2378.23 | 0.041 | 0.058 |
| 21 | 3199.91 | 99.135 | 1.054 | 3209.55 | 3124.68 | 0.132 | 0.189 |
| 22 | 3439.08 | 94.427 | 0.309 | 3454.51 | 3419.79 | 0.835 | 0.021 |

**Ag/TiO₂**



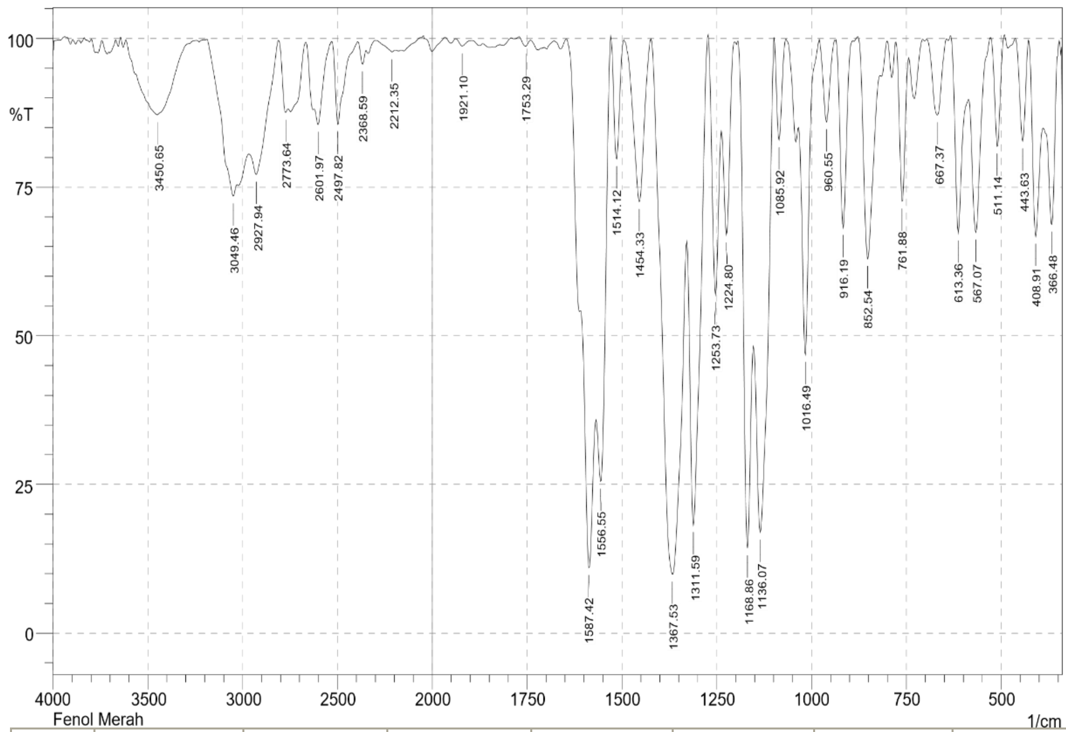

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 354.9 | 29.754 | 66.876 | 368.4 | 343.33 | 6.187 | 5.814 |
| 2 | 536.21 | 2.414 | 0.083 | 609.51 | 526.57 | 132.148 | 0.893 |
| 3 | 671.23 | 2.103 | 17.573 | 956.69 | 611.43 | 333.132 | 78.807 |
| 4 | 970.19 | 98.825 | 1.476 | 1008.77 | 956.69 | 0.076 | 0.15 |
| 5 | 1099.43 | 98.734 | 0.919 | 1128.36 | 1058.92 | 0.193 | 0.096 |
| 6 | 1184.29 | 98.194 | 0.005 | 1193.94 | 1182.36 | 0.091 | 0 |
| 7 | 1269.16 | 98.882 | 0.903 | 1298.09 | 1246.02 | 0.136 | 0.078 |
| 8 | 1413.82 | 97.967 | 0.153 | 1415.75 | 1404.18 | 0.096 | 0.008 |
| 9 | 1625.99 | 93.693 | 0.223 | 1627.92 | 1575.84 | 0.862 | 0.019 |
| 10 | 2358.94 | 95.002 | 2.279 | 2418.74 | 2341.58 | 0.715 | 0.081 |
| 11 | 2756.28 | 99.237 | 0.166 | 2831.5 | 2742.78 | 0.177 | 0.019 |
| 12 | 2929.87 | 99.03 | 0.285 | 2947.23 | 2904.8 | 0.154 | 0.028 |
| 13 | 3448.72 | 75.231 | 0.789 | 3458.37 | 2983.88 | 25.106 | 0.372 |

Titan kuning



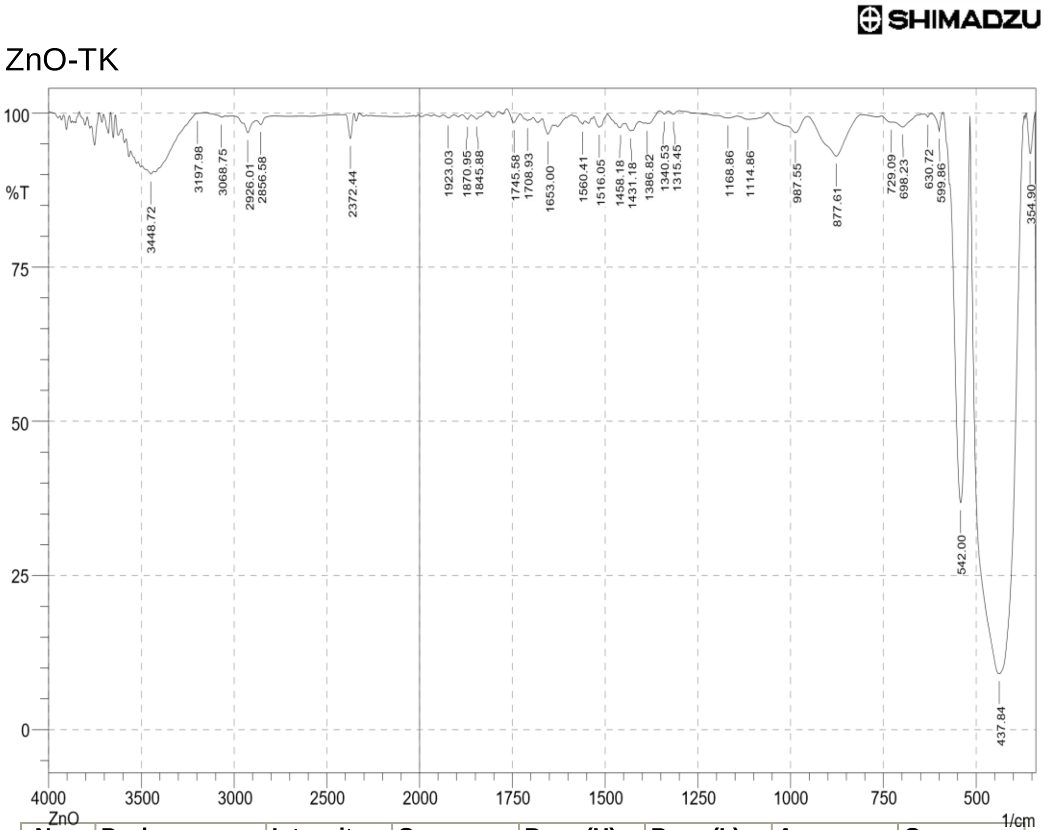

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 364.55 | 57.18 | 24.31 | 376.12 | 345.26 | 3.6 | 1.4 |
| 2 | 383.83 | 69.11 | 3.33 | 426.27 | 378.05 | 5.51 | 0.37 |
| 3 | 478.35 | 96.01 | 1.24 | 486.06 | 453.27 | 0.36 | 0.09 |
| 4 | 553.57 | 85.7 | 10.63 | 567.07 | 522.71 | 1.48 | 0.97 |
| 5 | 648.08 | 46.29 | 53.32 | 694.37 | 592.15 | 10.55 | 10.37 |
| 6 | 715.59 | 96.61 | 2.98 | 731.02 | 694.37 | 0.29 | 0.23 |
| 7 | 750.31 | 91.4 | 8.34 | 767.67 | 731.02 | 0.71 | 0.67 |
| 8 | 825.53 | 69.72 | 30.09 | 869.9 | 781.17 | 5.57 | 5.5 |
| 9 | 927.76 | 94.45 | 5.43 | 941.26 | 910.4 | 0.41 | 0.4 |
| 10 | 987.55 | 74.59 | 24.41 | 1001.06 | 970.19 | 1.99 | 1.86 |
| 11 | 1047.35 | 37.2 | 57.48 | 1068.56 | 1024.2 | 8.37 | 7.18 |
| 12 | 1116.78 | 90.4 | 9.46 | 1134.14 | 1087.85 | 1.07 | 1.06 |
| 13 | 1195.87 | 29.29 | 39.14 | 1228.66 | 1136.07 | 33.31 | 20.1 |
| 14 | 1246.02 | 44.61 | 19.69 | 1288.45 | 1230.58 | 11.56 | 3.3 |
| 15 | 1307.74 | 86.31 | 13.71 | 1328.95 | 1290.38 | 1.2 | 1.2 |
| 16 | 1400.32 | 63.27 | 13.23 | 1413.82 | 1355.96 | 6.56 | 2.26 |
| 17 | 1433.11 | 60.55 | 22.39 | 1454.33 | 1415.75 | 5.9 | 2.64 |
| 18 | 1477.47 | 52.37 | 47.82 | 1516.05 | 1456.26 | 5.98 | 6.04 |
| 19 | 1531.48 | 84.52 | 15.48 | 1546.91 | 1517.98 | 1.05 | 1.05 |
| 20 | 1570.06 | 86.13 | 7.03 | 1585.49 | 1548.84 | 1.78 | 0.83 |
| 21 | 1604.77 | 61.26 | 32.69 | 1624.06 | 1587.42 | 4.09 | 3.07 |
| 22 | 1658.78 | 90.9 | 9.11 | 1697.36 | 1625.99 | 1.59 | 1.59 |
| 27 | 2362.8 | 90.9 | 5.13 | 2391.73 | 2347.37 | 1.04 | 0.42 |
| 24 | 3450.65 | 41.73 | 57.84 | 3680.18 | 3101.54 | 116.21 | 115.27 |

Fenol Merah




| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 366.48 | 68.74 | 24.32 | 389.62 | 349.12 | 3.63 | 2.19 |
| 2 | 408.91 | 66.73 | 25.4 | 426.27 | 391.55 | 3.68 | 2.33 |
| 3 | 443.63 | 82.75 | 17.11 | 462.92 | 428.2 | 1.35 | 1.33 |
| 4 | 511.14 | 81.87 | 18.28 | 526.57 | 493.78 | 1.35 | 1.37 |
| 5 | 567.07 | 67.39 | 25.42 | 584.43 | 528.5 | 4.23 | 2.95 |
| 6 | 613.36 | 67.26 | 28.68 | 632.65 | 586.36 | 3.85 | 2.76 |
| 7 | 667.37 | 87.14 | 12.73 | 696.3 | 646.15 | 1.52 | 1.49 |
| 8 | 761.88 | 72.64 | 25.54 | 777.31 | 744.52 | 2.29 | 2 |
| 9 | 852.54 | 62.94 | 34.52 | 877.61 | 819.75 | 5.58 | 4.79 |
| 10 | 916.19 | 68.21 | 31.5 | 935.48 | 893.04 | 2.97 | 2.92 |
| 11 | 960.55 | 85.96 | 13.83 | 979.84 | 939.33 | 1.26 | 1.22 |
| 12 | 1016.49 | 46.82 | 43.04 | 1033.85 | 981.77 | 6.39 | 4.56 |
| 13 | 1085.92 | 82.93 | 16.58 | 1097.5 | 1068.56 | 1.2 | 1.15 |
| 14 | 1136.07 | 16.91 | 46.15 | 1151.5 | 1099.43 | 21.66 | 13.56 |
| 15 | 1168.86 | 14.32 | 53.45 | 1193.94 | 1153.43 | 16.09 | 9.4 |
| 16 | 1224.8 | 66.94 | 22.45 | 1236.37 | 1203.58 | 3.02 | 1.81 |
| 17 | 1253.73 | 56.89 | 34.73 | 1273.02 | 1238.3 | 4.67 | 3.36 |
| 18 | 1311.59 | 18.21 | 58.69 | 1328.95 | 1274.95 | 18.7 | 14 |
| 19 | 1367.53 | 9.91 | 69.03 | 1423.47 | 1330.88 | 43.79 | 35 |
| 20 | 1454.33 | 72.53 | 27.18 | 1494.83 | 1425.4 | 4.18 | 4.09 |
| 21 | 1514.12 | 79.78 | 19.8 | 1527.62 | 1496.76 | 1.56 | 1.51 |
| 22 | 1556.55 | 25.52 | 29.68 | 1568.13 | 1529.55 | 12.9 | 4.86 |
| 23 | 1587.42 | 11.02 | 32.85 | 1608.63 | 1570.06 | 23.28 | 9.28 |
| 24 | 2497.82 | 85.53 | 13.97 | 2530.61 | 2393.66 | 3.58 | 3.28 |
| 25 | 2773.64 | 87.57 | 3.37 | 2810.28 | 2762.06 | 1.74 | 0.38 |
| 26 | 2927.94 | 77.16 | 8.2 | 2966.52 | 2812.21 | 10.64 | 3.39 |
| 27 | 3049.46 | 73.49 | 4.66 | 3186.4 | 3032.1 | 11.19 | 1.62 |
| 28 | 3450.65 | 87.18 | 8.89 | 3564.45 | 3246.2 | 10.67 | 6.28 |

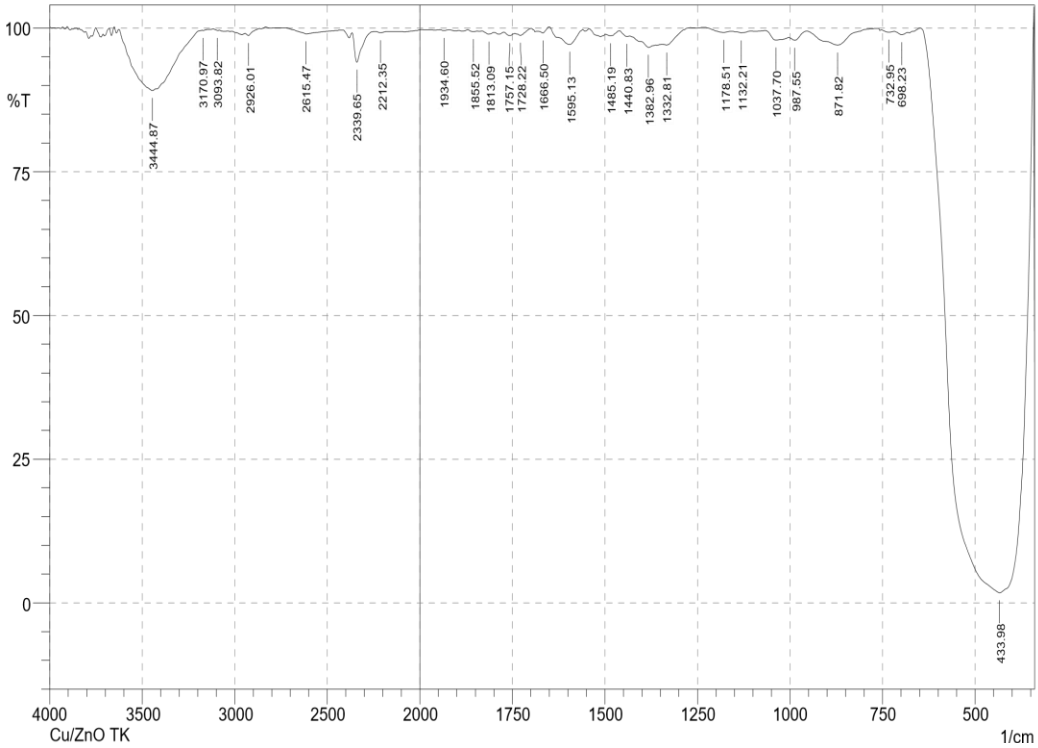
ZnO-TK




ZnO

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 354.9 | 93.42 | 6.549 | 366.48 | 341.4 | 0.363 | 0.359 |
| 2 | 437.84 | 9.064 | 90.303 | 516.92 | 372.26 | 87.673 | 87.281 |
| 3 | 542 | 36.781 | 59.075 | 588.29 | 518.85 | 13.272 | 12.277 |
| 4 | 599.86 | 97.069 | 2.991 | 621.08 | 590.22 | 0.133 | 0.136 |
| 5 | 630.72 | 99.313 | 0.573 | 640.37 | 621.08 | 0.026 | 0.016 |
| 6 | 698.23 | 97.734 | 1.178 | 723.31 | 640.37 | 0.443 | 0.144 |
| 7 | 729.09 | 98.501 | 0.189 | 756.1 | 723.31 | 0.161 | 0.021 |
| 8 | 877.61 | 93.022 | 6.57 | 952.84 | 810.1 | 2.314 | 2.057 |
| 9 | 987.55 | 96.821 | 2.816 | 1060.85 | 954.76 | 0.818 | 0.709 |
| 10 | 1114.86 | 98.95 | 0.755 | 1143.79 | 1060.85 | 0.27 | 0.196 |
| 11 | 1168.86 | 99.162 | 0.387 | 1197.79 | 1143.79 | 0.151 | 0.046 |
| 17 | 1516.05 | 97.674 | 1.883 | 1529.55 | 1494.83 | 0.225 | 0.165 |
| 18 | 1560.41 | 98.192 | 0.695 | 1581.63 | 1554.63 | 0.139 | 0.036 |
| 19 | 1653 | 96.587 | 1.909 | 1668.43 | 1641.42 | 0.296 | 0.126 |
| 20 | 1708.93 | 98.787 | 0.172 | 1714.72 | 1703.14 | 0.057 | 0.004 |
| 21 | 1745.58 | 98.444 | 1.796 | 1764.87 | 1730.15 | 0.098 | 0.141 |
| 25 | 2372.44 | 95.871 | 4.015 | 2401.38 | 2353.16 | 0.393 | 0.366 |
| 26 | 2856.58 | 98.118 | 0.85 | 2881.65 | 2789.07 | 0.408 | 0.066 |
| 27 | 2926.01 | 96.828 | 2.183 | 3018.6 | 2881.65 | 0.881 | 0.374 |
| 28 | 3068.75 | 99.331 | 0.266 | 3091.89 | 3047.53 | 0.102 | 0.025 |
| 29 | 3197.98 | 99.916 | 0.019 | 3201.83 | 3180.62 | 0.004 | 0.001 |
| 30 | 3448.72 | 90.116 | 0.596 | 3495.01 | 3435.22 | 2.55 | 0.084 |

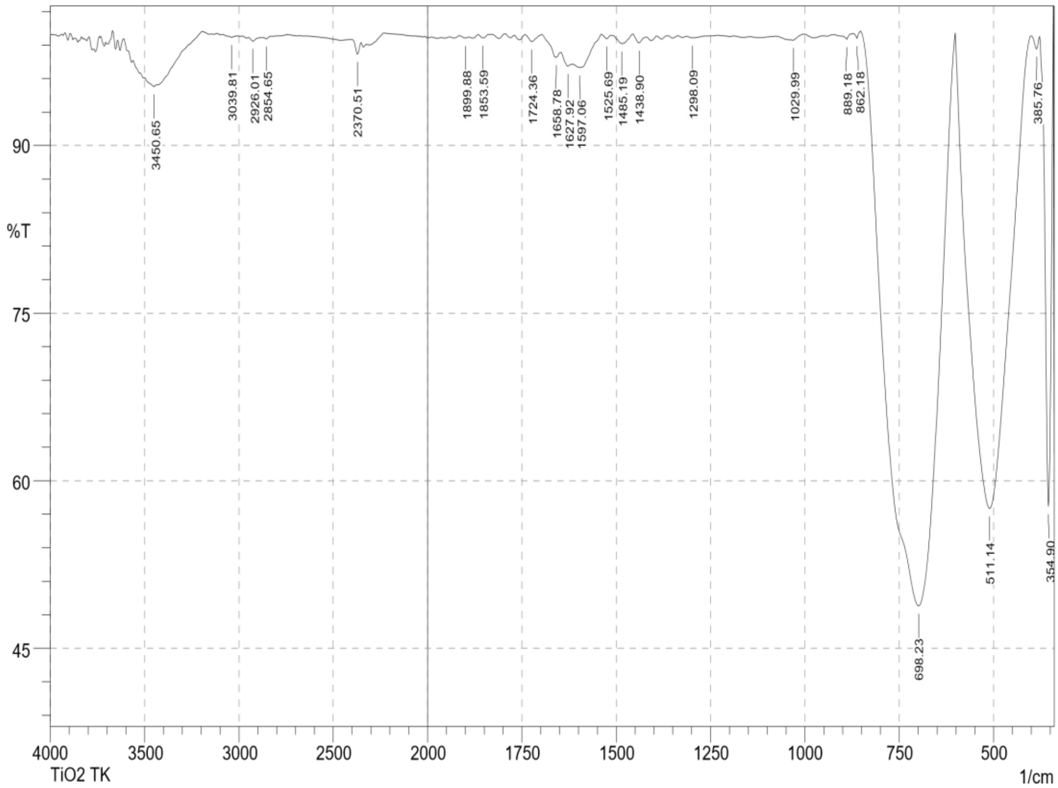
Cu/ZnO TK




| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 433.98 | 1.772 | 96.348 | 648.08 | 343.33 | 263.211 | 261.399 |
| 2 | 698.23 | 98.84 | 0.471 | 719.45 | 680.87 | 0.152 | 0.037 |
| 3 | 732.95 | 99.266 | 0.236 | 754.17 | 719.45 | 0.091 | 0.02 |
| 4 | 871.82 | 97.035 | 2.632 | 954.76 | 767.67 | 1.179 | 0.931 |
| 5 | 987.55 | 97.887 | 0.836 | 1004.91 | 954.76 | 0.324 | 0.082 |
| 6 | 1037.7 | 97.904 | 1.079 | 1066.64 | 1004.91 | 0.438 | 0.153 |
| 7 | 1132.21 | 99.141 | 0.314 | 1159.22 | 1105.21 | 0.161 | 0.032 |
| 8 | 1178.51 | 99.234 | 0.383 | 1232.51 | 1159.22 | 0.136 | 0.066 |
| 9 | 1332.81 | 97.053 | 0.653 | 1344.38 | 1288.45 | 0.479 | 0.095 |
| 10 | 1382.96 | 96.652 | 0.8 | 1433.11 | 1363.67 | 0.765 | 0.093 |
| 11 | 1440.83 | 98.532 | 0.318 | 1460.11 | 1433.11 | 0.135 | 0.023 |
| 12 | 1485.19 | 98.649 | 0.448 | 1496.76 | 1460.11 | 0.166 | 0.04 |
| 13 | 1595.13 | 97.16 | 2.741 | 1651.07 | 1560.41 | 0.658 | 0.637 |
| 14 | 1666.5 | 99.121 | 0.648 | 1680 | 1651.07 | 0.063 | 0.037 |
| 15 | 2212.35 | 99.172 | 0.21 | 2239.36 | 2154.49 | 0.255 | 0.027 |
| 16 | 2339.65 | 94.047 | 5.122 | 2364.73 | 2239.36 | 1.411 | 1 |
| 17 | 2615.47 | 98.976 | 0.926 | 2723.49 | 2420.66 | 0.775 | 0.567 |
| 18 | 2926.01 | 98.706 | 0.566 | 2945.3 | 2868.15 | 0.238 | 0.063 |
| 19 | 3444.87 | 89.132 | 10.543 | 3626.17 | 3178.69 | 12.454 | 11.796 |

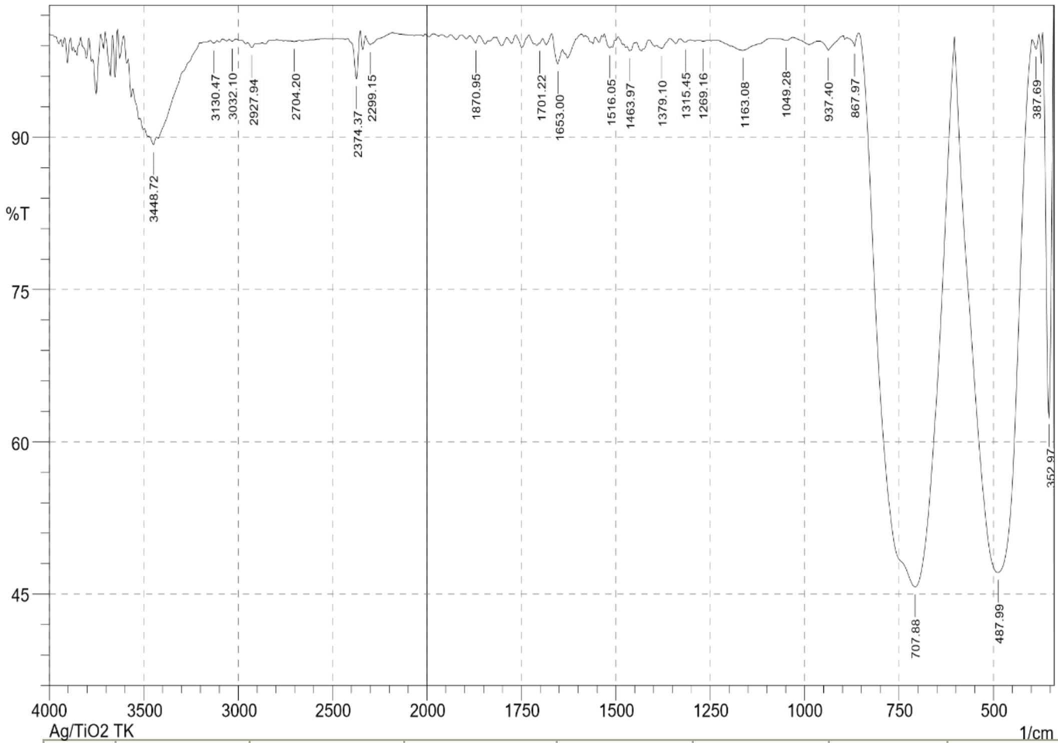
TiO2-TK

SHIMADZU



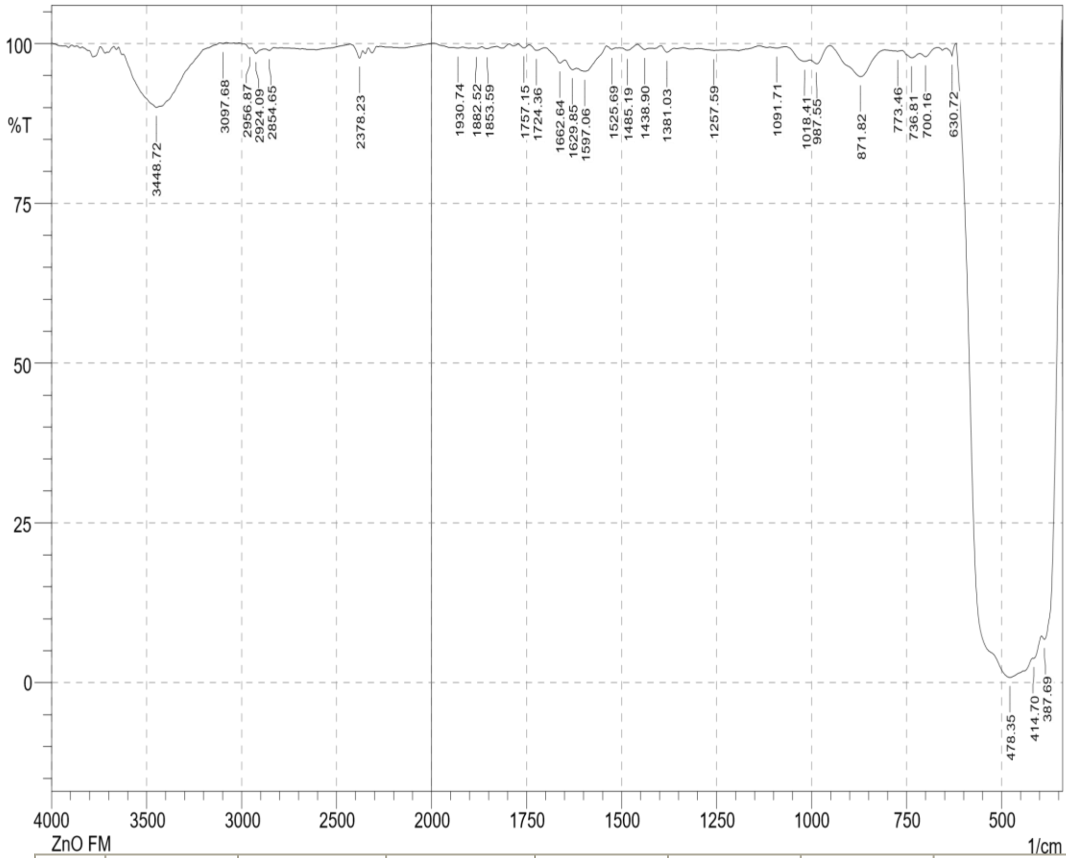

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 354.9 | 57.693 | 39.024 | 378.05 | 343.33 | 3.797 | 3.388 |
| 2 | 385.76 | 98.663 | 1.116 | 401.19 | 378.05 | 0.073 | 0.052 |
| 3 | 511.14 | 57.52 | 42.435 | 601.79 | 403.12 | 25.84 | 25.788 |
| 4 | 698.23 | 48.807 | 50.995 | 852.54 | 603.72 | 43.459 | 43.335 |
| 5 | 862.18 | 99.583 | 0.576 | 873.75 | 852.54 | 0.004 | 0.018 |
| 6 | 889.18 | 99.522 | 0.466 | 923.9 | 877.61 | 0.038 | 0.031 |
| 7 | 1029.99 | 99.428 | 0.48 | 1076.28 | 1002.98 | 0.111 | 0.073 |
| 8 | 1298.09 | 99.64 | 0.148 | 1313.52 | 1257.59 | 0.066 | 0.017 |
| 9 | 1438.9 | 99.195 | 0.681 | 1456.26 | 1419.61 | 0.073 | 0.052 |
| 10 | 1485.19 | 99.111 | 0.796 | 1506.41 | 1456.26 | 0.118 | 0.1 |
| 11 | 1525.69 | 99.565 | 0.363 | 1539.2 | 1512.19 | 0.028 | 0.019 |
| 12 | 1597.06 | 96.988 | 0.984 | 1616.35 | 1539.2 | 0.662 | 0.2 |
| 13 | 1627.92 | 97.105 | 0.591 | 1647.21 | 1616.35 | 0.34 | 0.045 |
| 14 | 1658.78 | 97.909 | 0.807 | 1697.36 | 1647.21 | 0.261 | 0.073 |
| 15 | 1724.36 | 99.307 | 0.631 | 1741.72 | 1697.36 | 0.069 | 0.058 |
| 16 | 1853.59 | 99.638 | 0.311 | 1867.09 | 1834.3 | 0.028 | 0.02 |
| 17 | 1899.88 | 99.635 | 0.131 | 1915.31 | 1890.24 | 0.031 | 0.007 |
| 18 | 2370.51 | 98.202 | 1.117 | 2399.45 | 2353.16 | 0.23 | 0.1 |
| 19 | 2854.65 | 99.568 | 0.165 | 2873.94 | 2831.5 | 0.062 | 0.014 |
| 20 | 2926.01 | 99.345 | 0.331 | 2949.16 | 2873.94 | 0.144 | 0.039 |
| 21 | 3039.81 | 99.702 | 0.164 | 3086.11 | 3010.88 | 0.066 | 0.026 |
| 22 | 3450.65 | 95.296 | 0.312 | 3500.8 | 3435.22 | 1.293 | 0.059 |

Ag/TiO2-TK



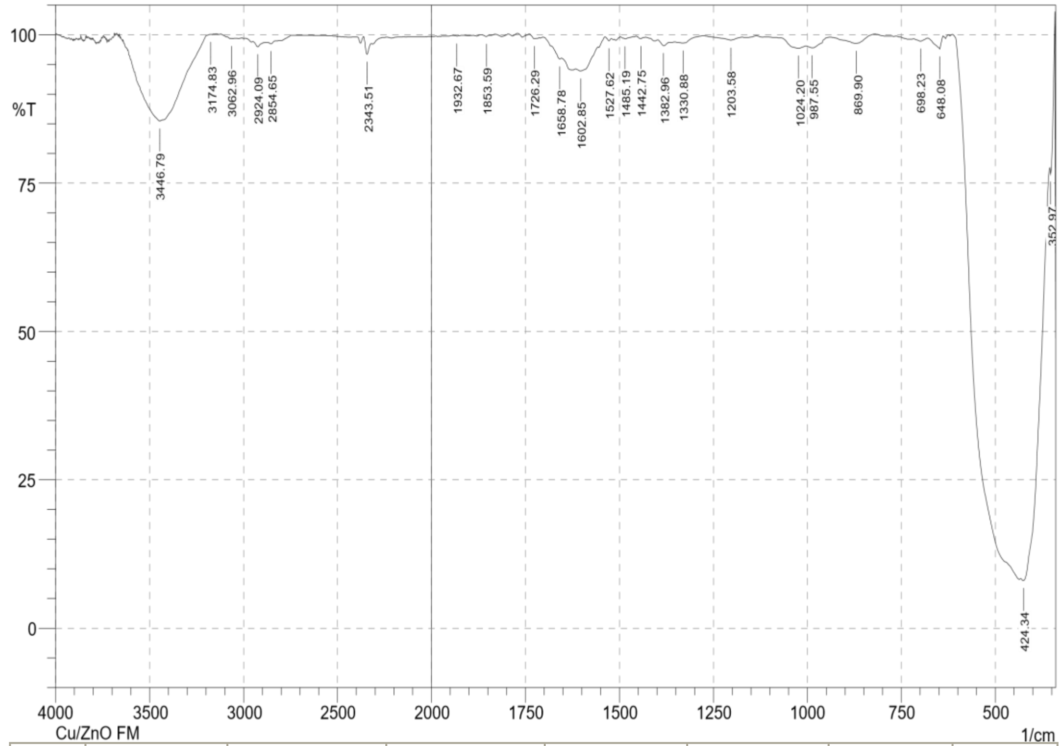

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 352.97 | 62.474 | 34.429 | 370.33 | 343.33 | 2.973 | 2.669 |
| 2 | 387.69 | 98.666 | 1.233 | 397.34 | 379.98 | 0.059 | 0.049 |
| 3 | 487.99 | 47.127 | 52.594 | 603.72 | 399.26 | 38.91 | 38.678 |
| 4 | 707.88 | 45.706 | 53.718 | 856.39 | 605.65 | 51.784 | 51.291 |
| 5 | 867.97 | 98.963 | 1.136 | 887.26 | 856.39 | 0.047 | 0.053 |
| 6 | 937.4 | 98.544 | 1.137 | 964.41 | 896.9 | 0.205 | 0.126 |
| 7 | 1049.28 | 99.533 | 0.226 | 1066.64 | 1029.99 | 0.055 | 0.018 |
| 8 | 1163.08 | 98.569 | 0.663 | 1195.87 | 1093.64 | 0.445 | 0.163 |
| 9 | 1269.16 | 99.457 | 0.081 | 1280.73 | 1255.66 | 0.054 | 0.004 |
| 10 | 1315.45 | 99.341 | 0.291 | 1330.88 | 1303.88 | 0.058 | 0.015 |
| 11 | 1379.1 | 98.757 | 0.572 | 1392.61 | 1357.89 | 0.137 | 0.046 |
| 12 | 1463.97 | 98.514 | 0.52 | 1469.76 | 1444.68 | 0.118 | 0.024 |
| 13 | 1516.05 | 98.795 | 0.418 | 1529.55 | 1512.19 | 0.062 | 0.028 |
| 14 | 1653 | 97.246 | 1.992 | 1670.35 | 1641.42 | 0.206 | 0.13 |
| 15 | 1701.22 | 99.256 | 0.108 | 1703.14 | 1693.5 | 0.022 | 0.002 |
| 16 | 1870.95 | 99.301 | 0.701 | 1886.38 | 1861.31 | 0.034 | 0.034 |
| 17 | 2299.15 | 99.145 | 0.907 | 2326.15 | 2185.35 | 0.175 | 0.269 |
| 18 | 2374.37 | 95.759 | 4.475 | 2416.81 | 2353.16 | 0.449 | 0.477 |
| 19 | 2704.2 | 99.441 | 0.07 | 2725.42 | 2677.2 | 0.111 | 0.009 |
| 20 | 2927.94 | 98.842 | 0.437 | 2949.16 | 2906.73 | 0.173 | 0.039 |
| 21 | 3032.1 | 99.461 | 0.188 | 3047.53 | 3010.88 | 0.069 | 0.014 |
| 22 | 3130.47 | 99.269 | 0.248 | 3147.83 | 3111.18 | 0.098 | 0.021 |
| 23 | 3448.72 | 89.267 | 0.934 | 3496.94 | 3433.29 | 2.931 | 0.145 |

ZnO-FM



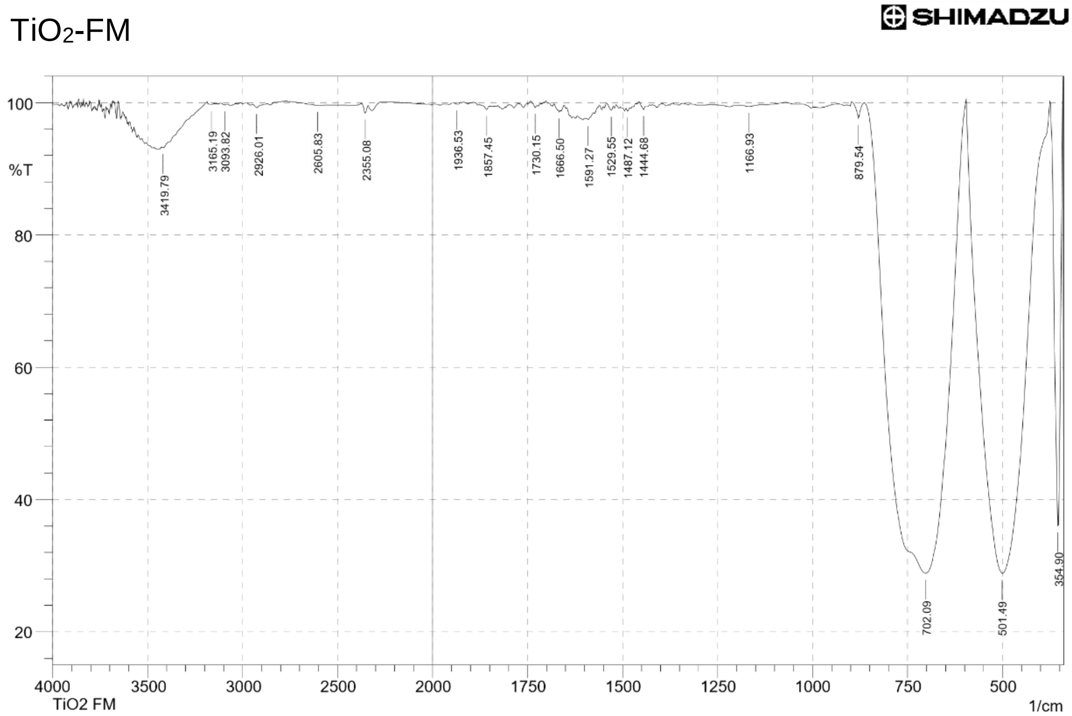

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 387.69 | 6.774 | 13.805 | 395.41 | 343.33 | 36.831 | 8.008 |
| 2 | 414.7 | 3.795 | 0.649 | 418.55 | 397.34 | 27.706 | 0.839 |
| 3 | 478.35 | 0.835 | 31.678 | 619.15 | 418.55 | 248.936 | 106.063 |
| 4 | 630.72 | 98.058 | 1.672 | 646.15 | 619.15 | 0.104 | 0.065 |
| 5 | 700.16 | 97.962 | 0.804 | 715.59 | 667.37 | 0.292 | 0.067 |
| 6 | 736.81 | 97.78 | 0.893 | 761.88 | 715.59 | 0.364 | 0.099 |
| 7 | 773.46 | 98.819 | 0.127 | 808.17 | 761.88 | 0.223 | 0.016 |
| 8 | 871.82 | 94.838 | 4.488 | 950.91 | 808.17 | 1.834 | 1.433 |
| 9 | 987.55 | 96.857 | 1.345 | 1004.91 | 952.84 | 0.476 | 0.15 |
| 10 | 1018.41 | 97.219 | 0.67 | 1068.56 | 1004.91 | 0.521 | 0.096 |
| 11 | 1091.71 | 99.307 | 0.162 | 1109.07 | 1068.56 | 0.106 | 0.013 |
| 12 | 1257.59 | 98.921 | 0.208 | 1298.09 | 1217.08 | 0.34 | 0.032 |
| 18 | 1629.85 | 95.919 | 0.69 | 1649.14 | 1618.28 | 0.491 | 0.052 |
| 19 | 1662.64 | 97.001 | 0.935 | 1701.22 | 1649.14 | 0.445 | 0.079 |
| 25 | 2378.23 | 97.728 | 1.407 | 2426.45 | 2362.8 | 0.311 | 0.146 |
| 30 | 3448.72 | 90.024 | 8.938 | 3624.25 | 3113.11 | 12.016 | 10.309 |

Cu/ZnO-FM



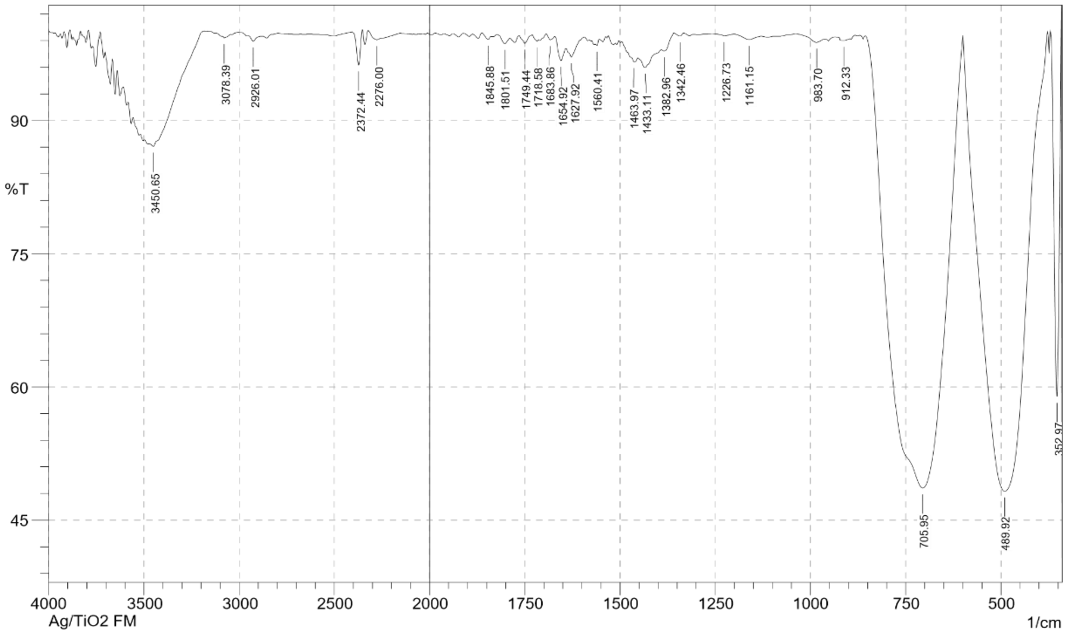

| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 352.97 | 76.506 | 4.877 | 354.9 | 341.4 | 0.956 | 0.326 |
| 2 | 424.34 | 8.013 | 7.423 | 432.05 | 356.83 | 46.942 | 4.153 |
| 3 | 648.08 | 97.592 | 2.126 | 678.94 | 640.37 | 0.237 | 0.171 |
| 4 | 698.23 | 98.93 | 0.433 | 717.52 | 678.94 | 0.141 | 0.034 |
| 5 | 869.9 | 98.542 | 1.356 | 941.26 | 821.68 | 0.416 | 0.336 |
| 6 | 987.55 | 97.78 | 0.721 | 1004.91 | 941.26 | 0.425 | 0.101 |
| 7 | 1024.2 | 97.743 | 0.648 | 1107.14 | 1004.91 | 0.562 | 0.059 |
| 8 | 1602.85 | 93.897 | 1.204 | 1616.35 | 1558.48 | 1.246 | 0.25 |
| 10 | 1658.78 | 95.909 | 0.573 | 1681.93 | 1653 | 0.397 | 0.027 |
| 11 | 1726.29 | 99.328 | 0.266 | 1741.72 | 1720.5 | 0.031 | 0.009 |
| 12 | 1853.59 | 99.726 | 0.235 | 1867.09 | 1843.95 | 0.013 | 0.01 |
| 13 | 1932.67 | 99.775 | 0.111 | 1944.25 | 1915.31 | 0.019 | 0.006 |
| 14 | 2343.51 | 96.723 | 2.459 | 2362.8 | 2320.37 | 0.376 | 0.214 |
| 15 | 3446.79 | 85.484 | 1.041 | 3641.6 | 3433.29 | 8.9 | 1.44 |

TiO2-FM




| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 354.9 | 36.027 | 60.145 | 374.19 | 343.33 | 6.591 | 6.137 |
| 2 | 501.49 | 28.815 | 71.515 | 596 | 376.12 | 59.779 | 60.078 |
| 3 | 702.09 | 28.862 | 71.39 | 864.11 | 596 | 82.736 | 82.976 |
| 4 | 879.54 | 97.594 | 2.467 | 898.83 | 864.11 | 0.115 | 0.126 |
| 5 | 1166.93 | 99.415 | 0.243 | 1193.94 | 1134.14 | 0.118 | 0.031 |
| 6 | 1444.68 | 98.937 | 0.658 | 1456.26 | 1440.83 | 0.038 | 0.024 |
| 7 | 1487.12 | 98.719 | 0.469 | 1490.97 | 1481.33 | 0.044 | 0.011 |
| 8 | 1529.55 | 98.828 | 0.808 | 1543.05 | 1523.76 | 0.055 | 0.032 |
| 9 | 1591.27 | 97.406 | 0.548 | 1600.92 | 1575.84 | 0.244 | 0.03 |
| 10 | 1666.5 | 98.581 | 0.378 | 1680 | 1664.57 | 0.063 | 0.019 |
| 11 | 1730.15 | 99.269 | 0.544 | 1741.72 | 1724.36 | 0.025 | 0.019 |
| 12 | 1857.45 | 98.944 | 0.568 | 1869.02 | 1847.81 | 0.064 | 0.02 |
| 13 | 1936.53 | 99.77 | 0.027 | 1946.18 | 1934.6 | 0.007 | -0.001 |
| 14 | 2355.08 | 98.434 | 1.26 | 2374.37 | 2339.65 | 0.132 | 0.089 |
| 15 | 2605.83 | 99.552 | 0.166 | 2681.05 | 2565.33 | 0.161 | 0.041 |
| 16 | 2926.01 | 99.241 | 0.51 | 2947.23 | 2870.08 | 0.139 | 0.062 |
| 17 | 3093.82 | 99.653 | 0.161 | 3116.97 | 3082.25 | 0.037 | 0.013 |
| 18 | 3165.19 | 99.71 | 0.109 | 3182.55 | 3151.69 | 0.031 | 0.007 |
| 19 | 3419.79 | 93.168 | 0.24 | 3425.58 | 3188.33 | 3.491 | 0.071 |

Ag/$TiO_2$-FM




| No. | Peak | Intensity | Corr. Intensity | Base (H) | Base (L) | Area | Corr. Area |
|---|---|---|---|---|---|---|---|
| 1 | 352.97 | 58.905 | 37.562 | 370.33 | 343.33 | 3.235 | 2.882 |
| 2 | 489.92 | 48.259 | 51.335 | 599.86 | 379.98 | 38.099 | 37.709 |
| 3 | 705.95 | 48.618 | 50.497 | 856.39 | 601.79 | 47.569 | 46.654 |
| 4 | 912.33 | 99.007 | 0.276 | 935.48 | 896.9 | 0.141 | 0.023 |
| 5 | 983.7 | 98.799 | 0.541 | 1037.7 | 962.48 | 0.242 | 0.069 |
| 6 | 1161.15 | 99.112 | 0.5 | 1199.72 | 1130.29 | 0.188 | 0.074 |
| 7 | 1226.73 | 99.538 | 0.218 | 1259.52 | 1199.72 | 0.085 | 0.023 |
| 8 | 1342.46 | 99.502 | 0.357 | 1357.89 | 1332.81 | 0.036 | 0.021 |
| 9 | 1382.96 | 97.828 | 0.679 | 1392.61 | 1357.89 | 0.215 | 0.051 |
| 10 | 1433.11 | 95.988 | 1.36 | 1452.4 | 1392.61 | 0.814 | 0.16 |
| 11 | 1463.97 | 96.627 | 0.126 | 1471.69 | 1462.04 | 0.133 | 0.001 |
| 12 | 1560.41 | 98.443 | 0.381 | 1564.27 | 1554.63 | 0.054 | 0.007 |
| 13 | 1627.92 | 97.143 | 1.347 | 1641.42 | 1595.13 | 0.362 | 0.11 |
| 14 | 1654.92 | 96.752 | 1.949 | 1672.28 | 1641.42 | 0.287 | 0.123 |
| 15 | 1683.86 | 99.077 | 0.16 | 1693.5 | 1681.93 | 0.032 | 0.004 |
| 16 | 1718.58 | 98.941 | 0.337 | 1730.15 | 1712.79 | 0.062 | 0.015 |
| 17 | 1749.44 | 98.699 | 0.84 | 1764.87 | 1737.86 | 0.107 | 0.053 |
| 18 | 1801.51 | 98.663 | 0.759 | 1822.73 | 1789.94 | 0.127 | 0.053 |
| 19 | 1845.88 | 99.133 | 0.437 | 1863.24 | 1840.09 | 0.056 | 0.023 |
| 20 | 2276 | 99.098 | 0.971 | 2322.29 | 2156.42 | 0.388 | 0.389 |
| 21 | 2372.44 | 96.229 | 3.914 | 2407.16 | 2353.16 | 0.353 | 0.379 |
| 22 | 2926.01 | 98.938 | 0.59 | 2951.09 | 2875.86 | 0.227 | 0.07 |
| 23 | 3078.39 | 99.305 | 0.457 | 3120.82 | 3043.67 | 0.153 | 0.076 |
| 24 | 3450.65 | 87.096 | 1.458 | 3477.66 | 3184.48 | 9.195 | 0.882 |

**Lampiran 4.** Hasil Karakterisasi dengan XRD

Hkl ZnO

## Name and formula

| | |
|---|---|
| Reference code: | 00-036-1451 |
| Mineral name: | Zincite, syn |
| Common name: | chinese white |
| PDF index name: | Zinc Oxide |
| Empirical formula: | OZn |
| Chemical formula: | ZnO |

## Crystallographic parameters

| | |
|---|---|
| Crystal system: | Hexagonal |
| Space group: | P63mc |
| Space group number: | 186 |
| a (Å): | 3,2498 |
| b (Å): | 3,2498 |
| c (Å): | 5,2066 |
| Alpha (°): | 90,0000 |
| Beta (°): | 90,0000 |
| Gamma (°): | 120,0000 |
| Volume of cell (10^6 pm^3): | 47,62 |
| Z: | 2,00 |
| RIR: | - |

## Subfiles and Quality

| | |
|---|---|
| Subfiles: | Inorganic<br>Mineral<br>Alloy, metal or intermetalic<br>Common Phase<br>Educational pattern<br>Forensic<br>NBS pattern<br>Pigment/Dye |
| Quality: | Star (S) |

## Comments

| | |
|---|---|
| Color: | Colorless |
| General comments: | The structure was determined by Bragg (1) and refined by Abrahams, Bernstein (2). |
| Sample source: | The sample was obtained from the New Jersey Zinc |

| | |
|---|---|
| | Co., Bethlehem, PA, USA. |
| Optical data: | B=2.013, Q=2.029, Sign=+ |
| Polymorphism: | A high pressure cubic NaCl-type of ZnO is reported by Bates et al. (3) and a cubic, sphalerite type is reported by Radczewski, Schicht (4). |
| Additional pattern: | To replace 5-664 (5). |
| Temperature: | The approximate temperature of data collection was 26 C. |
| Powder data (additional reference): | References to other early patterns may be found in reference (5). |

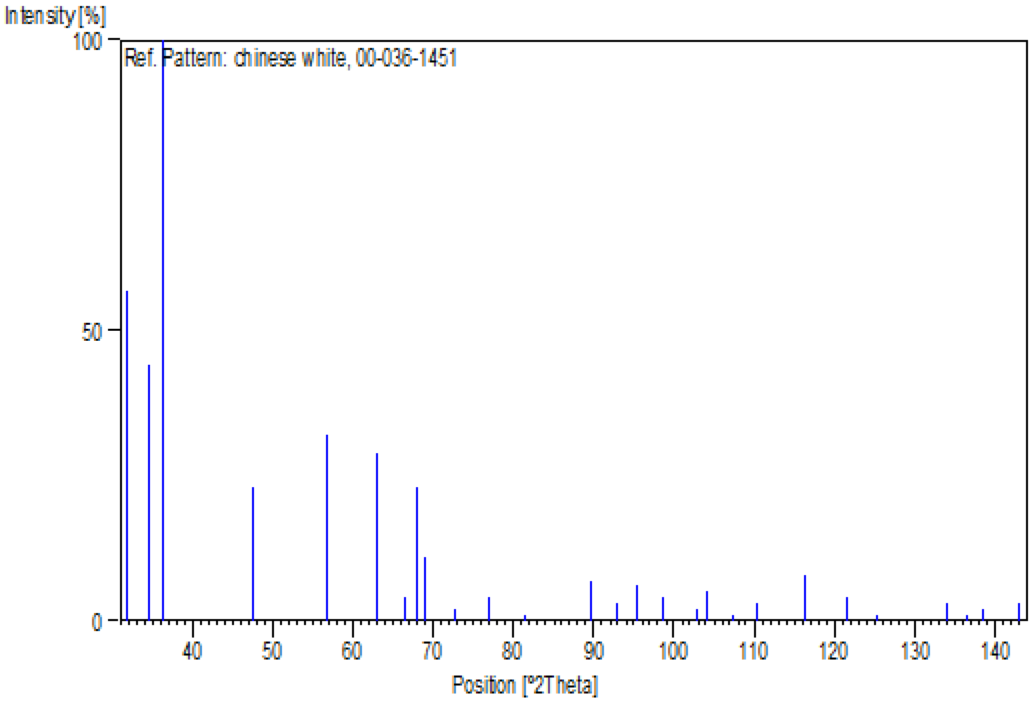
## References


| | |
|---|---|
| Primary reference: | McMurdie, H., Morris, M., Evans, E., Paretzkin, B., Wong-Ng, W., Ettlinger, L., Hubbard, C., *Powder Diffraction*, **1**, 76, (1986) |
| Structure: | 1. Bragg, W., *Philos. Mag.*, **39**, 647, (1920) |
| Optical data: | *Dana's System of Mineralogy, 7th Ed.*, **I**, 504 |
| Polymorphism: | 3. Bates, C., White, W., Roy, R., *Science*, **137**, 993, (1962) |
| Additional pattern: | 5. Swanson, H., Fuyat, R., *Natl. Bur. Stand. (U.S.), Circ. 539*, **2**, 25, (1953) |


## Peak list

| No. | h | k | l | d [A] | 2Theta[deg] | I [%] |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 2,81430 | 31,770 | 57,0 |
| 2 | 0 | 0 | 2 | 2,60332 | 34,422 | 44,0 |
| 3 | 1 | 0 | 1 | 2,47592 | 36,253 | 100,0 |
| 4 | 1 | 0 | 2 | 1,91114 | 47,539 | 23,0 |
| 5 | 1 | 1 | 0 | 1,62472 | 56,603 | 32,0 |
| 6 | 1 | 0 | 3 | 1,47712 | 62,864 | 29,0 |
| 7 | 2 | 0 | 0 | 1,40715 | 66,380 | 4,0 |
| 8 | 1 | 1 | 2 | 1,37818 | 67,963 | 23,0 |
| 9 | 2 | 0 | 1 | 1,35825 | 69,100 | 11,0 |
| 10 | 0 | 0 | 4 | 1,30174 | 72,562 | 2,0 |
| 11 | 2 | 0 | 2 | 1,23801 | 76,955 | 4,0 |
| 12 | 1 | 0 | 4 | 1,18162 | 81,370 | 1,0 |
| 13 | 2 | 0 | 3 | 1,09312 | 89,607 | 7,0 |
| 14 | 2 | 1 | 0 | 1,06384 | 92,784 | 3,0 |
| 15 | 2 | 1 | 1 | 1,04226 | 95,304 | 6,0 |
| 16 | 1 | 1 | 4 | 1,01595 | 98,613 | 4,0 |
| 17 | 2 | 1 | 2 | 0,98464 | 102,946 | 2,0 |
| 18 | 1 | 0 | 5 | 0,97663 | 104,134 | 5,0 |
| 19 | 2 | 0 | 4 | 0,95561 | 107,430 | 1,0 |
| 20 | 3 | 0 | 0 | 0,93812 | 110,392 | 3,0 |
| 21 | 2 | 1 | 3 | 0,90694 | 116,279 | 8,0 |
| 22 | 3 | 0 | 2 | 0,88256 | 121,572 | 4,0 |
| 23 | 0 | 0 | 6 | 0,86768 | 125,188 | 1,0 |
| 24 | 2 | 0 | 5 | 0,83703 | 133,932 | 3,0 |
| 25 | 1 | 0 | 6 | 0,82928 | 136,521 | 1,0 |
| 26 | 2 | 1 | 4 | 0,82370 | 138,513 | 2,0 |
| 27 | 2 | 2 | 0 | 0,81247 | 142,918 | 3,0 |

**Stick Pattern**



Hkl $TiO_2$

## Name and formula

| | |
|---|---|
| Reference code: | 01-075-1537 |
| Mineral name: | Anatase |
| ICSD name: | Titanium Oxide |
| Empirical formula: | $O_2Ti$ |
| Chemical formula: | $TiO_2$ |

## Crystallographic parameters

| | |
|---|---|
| Crystal system: | Tetragonal |
| Space group: | I41/amd |
| Space group number: | 141 |
| a (Å): | 3,7300 |
| b (Å): | 3,7300 |
| c (Å): | 9,3700 |
| Alpha (°): | 90,0000 |
| Beta (°): | 90,0000 |
| Gamma (°): | 90,0000 |
| Calculated density (g/cm^3): | 4,07 |
| Volume of cell (10^6 pm^3): | 130,36 |
| Z: | 4,00 |
| RIR: | 5,20 |

## Subfiles and Quality

| | |
|---|---|
| Subfiles: | Inorganic<br>Mineral<br>Alloy, metal or intermetalic<br>Corrosion<br>Modelled additional pattern |
| Quality: | Calculated (C) |

## Comments

| | |
|---|---|
| ICSD collection code: | 031064 |
| Test from ICSD: | No R value given.<br>At least one TF missing. |

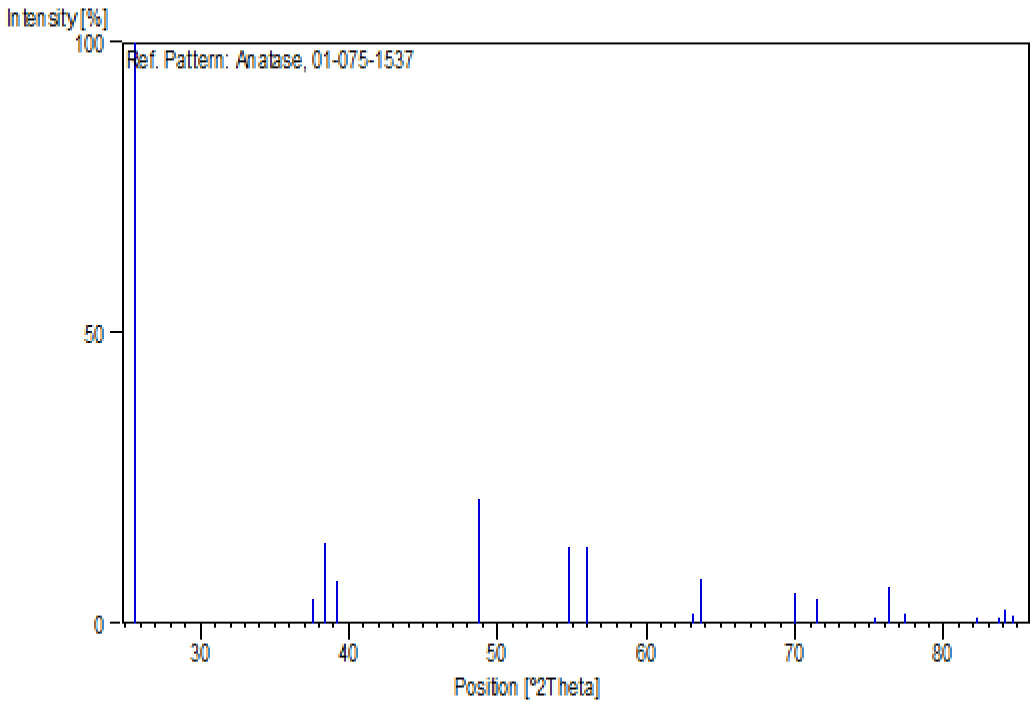
## References

| | |
|---|---|
| Primary reference: | *Calculated from ICSD using POWD-12++*, (1997) |
| Structure: | Parker, R.L., *Z. Kristallogr., Kristallgeom., Kristallphys., Kristallchem.*, **59**, 1, (1924) |

## Peak list

| No. | h | k | l | d [A] | 2Theta[deg] | I [%] |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 1 | 3,46551 | 25,686 | 100,0 |
| 2 | 1 | 0 | 3 | 2,39467 | 37,528 | 4,2 |
| 3 | 0 | 0 | 4 | 2,34250 | 38,396 | 13,8 |
| 4 | 1 | 1 | 2 | 2,29833 | 39,164 | 7,3 |
| 5 | 2 | 0 | 0 | 1,86500 | 48,791 | 21,4 |
| 6 | 1 | 0 | 5 | 1,67454 | 54,775 | 13,2 |
| 7 | 2 | 1 | 1 | 1,64228 | 55,944 | 13,2 |
| 8 | 2 | 1 | 3 | 1,47140 | 63,137 | 1,7 |
| 9 | 2 | 0 | 4 | 1,45905 | 63,734 | 7,6 |
| 10 | 1 | 1 | 6 | 1,34378 | 69,952 | 5,1 |
| 11 | 2 | 2 | 0 | 1,31875 | 71,481 | 4,1 |
| 12 | 1 | 0 | 7 | 1,25990 | 75,381 | 0,5 |
| 13 | 2 | 1 | 5 | 1,24599 | 76,373 | 6,2 |
| 14 | 3 | 0 | 1 | 1,23253 | 77,361 | 1,7 |
| 15 | 0 | 0 | 8 | 1,17125 | 82,245 | 0,2 |
| 16 | 3 | 0 | 3 | 1,15517 | 83,645 | 0,3 |
| 17 | 2 | 2 | 4 | 1,14916 | 84,183 | 2,5 |
| 18 | 3 | 1 | 2 | 1,14383 | 84,666 | 1,2 |

## Stick Pattern



**Ukuran kristal ZnO**

| Posisi Puncak 2θ | FWHM (rad) | Ukuran Kristal D (nm) | Ukuran rata-rata kristal D (nm) |
|---|---|---|---|
| 31,842 | 0,269 | 30,673 | 30,224 |
| 34,496 | 0,259 | 32,038 | |
| 36,330 | 0,254 | 32,830 | |
| 47,621 | 0,241 | 35,972 | |
| 56,680 | 0,271 | 33,220 | |
| 62,945 | 0,277 | 33,518 | |
| 66,454 | 0,246 | 38,460 | |
| 68,033 | 0,296 | 32,353 | |
| 69,167 | 0,291 | 33,112 | |

**Ukuran kristal Cu/ZnO**

| Posisi Puncak 2θ | FWHM (rad) | Ukuran Kristal D (nm) | Ukuran rata-rata kristal D (nm) |
|---|---|---|---|
| 28,680 | 0,356 | 23,031 | 16,285 |
| 28,680 | 123,639 | 0,066 | |
| 31,838 | 0,344 | 23,954 | |
| 33,234 | 5,721 | 1,448 | |
| 34,500 | 0,319 | 25,999 | |
| 36,326 | 0,371 | 22,512 | |
| 45,367 | 74,634 | 0,115 | |
| 56,664 | 0,464 | 19,425 | |
| 62,957 | 0,429 | 21,704 | |
| 68,053 | 0,475 | 20,178 | |
| 69,176 | 0,465 | 20,708 | |

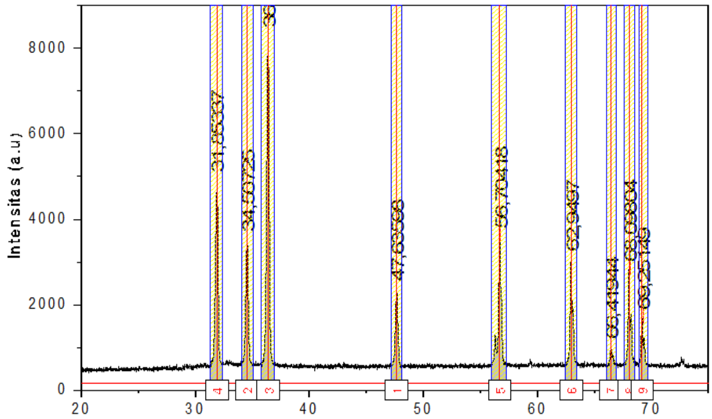
**Ukuran kristal $TiO_2$**

| Posisi Puncak 2θ | FWHM (rad) | Ukuran Kristal D (nm) | Ukuran rata-rata kristal D (nm) |
|---|---|---|---|
| 25,362 | 0,295 | 27,559 | 32,492 |
| 37,021 | 0,233 | 35,812 | |
| 37,865 | 0,249 | 33,683 | |
| 38,638 | 0,257 | 32,682 | |
| 48,126 | 0,280 | 30,989 | |
| 53,972 | 0,267 | 33,355 | |
| 55,145 | 0,263 | 34,058 | |
| 62,197 | 0,288 | 32,188 | |
| 62,768 | 0,275 | 33,748 | |
| 68,841 | 0,299 | 32,128 | |
| 70,367 | 0,291 | 33,289 | |
| 75,126 | 0,329 | 30,416 | |

**Ukuran kristal $Ag/TiO_2$**

| Posisi Puncak 2θ | FWHM (rad) | Ukuran Kristal D (nm) | Ukuran rata-rata kristal D (nm) |
|---|---|---|---|
| 25,812 | 0,831 | 9,804 | 28,723 |
| 38,059 | 0,529 | 15,859 | |
| 43,410 | 0,367 | 23,238 | |
| 48,165 | 0,342 | 25,399 | |
| 54,015 | 0,323 | 27,534 | |
| 55,179 | 0,214 | 41,821 | |
| 62,979 | 0,214 | 43,462 | |
| 64,412 | 0,214 | 43,744 | |
| 75,396 | 0,363 | 27,647 | |

## Derajat Kristalinitas ZnO




| Index | Area | AreaIntgP(%) | Row Index | Beginning X | Ending X | FWHM | Center | Height |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" |
| | | | | | | | | |
| 1 | 1618,43226 | 4,9811 | 2687 | 31,28 | 32,3 | 0,27871 | 31,86 | 4663,192 |
| 2 | 1267,55285 | 3,90119 | 2953 | 33,88 | 35,03 | 0,27532 | 34,52 | 3335,61932 |
| 3 | 2469,73704 | 7,60119 | 3135 | 35,79 | 36,79 | 0,25733 | 36,34 | 8054,98151 |
| 4 | 775,52073 | 2,38684 | 4262 | 47,19 | 48,01 | 0,27913 | 47,61 | 2197,60486 |
| 5 | 1378,13798 | 4,24154 | 5167 | 55,96 | 57,14 | 0,29185 | 56,66 | 3356,34709 |
| 6 | 1094,97622 | 3,37004 | 5792 | 62,37 | 63,47 | 0,31001 | 62,91 | 2884,48689 |
| 7 | 356,11126 | 1,09601 | 6144 | 66,16 | 66,8 | 0,62245 | 66,43 | 808,67753 |
| 8 | 1014,17816 | 3,12137 | 6301 | 67,55 | 68,62 | 0,32322 | 68 | 2598,49169 |
| 9 | 603,00643 | 1,85589 | 6414 | 68,77 | 69,57 | 0,38385 | 69,13 | 1500,54246 |

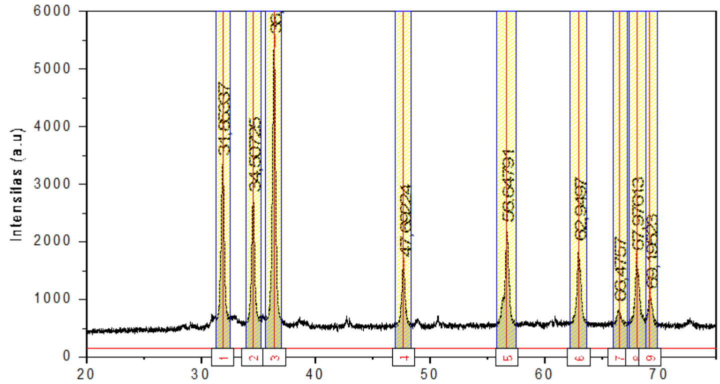
| **Area Puncak Kristalin 2θ** | **Fraksi Luas Kristalin** | **Luas Difraktogram** |
|---|---|---|
| 1618,432 | 10577,652 | 18491,470 |
| 1267,552 | | |
| 2469,737 | | |
| 775,520 | | |
| 1378,137 | | |
| 1094,976 | | |
| 356,111 | | |
| 1014,178 | | |
| 603,006 | | |

$$\text{Kristalinitas} = \frac{\text{Fraksi luas kristalin}}{\text{Luas difragtogram}} \text{ x } 100$$

$$= \frac{10577{,}652}{18491{,}470}\, x\ 100$$

= 57,20%.

## Derajat Kristalinitas Cu/ ZnO




| Index | Area | AreaIntgP(%) | Row Index | Beginning X | Ending X | FWHM | Center | Height |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" |
| | | | | | | | | |
| 1 | 2264,57928 | 7,62388 | 2808 | 30,57 | 33,51 | 0,34163 | 31,85 | 3141,90938 |
| 2 | 1331,39194 | 4,48223 | 2951 | 33,71 | 35,17 | 0,33423 | 34,5 | 2568,63628 |
| 3 | 2423,69334 | 8,15955 | 3134 | 35,58 | 37,32 | 0,32639 | 36,33 | 5175,78238 |
| 4 | 880,4783 | 2,9642 | 4264 | 46,88 | 48,28 | 0,41999 | 47,63 | 1389,24231 |
| 5 | 1472,787 | 4,95825 | 5168 | 55,68 | 57,65 | 0,41843 | 56,67 | 1971,31961 |
| 6 | 1180,06475 | 3,97278 | 5793 | 62,14 | 63,8 | 0,45475 | 62,92 | 1671,29902 |
| 7 | 475,20584 | 1,59982 | 6144 | 65,97 | 66,96 | 0,98 | 66,43 | 617,0758 |
| 8 | 1109,66767 | 3,73578 | 6301 | 67,14 | 68,71 | 0,50855 | 68 | 1503,78591 |
| 9 | 591,33241 | 1,99077 | 6415 | 68,71 | 69,7 | 0,80365 | 69,14 | 881,50018 |

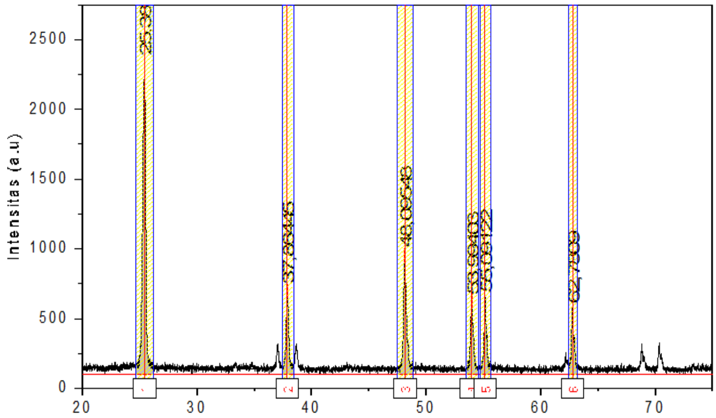
| Area Puncak Kristalin 2θ | Fraksi Luas Kristalin | Luas Difraktogram |
|---|---|---|
| 2264,579 | 11729,200 | 33703,766 |
| 1331,391 | | |
| 2423,693 | | |
| 880,478 | | |
| 1472,787 | | |
| 1180,064 | | |
| 475,205 | | |
| 1109,667 | | |
| 591,332 | | |

$$\text{Kristalinitas} = \frac{\text{Fraksi luas kristalin}}{\text{Luas difragtogram}} \text{ x } 100$$

$$= \frac{11729{,}200}{33703{,}766}\, x\ 100$$

= 34,80%

**Derajat Kristalinitas $TiO_2$**




| Index | Area | AreaIntgP(%) | Row Index | Beginning X | Ending X | FWHM | Center | Height |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" |
| | | | | | | | | |
| 1 | 746,04053 | 19,49182 | 2041 | 24,6 | 26,28 | 0,30151 | 25,39 | 2122,94553 |
| 2 | 169,41388 | 4,42628 | 3289 | 37,41 | 38,32 | 0,25154 | 37,87 | 561,27876 |
| 3 | 276,87052 | 7,2338 | 4313 | 47,61 | 48,85 | 0,26161 | 48,11 | 829,64384 |
| 4 | 163,90208 | 4,28227 | 4886 | 53,37 | 54,49 | 0,27641 | 53,94 | 514,24781 |
| 5 | 165,33603 | 4,31974 | 5004 | 54,63 | 55,84 | 0,26633 | 55,12 | 511,03195 |
| 6 | 125,58848 | 3,2812 | 5768 | 62,46 | 63,18 | 0,2852 | 62,74 | 435,50498 |

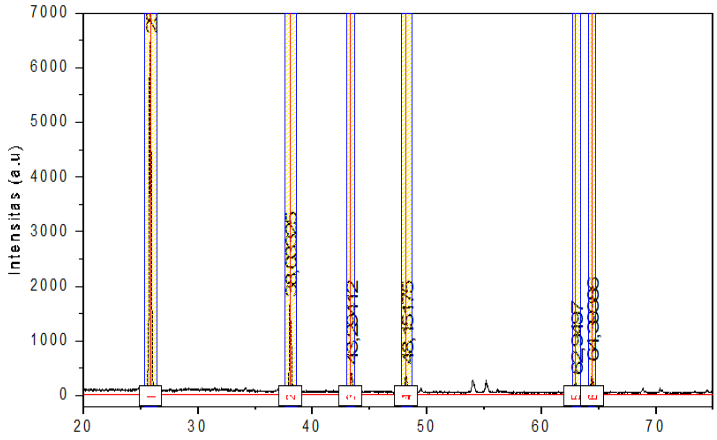
| Area Puncak Kristalin 2θ | Fraksi Luas Kristalin | Luas Difraktogram |
|---|---|---|
| 746,040 | 1647,149 | 2554,773 |
| 169,413 | | |
| 276,870 | | |
| 163,902 | | |
| 165,336 | | |
| 125,586 | | |

$$\text{Kristalinitas} = \frac{\text{Fraksi luas kristalin}}{\text{Luas difragtogram}} \text{ x } 100$$

$$= \frac{1647{,}149}{2554{,}773} \, x \, 100$$

= 64,47%.

## Derajat Kristalinitas Ag/$TiO_2$




| Index | Area | AreaIntgP(%) | Row Index | Beginning X | Ending X | FWHM | Center | Height |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" | Integral Result of "Data" |
| | | | | | | | | |
| 1 | 1484,76381 | 28,13189 | 2085 | 25,1 | 26,78 | 0,24779 | 25,84 | 5767,39788 |
| 2 | 349,96179 | 6,63074 | 3313 | 37,41 | 38,58 | 0,23427 | 38 | 1299,81785 |
| 3 | 91,10453 | 1,72616 | 3855 | 42,89 | 43,77 | 0,18415 | 43,42 | 381,34049 |
| 4 | 122,55942 | 2,32214 | 4327 | 47,68 | 48,87 | 0,25374 | 48,14 | 358,92338 |
| 5 | 92,16949 | 1,74634 | 5953 | 64,1 | 64,83 | 0,16843 | 64,4 | 373,33229 |
| 6 | 163,07248 | 3,08974 | 7051 | 74,71 | 75,94 | 0,14178 | 75,38 | 584,1872 |

| Area Puncak Kristalin 2θ | Fraksi Luas Kristalin | Luas Difraktogram |
|---|---|---|
| 1484,763 | 2303,631 | 5764,708 |
| 349,961 | | |
| 91,104 | | |
| 122,559 | | |
| 92,169 | | |
| 163,072 | | |

$$\text{Kristalinitas} = \frac{\text{Fraksi luas kristalin}}{\text{Luas difragtogram}} \text{ x } 100$$

$$= \frac{2303{,}631}{5764{,}708}\ x\ 100$$

= 39,96%.

## Lampiran 5. Hasil Karakterisasi dengan SEM

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET DAN TEKNOLOGI
UNIVERSITAS DIPONEGORO
UPT. LABORATORIUM TERPADU

Jalan Prof. Sudarto, S.H.
Tembalang Semarang Kode Pos 50275
Tel. (024) 76918147 Faks. (024) 76918147
www.labterpadu.undip.ac.id
email: labterpadu@live.undip.ac.id

Halaman : 1 dari 1

| | | |
|---|---|---|
| Nomor Sampel Uji | : | SP-XII-1432 |
| Nama | : | Desy Nurhasanah Sari |
| Alamat/Instansi | : | Universitas Hasanuddin |
| Dibuat untuk | : | - |
| Tanggal Pengambilan / Penerimaan Sampel Uji | : | 23 Agustus 2021 |
| Kemasan Sampel Uji | : | Tube Plastik |

**HASIL PENGUJIAN / PENGUKURAN**

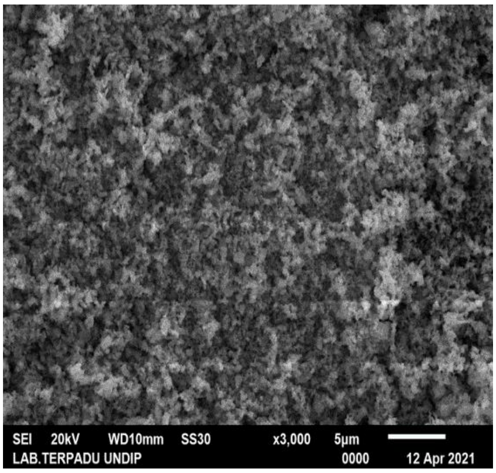
**Catatan**:
1. Laboratorium Terpadu Universitas Diponegoro Semarang tidak bertanggung jawab terhadap penyalahgunaan hasil analisis ini.
2. Hasil analisis ini hanya berlaku untuk sampel uji yang dikirimkan ke UPT Laboratorium Terpadu Universitas Diponegoro
3. Dilarang mengutip/meng-copy dan/atau mempublikasikan sebagian isi laporan ini tanpa seijin UPT Laboratorium Terpadu Universitas Diponegoro.

Semarang, 24 Agustus 2021
Ketua Bidang Pengujian dan Sertifikasi

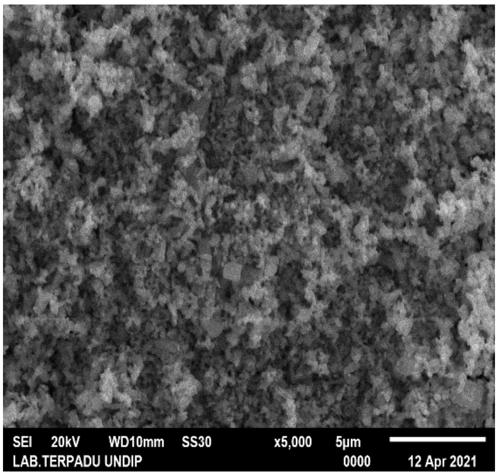
**Prof. Dr. Meiny Suzery, M.S.**
NIP. 196005101989032001

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

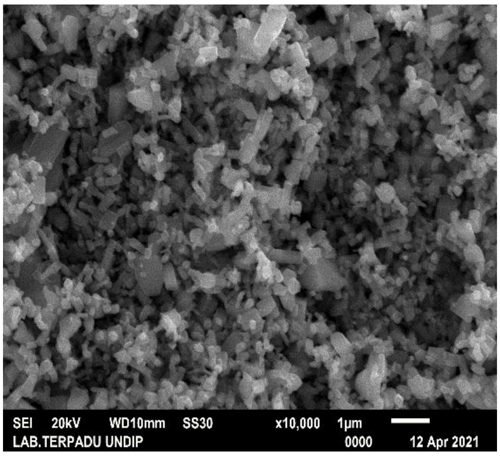
**Hasil Uji SEM ZnO**



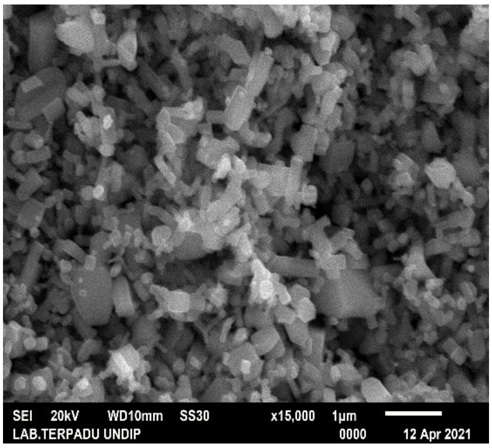

Perbesaran 3.000x




Perbesaran 5.000x



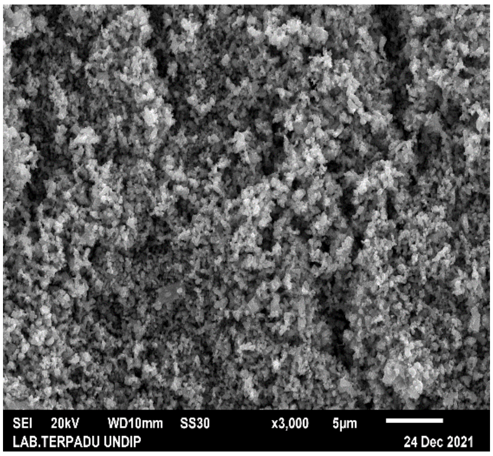

Perbesaran 10.000x



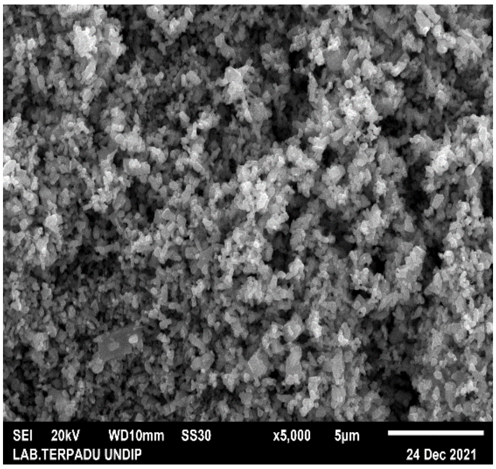

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

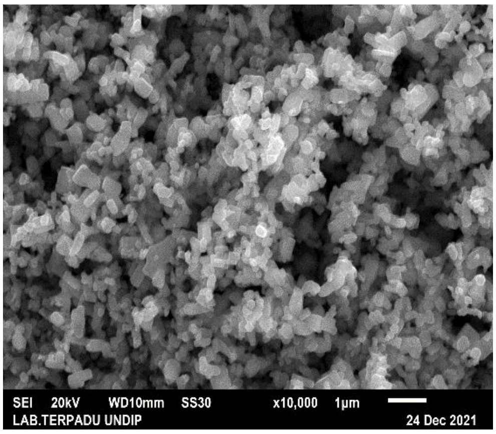
**Hasil Uji SEM ZnO TK**



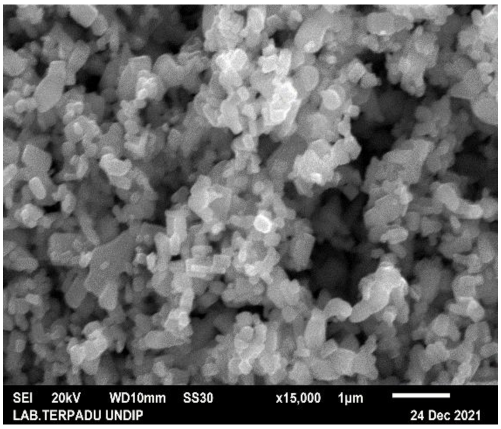

Perbesaran 3.000x




Perbesaran 5.000x



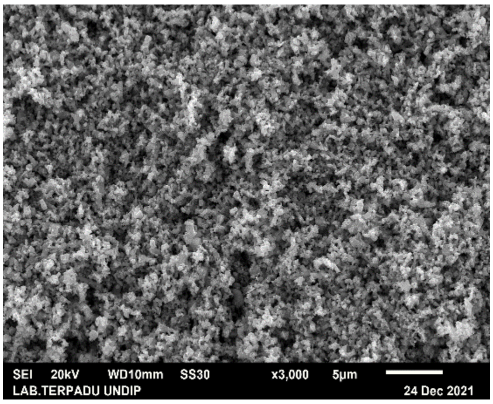

Perbesaran 10.000x



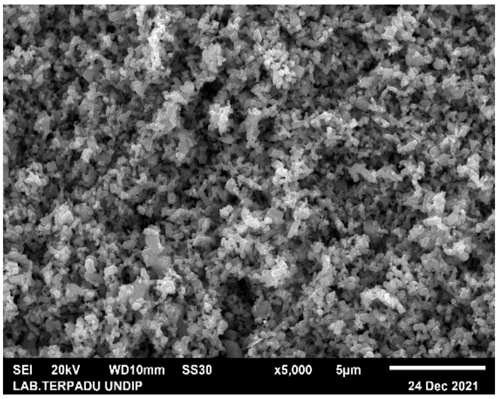

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

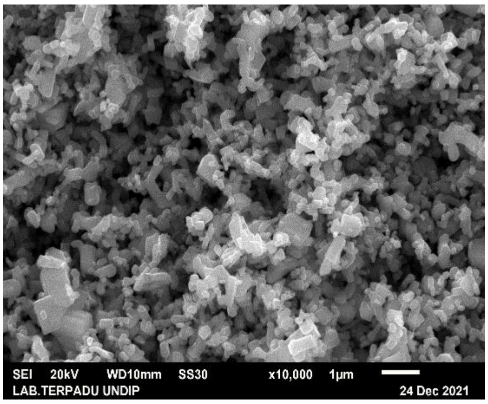
**Hasil Uji SEM ZnO FM**



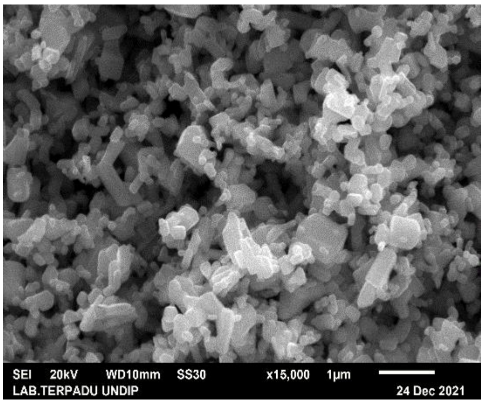

Perbesaran 3.000x




Perbesaran 5.000x



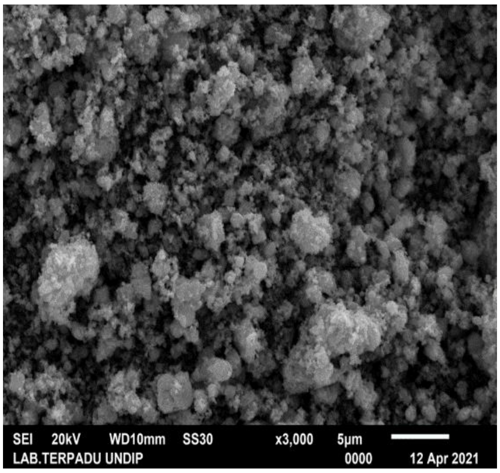

Perbesaran 10.000x



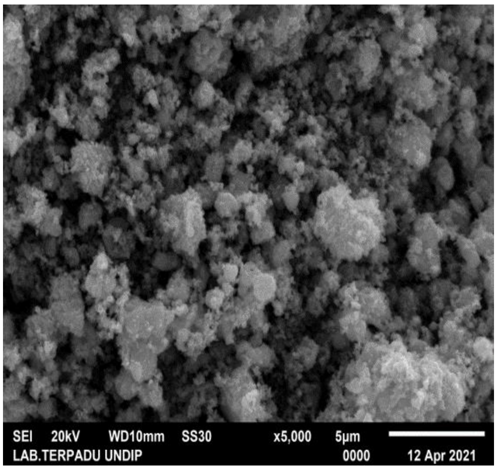

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

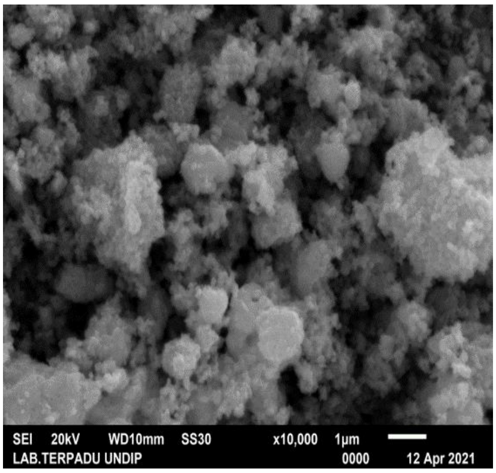
**Hasil Uji SEM Cu/ZnO**



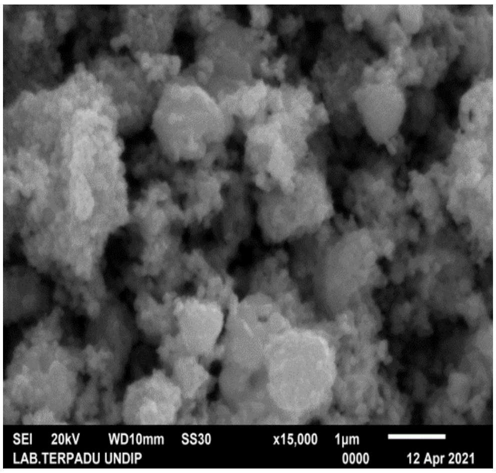

Perbesaran 3.000x




Perbesaran 5.000x



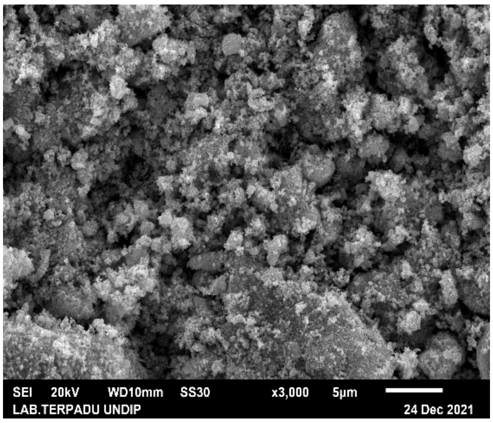

Perbesaran 10.000x



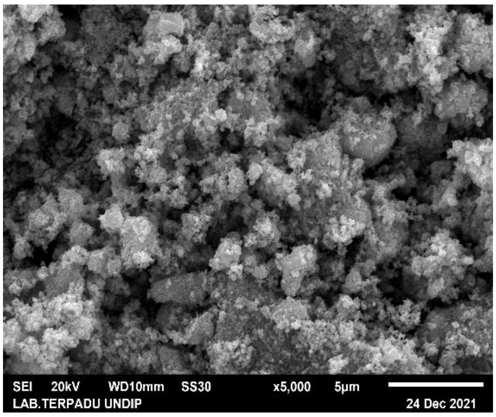

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

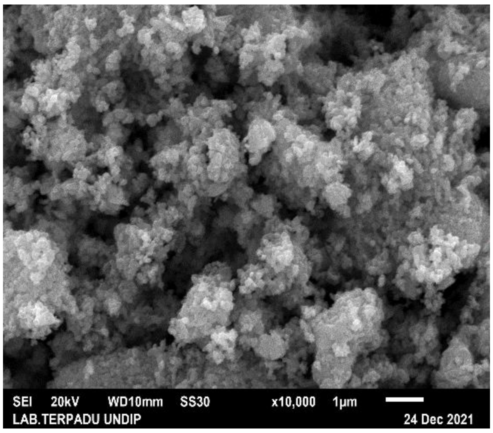
**Hasil Uji SEM Cu/ZnO TK**



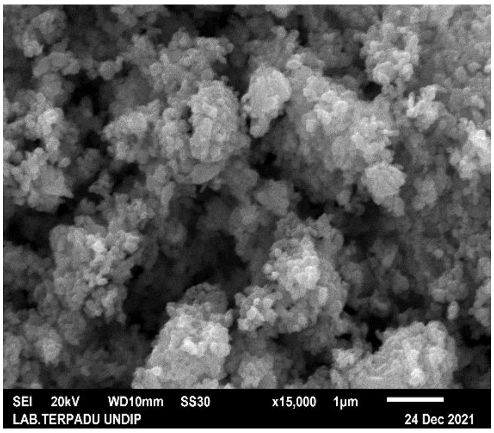

Perbesaran 3.000x




Perbesaran 5.000x



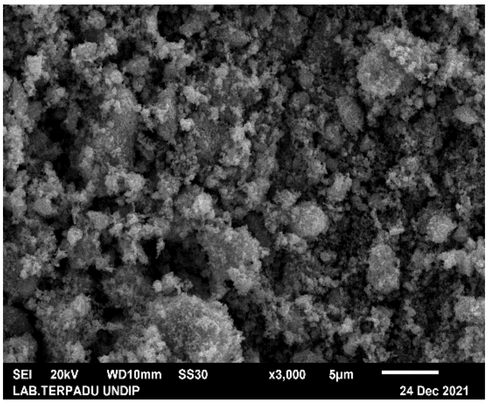

Perbesaran 10.000x



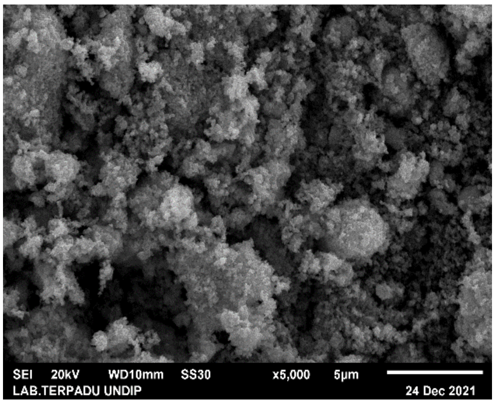

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

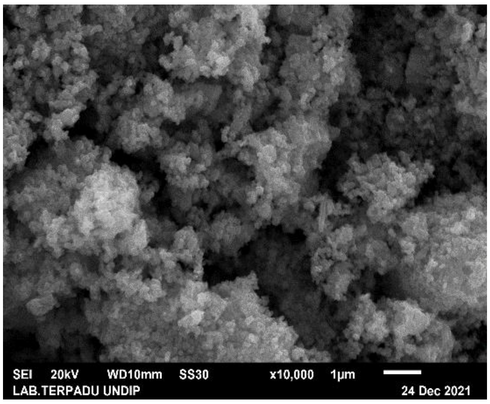
**Hasil Uji SEM Cu/ZnO FM**



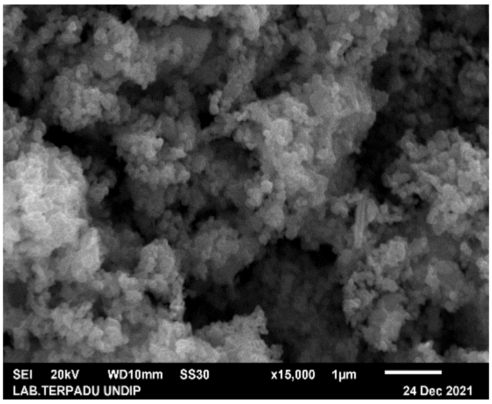

Perbesaran 3.000x




Perbesaran 5.000x



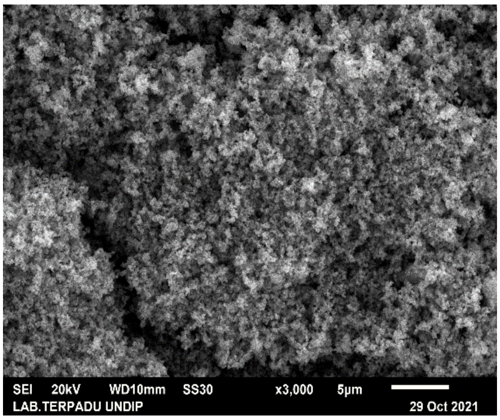

Perbesaran 10.000x



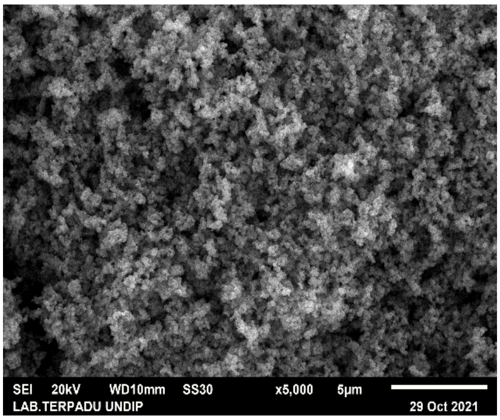

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

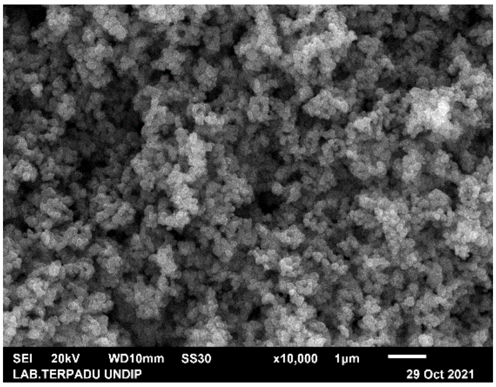
**Hasil Uji SEM $TiO_2$**



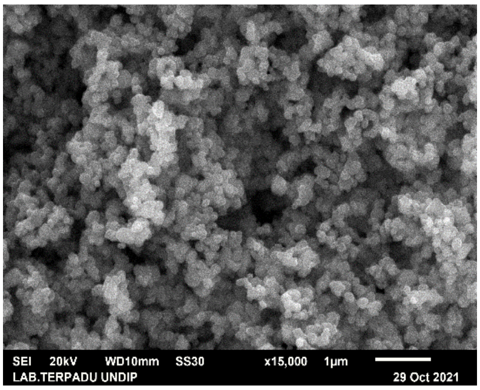

Perbesaran 3.000x




Perbesaran 5.000x



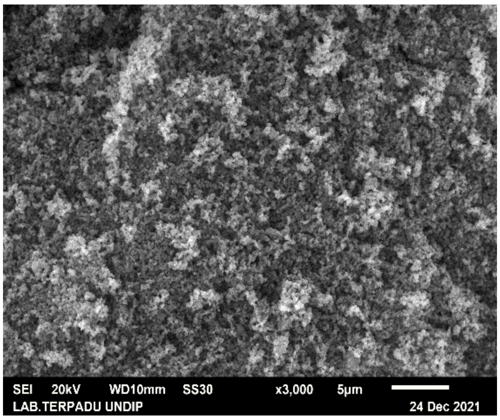

Perbesaran 10.000x



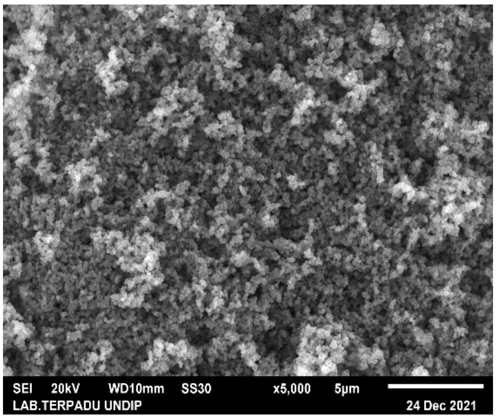

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

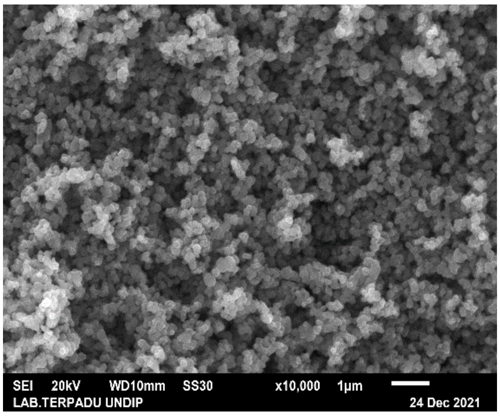
**Hasil Uji SEM $TiO_2$ TK**



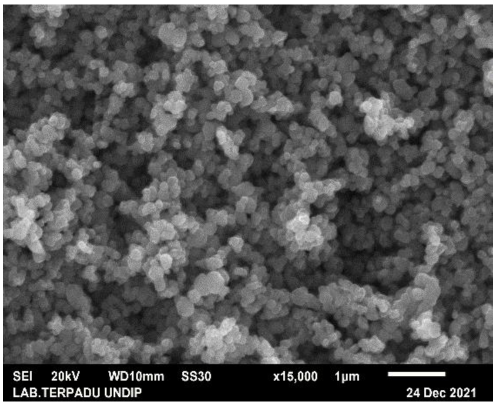

Perbesaran 3.000x




Perbesaran 5.000x



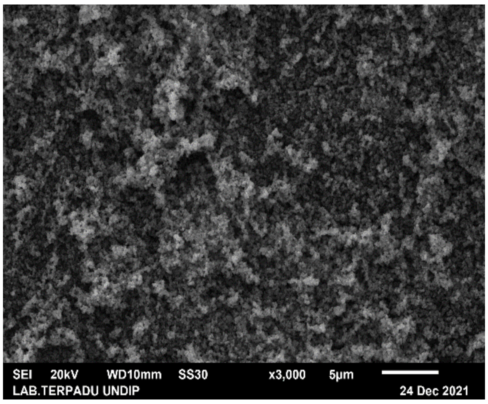

Perbesaran 10.000x



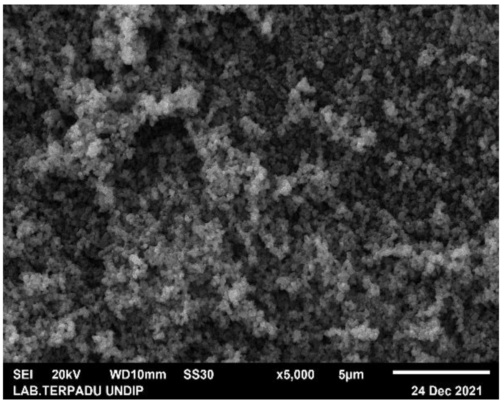

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

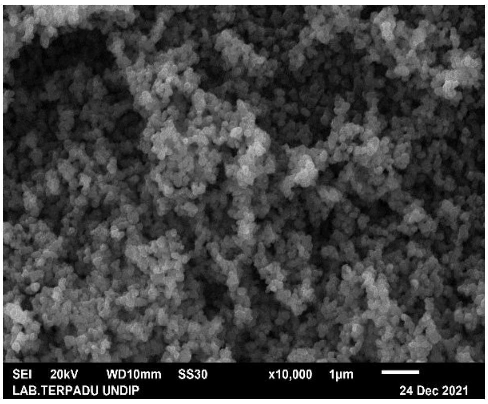
**Hasil Uji SEM $TiO_2$ FM**



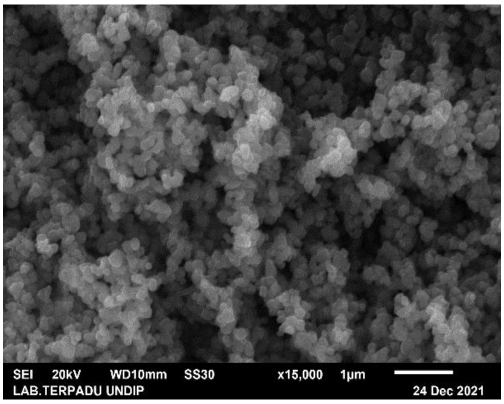

Perbesaran 10.000x




Perbesaran 15.000x



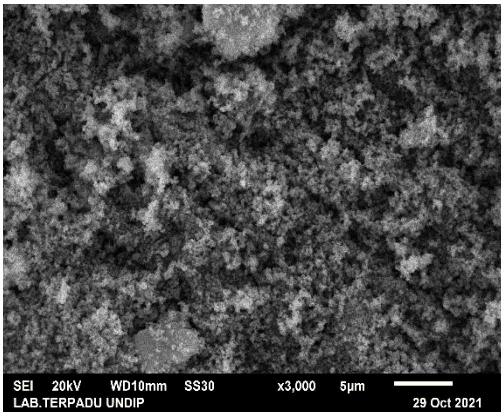

Perbesaran 10.000x



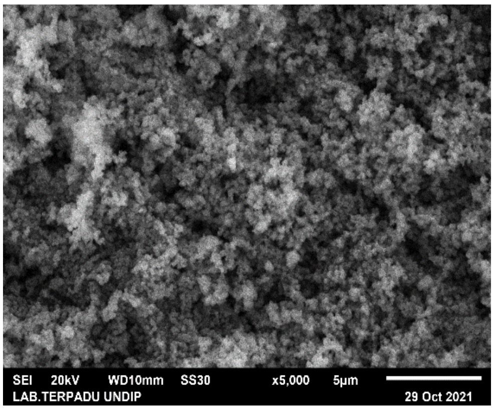

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

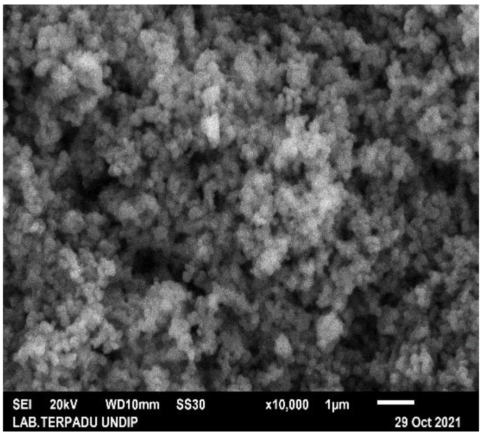
**Hasil Uji SEM Ag/$TiO_2$**



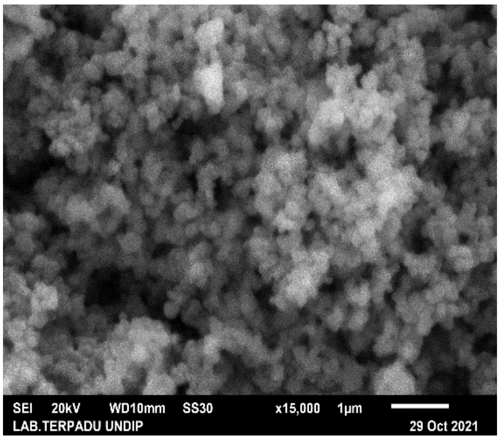

Perbesaran 3.000x




Perbesaran 5.000x



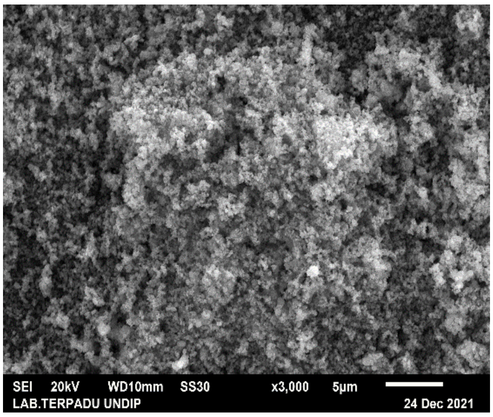

Perbesaran 10.000x



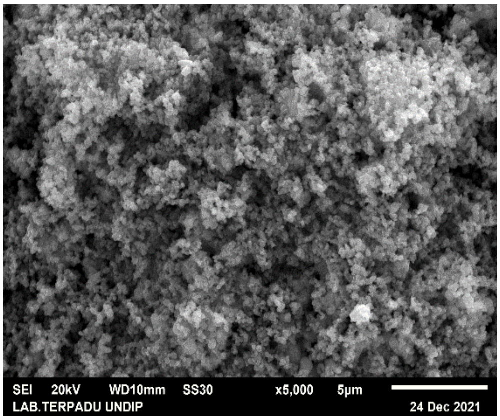

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

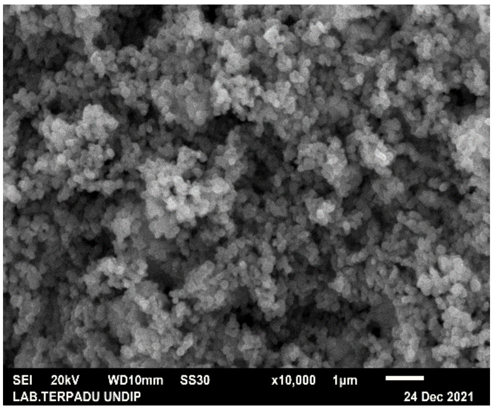
**Hasil Uji SEM Ag/$TiO_2$ TK**



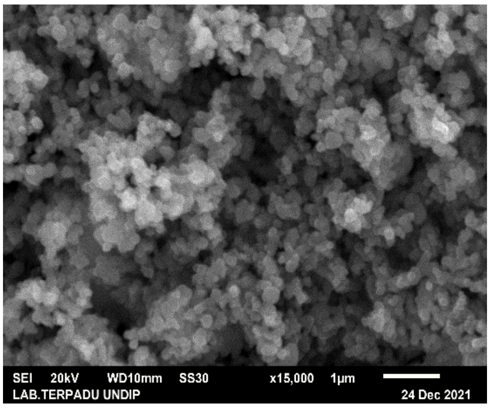

Perbesaran 3.000x




Perbesaran 5.000x



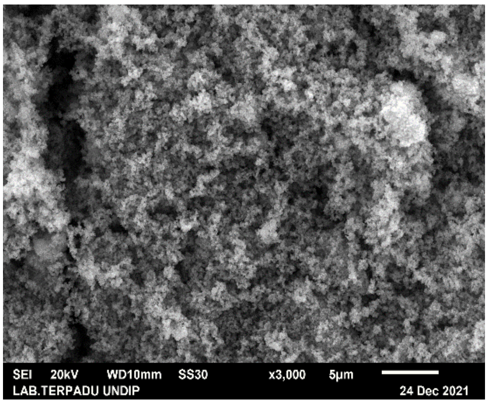

Perbesaran 10.000x



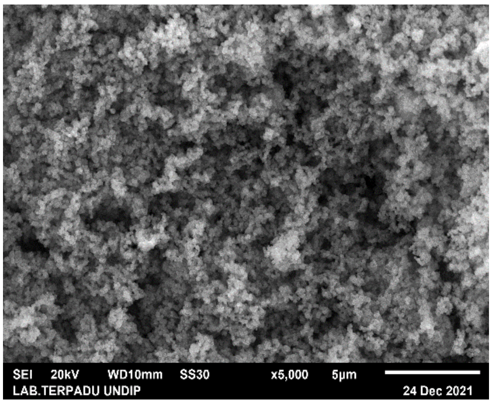

Perbesaran 15.000x

KEMENTERIAN RISET TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS DIPONEGORO
**UPT LABORATORIUM TERPADU**
Jalan Prof. Soedarto, SH Tembalang Semarang Kotak Pos 1269
Telepon (024) 76918147- Faksimile (024) 76918148, Website :
http://labterpadu.undip.ac.id;
E-mail : labterpadu@live.undip.ac.id

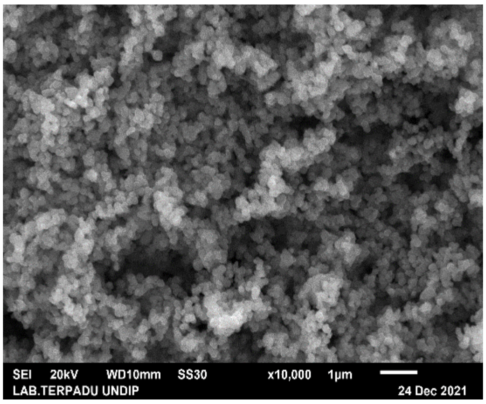
**Hasil Uji SEM Ag/$TiO_2$ FM**



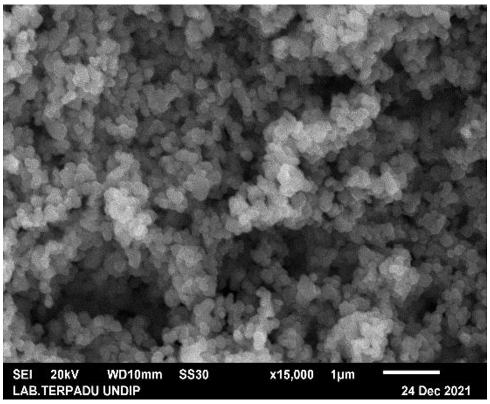

Perbesaran 3.000x




Perbesaran 5.000x




Perbesaran 10.000x




Perbesaran 15.000x

**Lampiran 6. Hasil karakterisasi dengan UV-Vis DRS**

UI CHEM
LAB UI - CHEM KIMIA UI

**LABORATORIUM UJI KIMIA**
DEPARTEMEN KIMIA-UKK LST,
FMIPAUNIVERSITAS INDONESIA

Gedung G Departemen Kimia, Gedung Multidisiplin lt.7
Fakultas Matematika dan Ilmu Pengetahuan Alam
Kampus UI Depok 16424
Tlp. : +6221 78849006
Email : uichemlab@gmail.com

**LABORATORY TEST RESULTS**

Customer : **Irma Nurfitasari**
Date Completed: October 26th 2021
Date Received : October 07th 2021

Parameter : %R, Abs
Test Number : 126-SPK-021
Sample Matrix : Serbuk Oksida

| No. | Sample Name | Sample Code | Parameter | Method |
|---|---|---|---|---|
| 1 | ZnO | 071021-0673 | %R, Abs | Spektrofotometer Uv-DRS |
| 2 | Ag/TiO2 | 071021-0674 | %R, Abs | Spektrofotometer Uv-DRS |
| 3 | TiO2 | 071021-0675 | %R, Abs | Spektrofotometer Uv-DRS |
| 4 | Cu/ZnO | 071021-0676 | %R, Abs | Spektrofotometer Uv-DRS |
| 5 | Co/ZnO | 071021-0677 | %R, Abs | Spektrofotometer Uv-DRS |
| 6 | TiO2/ZnO | 071021-0678 | %R, Abs | Spektrofotometer Uv-DRS |
| 7 | Graphite Oxide | 071021-0679 | %R, Abs | Spektrofotometer Uv-DRS |

Catatan:
1.Hasil yang ditampilkan hanya berhubungan dengan sampel yang diuji
2.Laporan Pengujian tidak boleh digandakan tanpa persetujuan tertulis dari laboratorium

Depok, October 26th 2021

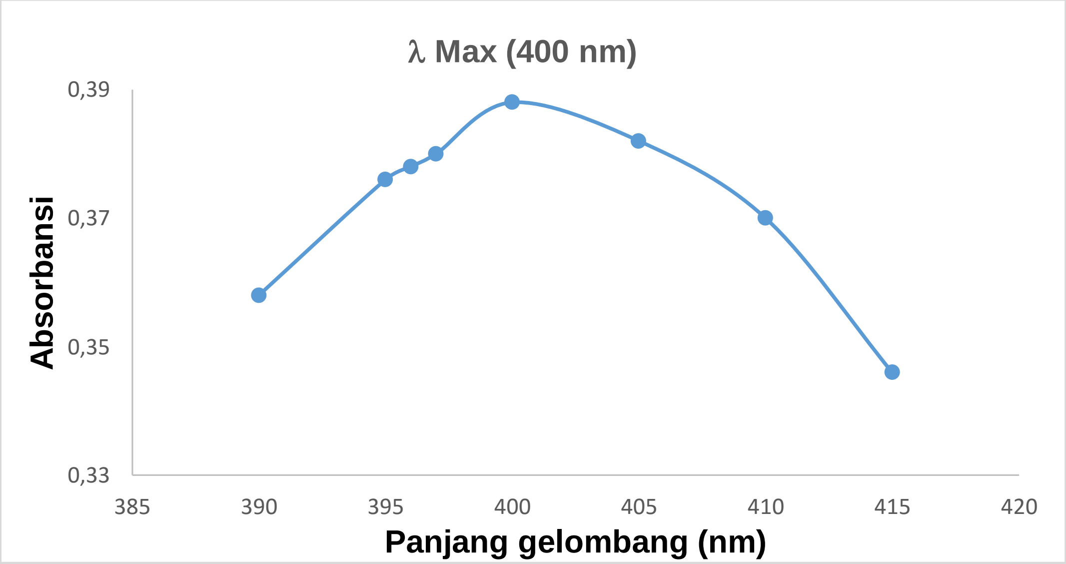
**Hedi Surahman**
**Lab UI-CHEM Departemen Kimia**
**FMIPA Universitas Indonesia**

**Lampiran 7.** Data Penentuan Panjang Gelombang Maksimum Titan Kuning

Hubungan antara absorbansi dan panjang gelombang titan kuning.

| Panjang gelombang (nm) | Absorbansi |
|---|---|
| 390 | 0,358 |
| 395 | 0,376 |
| 396 | 0,378 |
| 397 | 0,38 |
| **400** | **0,388** |
| 405 | 0,382 |
| 410 | 0,37 |
| 415 | 0,346 |

Kurva hubungan antara absorbansi dan panjang gelombang titan kuning

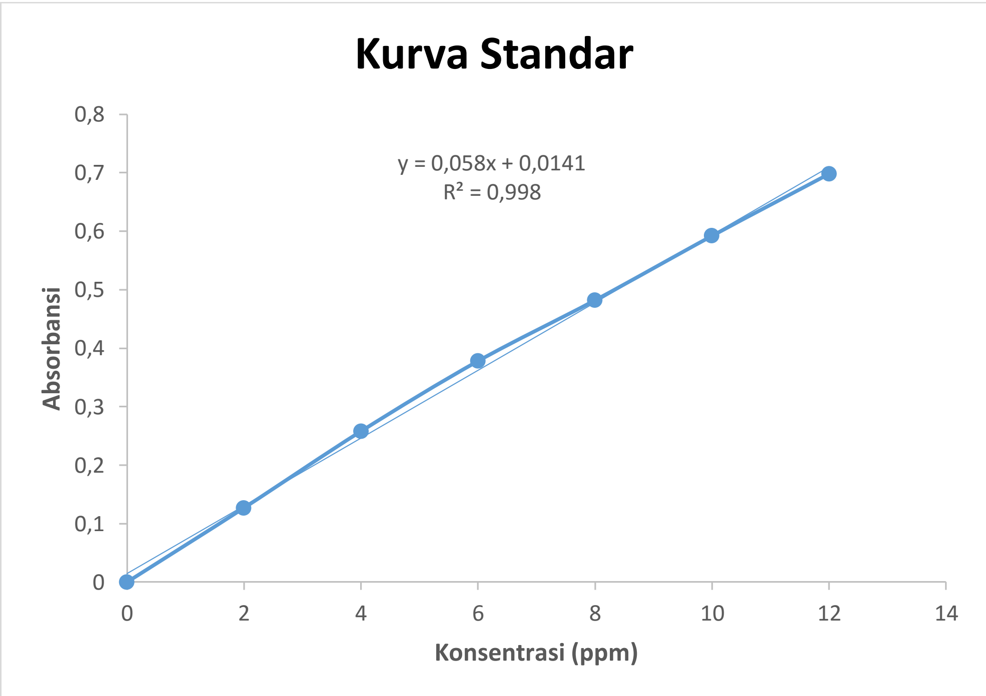


**Lampiran 8.** Data Absorbansi Kurva Standar Titan Kuning

Hubungan antara absorbansi dan konsentrasi titan kuning

| **Konsentrasi (ppm)** | **Absorbansi** |
|---|---|
| 0 | 0 |
| 2 | 0,127 |
| 4 | 0,258 |
| 6 | 0,388 |
| 8 | 0,482 |
| 10 | 0,602 |
| 12 | 0,698 |

Kurva standar titan kuning dengan spektrofotometer UV-Vis

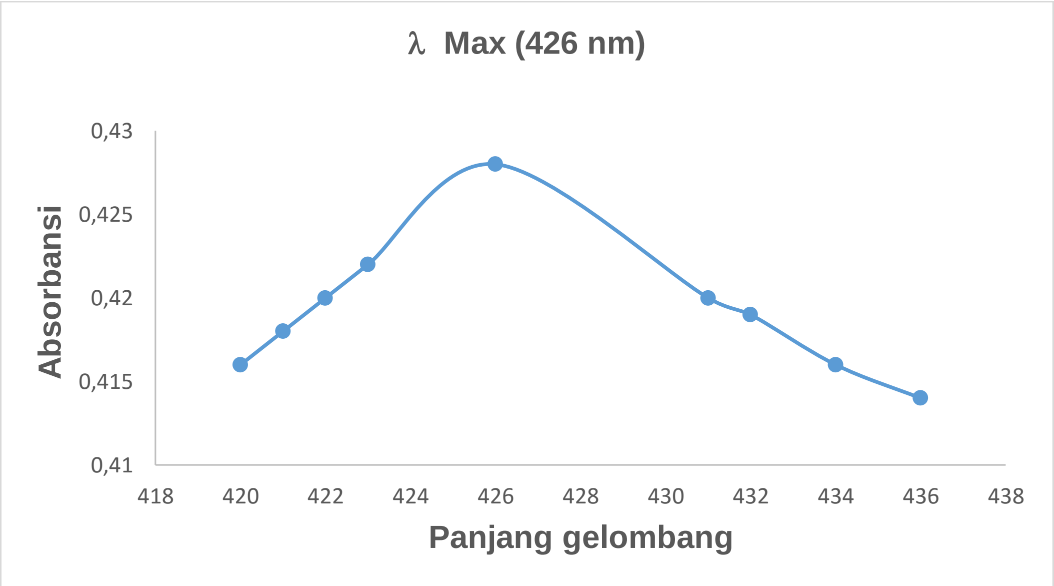


**Lampiran 9.** Data Penentuan Panjang Gelombang Maksimum Fenol Merah

Hubungan antara absorbansi dan panjang gelombang fenol merah.

| **Panjang gelombang (nm)** | **Absorbansi** |
|---|---|
| 420 | 0,416 |
| 421 | 0,418 |
| 422 | 0,42 |
| 423 | 0,422 |
| **426** | **0,428** |
| 431 | 0,420 |
| 432 | 0,419 |
| 434 | 0,416 |
| 436 | 0,414 |

Kurva hubungan antara absorbansi dan panjang gelombang fenol merah

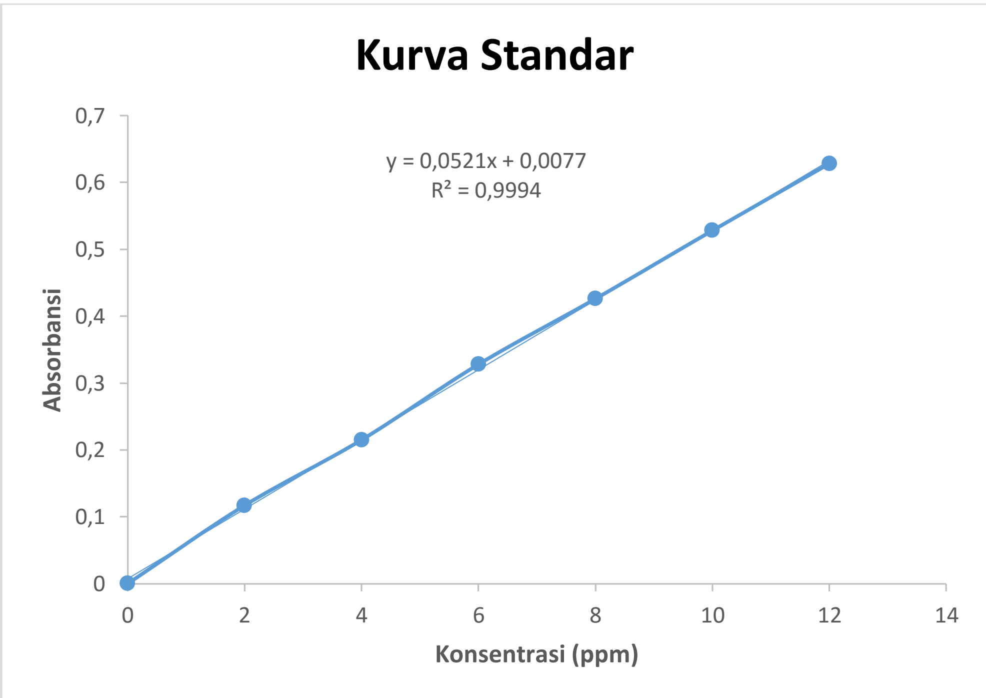


**Lampiran 10.** Data Absorbansi Kurva Standar Fenol Merah

Hubungan antara absorbansi dan konsentrasi fenol merah

| Konsentrasi (ppm) | Absorbansi |
|---|---|
| 0 | 0 |
| 2 | 0,117 |
| 4 | 0,215 |
| 6 | 0,328 |
| 8 | 0,426 |
| 10 | 0,528 |
| 12 | 0,628 |

Kurva standar fenol merah dengan spektrofotometer UV-Vis



**Penentuan bobot optimum fotodegradasi titan kuning oleh katalis ZnO, Cu/ZnO, $TiO_2$, dan Ag/$TiO_2$.**

**Lampiran 11.** Data penentuan bobot optimum fotodegradasi titan kuning oleh katalis ZnO

| Bobot ZnO (g) | Absorbansi | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 0,050 | 1,69 | 28,895 | 50 | 42,210 |
| 0,100 | 1,67 | 28,550 | 50 | 42,900 |
| 0,150 | 1,621 | 27,705 | 50 | 44,590 |
| 0,200 | 1,587 | 27,119 | 50 | 45,762 |
| 0,251 | 1,521 | 25,981 | 50 | 48,038 |
| 0,350 | 1,503 | 25,671 | 50 | 48,659 |
| **0,501** | **1,396** | **23,826** | **50** | **52,348** |
| 0,750 | 1,411 | 24,084 | 50 | 51,831 |
| 1,007 | 1,425 | 24,326 | 50 | 51,348 |

Cara menghitung nilai % degradasi pada bobot 0,501 g

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,396

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{1{,}396 - 0{,}014}{0{,}058}$$

x = 23,826 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 23{,}826}{50} \times 100\%$$

= 52,348%.

**Lampiran 12**. Data penentuan bobot optimum fotodegradasi titan kuning oleh katalis Cu/ZnO

| **Bobot Cu/ZnO (g)** | **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 0,050 | 1,154 | 19,655 | 50 | 60,690 |
| 0,100 | 0,76 | 12,862 | 50 | 74,276 |
| 0,151 | 0,49 | 8,207 | 50 | 83,586 |
| 0,201 | 0,38 | 6,310 | 50 | 87,379 |
| **0,251** | **0,288** | **4,724** | **50** | **90,552** |
| 0,350 | 0,321 | 5,293 | 50 | 89,414 |
| 0,501 | 0,38 | 6,310 | 50 | 87,379 |
| 0,751 | 0,407 | 6,776 | 50 | 86,448 |
| 1,007 | 0,4 | 6,655 | 50 | 86,690 |

Cara menghitung nilai % degradasi pada bobot 0,251 g

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,288

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}288 - 0{,}014}{0{,}058}$$

x = 4,724 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 4{,}724}{50} \times 100\%$$

= 90,552%.

**Lampiran 13**. Data penentuan bobot optimum fotodegradasi titan kuning oleh katalis $TiO_2$.

| **Bobot $TiO_2$ (g)** | **Absorbansi** | **FP** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|---|
| 0,050 | 0,217 | 10 | 37,172 | 50 | 25,655 |
| 0,100 | 0,213 | 10 | 36,483 | 50 | 27,034 |
| 0,150 | 1,989 | - | 34,052 | 50 | 31,897 |
| 0,200 | 1,945 | - | 33,293 | 50 | 33,414 |
| 0,258 | 1,893 | - | 32,397 | 50 | 35,207 |
| 0,350 | 1,782 | - | 30,483 | 50 | 39,034 |
| **0,504** | **1,752** | **-** | **29,966** | **50** | **40,069** |
| 0,750 | 1,775 | - | 30,362 | 50 | 39,276 |
| 1,002 | 1,767 | - | 30,224 | 50 | 39,552 |

Cara menghitung nilai % degradasi pada bobot 0,504 g

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,752

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{1{,}752 - 0{,}014}{0{,}058}$$

x = 29,966 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 29{,}966}{50} \times 100\%$$

= 40,069 %.

**Lampiran 14.** Data penentuan bobot optimum fotodegradasi titan kuning oleh katalis $Ag/TiO_2$

| **Bobot $Ag/TiO_2$ (g)** | **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 0,050 | 1,587 | 27,121 | 50 | 45,759 |
| 0,101 | 1,243 | 21,190 | 50 | 57,621 |
| 0,150 | 0,752 | 12,724 | 50 | 74,552 |
| 0,200 | 0,498 | 8,345 | 50 | 83,310 |
| **0,256** | **0,344** | **5,690** | **50** | **88,621** |
| 0,350 | 0,381 | 6,328 | 50 | 87,345 |
| 0,504 | 0,51 | 8,552 | 50 | 82,897 |
| 0,750 | 0,53 | 8,897 | 50 | 82,207 |
| 1,001 | 0,54 | 9,069 | 50 | 81,862 |

Cara menghitung nilai % degradasi pada bobot 0,256 g

Nilai absorbansi pada bobot 0,256 g dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,344

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}344 - 0{,}014}{0{,}058}$$

x = 5,690 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 5{,}690}{50} \times 100\%$$

= 88,621%.

**Penentuan bobot optimum fotodegradasi fenol merah oleh katalis ZnO, Cu/ZnO, $TiO_2$, dan Ag/$TiO_2$.**

**Lampiran 15.** Data penentuan bobot optimum fotodegradasi fenol merah oleh katalis ZnO

| Bobot ZnO (g) | Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|---|
| 0,050 | 0,212 | 10 | 40,543 | 50 | 18,914 |
| 0,100 | 1,997 | - | 38,182 | 50 | 23,635 |
| 0,15 | 1,895 | - | 36,225 | 50 | 27,551 |
| 0,201 | 1,87 | - | 35,745 | 50 | 28,511 |
| 0,253 | 1,861 | - | 35,572 | 50 | 28,856 |
| 0,351 | 1,74 | - | 33,250 | 50 | 33,501 |
| **0,501** | **1,646** | **-** | **31,445** | **50** | **37,109** |
| 0,750 | 1,681 | - | 32,117 | 50 | 35,766 |
| 1,041 | 1,714 | - | 32,750 | 50 | 34,499 |

Cara menghitung nilai % degradasi pada bobot 0,501 g

Nilai absorbansi pada bobot 0,501 g dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,646

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{1,646 - 0,0077}{0,0521}$$

x = 31,445 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 31,445}{50} \times 100\%$$

= 37,109%.

**Lampiran 16.** Data penentuan bobot optimum fotodegradasi fenol merah oleh katalis Cu/ZnO

| Bobot Cu/ZnO (g) | Absorbansi | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 0,050 | 1,2 | 22,885 | 50 | 54,230 |
| 0,105 | 0,999 | 19,027 | 50 | 61,946 |
| 0,151 | 0,764 | 14,516 | 50 | 70,967 |
| 0,200 | 0,642 | 12,175 | 50 | 75,651 |
| 0,250 | 0,561 | 10,620 | 50 | 78,760 |
| 0,350 | 0,554 | 10,486 | 50 | 79,029 |
| **0,505** | **0,487** | **9,200** | **50** | **81,601** |
| 0,750 | 0,556 | 10,524 | 50 | 78,952 |
| 1,005 | 0,665 | 12,616 | 50 | 74,768 |

Cara menghitung nilai % degradasi pada bobot 0,505 g

Nilai absorbansi pada bobot 0,505 g dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,487

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}487 - 0{,}0077}{0{,}0521}$$

x = 9,200 ppm.

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 9{,}200}{50} \times 100\%$$

= 81,601 %.

**Lampiran 17**. Data penentuan bobot optimum fotodegradasi fenol merah oleh katalis $TiO_2$

| **Bobot $TiO_2$ (g)** | **Absorbansi** | **FP** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|---|
| 0,051 | 0,205 | 10 | 39,200 | 50 | 21,601 |
| 0,101 | 1,862 | - | 35,591 | 50 | 28,818 |
| 0,150 | 1,784 | - | 34,094 | 50 | 31,812 |
| 0,200 | 1,72 | - | 32,866 | 50 | 34,269 |
| 0,250 | 1,711 | - | 32,693 | 50 | 34,614 |
| 0,350 | 1,68 | - | 32,098 | 50 | 35,804 |
| **0,502** | **1,672** | **-** | **31,944** | **50** | **36,111** |
| 0,750 | 1,7 | - | 32,482 | 50 | 35,036 |
| 1,005 | 1,724 | - | 32,942 | 50 | 34,115 |

Cara menghitung nilai % degradasi misal pada bobot 0,502 g

Nilai absorbansi pada bobot 0,502 g dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,672

$$x = \frac{y - b}{a}$$

$$= \frac{1,672 - 0,0077}{0,0521}$$

x = 31,944 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 31,944}{50} \times 100\%$$

= 36,111%

**Lampiran 18**. Data penentuan bobot optimum fotodegradasi fenol merah oleh katalis Ag/$TiO_2$

| **Bobot Ag/$TiO_2$ (g)** | **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 0,050 | 1,42 | 27,107 | 50 | 45,785 |
| 0,100 | 1,24 | 23,653 | 50 | 52,695 |
| 0,150 | 1,012 | 19,276 | 50 | 61,447 |
| 0,200 | 0,733 | 13,921 | 50 | 72,157 |
| **0,250** | **0,667** | **12,655** | **50** | **74,691** |
| 0,350 | 0,69 | 13,096 | 50 | 73,808 |
| 0,500 | 0,686 | 13,019 | 50 | 73,962 |
| 0,750 | 0,727 | 13,806 | 50 | 72,388 |
| 1,003 | 0,742 | 14,094 | 50 | 71,812 |

Cara menghitung nilai % degradasi pada bobot 0,250 g

Nilai absorbansi pada bobot 0,250 g dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,667

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}667 - 0{,}0077}{0{,}0521}$$

x = 12,655 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 12{,}655}{50} \times 100\%$$

= 74,691%

**Penentuan waktu optimum fotodegradasi titan kuning oleh katalis ZnO, Cu/ZnO, $TiO_2$, dan Ag/$TiO_2$.**

**Lampiran 19.** Data penentuan waktu optimum fotodegrdasi titan kuning oleh katalis ZnO

| Waktu (menit) | Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|---|
| 5 | 0,239 | 10 | 40,966 | 50 | 18,069 |
| 10 | 0,224 | 10 | 38,379 | 50 | 23,241 |
| 20 | 0,210 | 10 | 37,690 | 50 | 27,966 |
| 30 | 1,987 | - | 37,345 | 50 | 31,966 |
| 45 | 1,846 | - | 31,586 | 50 | 36,828 |
| 60 | 1,545 | - | 26,397 | 50 | 47,207 |
| **90** | **1,31** | **-** | **22,345** | **50** | **55,310** |
| 120 | 1,466 | - | 25,034 | 50 | 49,931 |
| 150 | 1,535 | - | 26,224 | 50 | 47,552 |
| 210 | 1,602 | - | 27,379 | 50 | 45,241 |

Cara menghitung nilai % degradasi pada waktu 90 menit

Nilai absorbansi pada waktu 90 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,31

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{1{,}31 - 0{,}014}{0{,}058}$$

x = 22,345 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 22{,}345}{50} \times 100\%$$

= 55,310%

**Lampiran 20**. Data penentuan waktu optimum fotodegradasi titan kuning oleh katalis Cu/ZnO

| **Waktu (menit)** | **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 5 | 1,04 | 17,690 | 50 | 64,621 |
| 10 | 1 | 17,000 | 50 | 66,000 |
| 20 | 0,807 | 13,672 | 50 | 72,655 |
| 30 | 0,62 | 10,448 | 50 | 79,103 |
| 45 | 0,43 | 7,172 | 50 | 85,655 |
| 60 | 0,287 | 4,707 | 50 | 90,586 |
| **90** | **0,122** | **1,862** | **50** | **96,276** |
| 120 | 0,124 | 2,241 | 50 | 95,517 |
| 150 | 0,15 | 2,345 | 50 | 95,310 |
| 210 | 0,152 | 2,379 | 50 | 95,241 |

Cara menghitung nilai % degradasi pada waktu 90 menit

Nilai absorbansi pada waktu 90 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,122

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{0{,}122 - 0{,}014}{0{,}058}$$

x = 1,862 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{50 - 1{,}862}{50}$$

= 96,276 %

**Lampiran 21**. Data penentuan waktu optimum fotodegradasi titan kuning oleh katalis $TiO_2$

| Waktu (menit) | Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|---|
| 5 | 0,241 | 10 | 41,310 | 50 | 17,379 |
| 10 | 0,231 | 10 | 39,586 | 50 | 20,828 |
| 20 | 0,219 | 10 | 37,517 | 50 | 24,966 |
| 30 | 1,994 | 10 | 34,138 | 50 | 31,724 |
| 45 | 1,852 | - | 31,690 | 50 | 36,621 |
| 60 | 1,782 | - | 30,483 | 50 | 39,034 |
| 90 | 1,68 | - | 28,724 | 50 | 42,552 |
| **120** | **1,597** | **-** | **27,293** | **50** | **45,414** |
| 150 | 1,657 | - | 28,328 | 50 | 43,345 |
| 210 | 1,732 | - | 29,621 | 50 | 40,759 |

Cara menghitung nilai % degradasi pada waktu 120 menit

Nilai absorbansi pada waktu 120 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,597

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{1{,}597 - 0{,}014}{0{,}058}$$

x = 27,293 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 27{,}293}{50} \times 100\%$$

= 45,414 %.

**Lampiran 22**. Data penentuan waktu optimum fotodegrdasi titan kuning oleh katalis Ag/$TiO_2$

| **Waktu (menit)** | **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 5 | 1,282 | 21,862 | 50 | 56,276 |
| 10 | 1,13 | 19,241 | 50 | 61,517 |
| 20 | 0,963 | 16,362 | 50 | 67,276 |
| 30 | 0,834 | 14,138 | 50 | 71,724 |
| 45 | 0,562 | 9,448 | 50 | 81,103 |
| **60** | **0,311** | **5,121** | **50** | **89,759** |
| 90 | 0,335 | 5,534 | 50 | 88,931 |
| 120 | 0,344 | 5,690 | 50 | 88,621 |
| 150 | 0,37 | 6,138 | 50 | 87,724 |
| 210 | 0,394 | 6,552 | 50 | 86,897 |

Cara menghitung nilai % degradasi pada waktu 60 menit

Nilai absorbansi pada waktu 60 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,311

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}311 - 0{,}014}{0{,}058}$$

x = 5,121 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 5{,}121}{50} \times 100\%$$

= 89,759 %.

Data penentuan waktu optimum fotodegrdasi titan kuning tanpa katalis

| **Waktu (menit)** | **Absorbansi** | **FP** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|---|
| 5 | 0,291 | 10 | 49,931 | 50 | 0,138 |
| 10 | 0,287 | 10 | 49,241 | 50 | 1,517 |
| 20 | 0,28 | 10 | 48,034 | 50 | 3,931 |
| 30 | 0,278 | 10 | 47,690 | 50 | 4,621 |
| 45 | 0,275 | 10 | 47,172 | 50 | 5,655 |
| 60 | 0,271 | 10 | 46,483 | 50 | 7,034 |
| 90 | 0,268 | 10 | 45,966 | 50 | 8,069 |
| 120 | 0,265 | 10 | 45,448 | 50 | 9,103 |
| 150 | 0,262 | 10 | 44,931 | 50 | 10,138 |
| **210** | **0,256** | **10** | **43,897** | **50** | **12,207** |

Cara menghitung nilai % degradasi pada waktu 210 menit

Nilai absorbansi pada waktu 210 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,256

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{0{,}256 - 0{,}014}{0{,}058}$$

x = 43,897 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 43{,}897}{50} \times 100\%$$

= 12,207 %.

**Lampiran 23**. Data penentuan waktu optimum fotodegradasi fenol merah oleh katalis ZnO

| **Waktu (menit)** | **Absorbansi** | **FP** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|---|
| 5 | 0,226 | 10 | 43,230 | 50 | 13,539 |
| 10 | 0,215 | 10 | 41,119 | 50 | 17,762 |
| 20 | 1,941 | - | 37,107 | 50 | 25,785 |
| 30 | 1,704 | - | 32,559 | 50 | 34,883 |
| 45 | 1,664 | - | 31,791 | 50 | 36,418 |
| 60 | 1,673 | - | 31,964 | 50 | 36,073 |
| 90 | 1,556 | - | 29,718 | 50 | 40,564 |
| **120** | **1,414** | **-** | **26,992** | **50** | **46,015** |
| 150 | 1,418 | - | 27,069 | 50 | 45,862 |
| 210 | 1,438 | - | 27,453 | 50 | 45,094 |

Cara menghitung nilai % degradasi pada waktu 120 menit

Nilai absorbansi pada waktu 120 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,414

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{1{,}414 - 0{,}0077}{0{,}0521}$$

x = 26,992 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 26{,}992}{50} \times 100\%$$

= 46,015%

**Lampiran 24.** Data penentuan waktu optimum fotodegradasi fenol merah oleh katalis Cu/ZnO

| Waktu (menit) | Absorbansi | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 5 | 1,21 | 23,115 | 50 | 53,770 |
| 10 | 1,2 | 22,885 | 50 | 54,230 |
| 20 | 1,142 | 21,772 | 50 | 56,457 |
| 30 | 1,014 | 19,315 | 50 | 61,370 |
| 45 | 0,724 | 13,749 | 50 | 72,503 |
| 60 | 0,52 | 9,833 | 50 | 80,334 |
| 90 | 0,355 | 6,666 | 50 | 86,668 |
| **120** | **0,241** | **4,478** | **50** | **91,044** |
| 150 | 0,257 | 4,785 | 50 | 90,430 |
| 210 | 0,3 | 5,610 | 50 | 88,779 |

Cara menghitung nilai % degradasi pada waktu 120 menit

Nilai absorbansi pada waktu 120 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,241

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}241 - 0{,}0077}{0{,}0521}$$

x = 4,478 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 4{,}478}{50} \times 100\%$$

= 91,04%

**Lampiran 25**. Data penentuan waktu optimum fotodegrdasi fenol merah oleh katalis $TiO_2$

| Waktu (menit) | Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|---|
| 5 | 0,23 | 10 | 43,998 | 50 | 12,004 |
| 10 | 0,213 | 10 | 40,735 | 50 | 18,530 |
| 20 | 1,992 | - | 38,086 | 50 | 23,827 |
| 30 | 1,856 | - | 35,476 | 50 | 29,048 |
| 45 | 1,77 | - | 33,825 | 50 | 32,349 |
| 60 | 1,76 | - | 33,633 | 50 | 32,733 |
| 90 | 1,74 | - | 33,250 | 50 | 33,501 |
| 120 | 1,73 | - | 33,058 | 50 | 33,885 |
| **150** | **1,67** | **-** | **31,906** | **50** | **36,188** |
| 210 | 1,712 | - | 32,712 | 50 | 34,576 |

Cara menghitung nilai % degradasi pada waktu 150 menit

Nilai absorbansi pada waktu 150 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 1,67

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{1{,}67 - 0{,}0077}{0{,}0521}$$

x = 31,906 ppm.

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 31{,}906}{50} \times 100\%$$

= 36,188 %

**Lampiran 26.** Data penentuan waktu optimum fotodegradasi fenol merah oleh katalis Ag/$TiO_2$

| Waktu (menit) | Absorbansi | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 5 | 1,332 | 25,071 | 50 | 49,858 |
| 10 | 1,252 | 23,536 | 50 | 52,929 |
| 20 | 1,132 | 21,232 | 50 | 57,536 |
| 30 | 0,992 | 18,545 | 50 | 62,910 |
| 45 | 0,821 | 15,263 | 50 | 69,474 |
| 60 | 0,643 | 11,846 | 50 | 76,307 |
| **90** | **0,397** | **7,125** | **50** | **85,750** |
| 120 | 0,431 | 7,777 | 50 | 84,445 |
| 150 | 0,422 | 7,605 | 50 | 84,791 |
| 210 | 0,451 | 8,161 | 50 | 83,678 |

Cara menghitung nilai % degradasi pada waktu 90 menit

Nilai absorbansi pada waktu 90 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,397

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}397 - 0{,}0077}{0{,}0521}$$

x = 7,125 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 7{,}125}{50} \times 100\%$$

= 85,750%.

Data penentuan waktu optimum fotodegradasi fenol merah tanpa penambahan katalis

| Waktu (menit) | Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|---|
| 5 | 0,26 | 10 | 49,756 | 50 | 0,488 |
| 10 | 0,252 | 10 | 48,221 | 50 | 3,559 |
| 20 | 0,25 | 10 | 47,837 | 50 | 4,326 |
| 30 | 0,247 | 10 | 47,261 | 50 | 5,478 |
| 45 | 0,241 | 10 | 46,109 | 50 | 7,781 |
| 60 | 0,237 | 10 | 45,342 | 50 | 9,317 |
| 90 | 0,234 | 10 | 44,766 | 50 | 10,468 |
| 120 | 0,233 | 10 | 44,574 | 50 | 10,852 |
| 150 | 0,23 | 10 | 43,998 | 50 | 12,004 |
| **210** | **0,228** | **10** | **43,614** | **50** | **12,772** |

Cara menghitung nilai % degradasi pada waktu 210 menit

Nilai absorbansi pada waktu 210 menit dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 2,28

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{2,28 - 0,0077}{0,0521}$$

x = 43,614 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{50 - 43,614}{50} \times 100\%$$

= 12,772 %.

**Penentuan kapasitas fotodegradasi titan kuning oleh katalis ZnO, Cu/ZnO, $TiO_2$, dan Ag/$TiO_2$**

**Lampiran 27.** Data penentuan kapasitas fotodegradasi titan kuning oleh katalis ZnO

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 1,81 | - | 30,966 | 65 | 52,361 |
| 0,213 | 10 | 36,483 | 75 | 51,356 |
| **0,275** | **10** | **47,172** | **100** | **52,828** |
| 0,355 | 10 | 60,966 | 125 | 51,228 |
| 0,438 | 10 | 75,276 | 150 | 49,816 |
| 0,611 | 10 | 105,103 | 200 | 47,448 |
| 0,813 | 10 | 139,931 | 250 | 44,028 |
| 0,98 | 10 | 168,724 | 300 | 43,759 |

Cara menghitung nilai % degradasi pada konsentrasi 100 ppm

Nilai absorbansi pada konsentrasi 100 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 100 ppm

Konsentrasi akhir ($C_e$)

y = 2,75

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{2,75 - 0,014}{0,058}$$

x = 47,172 ppm.

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{100 - 47,172}{100}$$

= 52,828%.

**Lampiran 28.** Data penentuan kapasitas fotodegrdasi titan kuning oleh katalis Cu/ZnO.

| **Absorbansi** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|
| 0,204 | 3,276 | 65 | 94,960 |
| 0,218 | 3,517 | 75 | 95,310 |
| 0,282 | 4,621 | 100 | 95,379 |
| 0,36 | 5,966 | 125 | 95,228 |
| **0,39** | **6,483** | **150** | **95,678** |
| 0,87 | 14,759 | 200 | 92,621 |
| 1,39 | 23,724 | 250 | 90,510 |
| 1,94 | 33,207 | 300 | 88,931 |

Cara menghitung nilai % degradasi pada konsentrasi 150 ppm

Nilai absorbansi pada konsentrasi 150 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 150 ppm

Konsentrasi akhir ($C_e$)

y = 0,39

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}39 - 0{,}014}{0{,}058}$$

x = 6,483 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{150 - 6{,}483}{150}$$

= 95,678%.

**Lampiran 29.** Data penentuan kapasitas fotodegrdasi titan kuning oleh katalis $TiO_2$

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 0,215 | 10 | 36,828 | 65 | 43,342 |
| 0,248 | 10 | 42,517 | 75 | 43,310 |
| **0,323** | **10** | **55,448** | **100** | **44,552** |
| 0,408 | 10 | 70,103 | 125 | 43,917 |
| 0,49 | 10 | 84,241 | 150 | 43,839 |
| 0,668 | 10 | 114,931 | 200 | 42,534 |
| 0,842 | 10 | 144,931 | 250 | 42,028 |
| 1,01 | 10 | 174,241 | 300 | 41,920 |

Cara menghitung nilai % degradasi pada konsentrasi 100 ppm

Nilai absorbansi pada konsentrasi 100 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 100 ppm

Konsentrasi akhir ($C_e$)

y = 3,23

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{3{,}23 - 0{,}014}{0{,}058}$$

x = 55,448 ppm

$$\textbf{Persentase Degradasi} = \frac{C_o - C_e}{C_o} \times \mathbf{100}\%$$

$$= \frac{100 - 55{,}448}{100}$$

= 44,552%

**Lampiran 30**. Data penentuan kapasitas fotodegradasi titan kuning oleh katalis Ag/$TiO_2$

| Absorbasi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 0,438 | - | 7,310 | 65 | 88,753 |
| 0,5 | - | 8,379 | 75 | 88,828 |
| 0,657 | - | 11,086 | 100 | 88,914 |
| **0,808** | **-** | **13,690** | **125** | **89,048** |
| 1,1 | - | 18,724 | 150 | 87,517 |
| 1,38 | - | 23,552 | 200 | 88,224 |
| 1,761 | - | 30,121 | 250 | 87,952 |
| 0,221 | 10 | 37,862 | 300 | 87,379 |

Cara menghitung nilai % degradasi pada konsentrasi 125 ppm

Nilai absorbansi pada konsentrasi 125 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 125 ppm

Konsentrasi akhir ($C_e$)

y = 0,808

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0,808 - 0,014}{0,058}$$

x = 13,690 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{125 - 13,690}{125}$$

= 89,048%

Data penentuan konsentrasi optimum fotodegradasi titan kuning tanpa penambahan katalis

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| **0,34** | **10** | **58,379** | **65** | **10,186** |
| 0,393 | 10 | 67,517 | 75 | 9,977 |
| 0,524 | 10 | 90,103 | 100 | 9,897 |
| 0,664 | 10 | 114,241 | 125 | 8,607 |
| 0,803 | 10 | 138,207 | 150 | 7,862 |
| 1,076 | 10 | 185,276 | 200 | 7,362 |
| 1,349 | 10 | 232,345 | 250 | 7,062 |
| 1,628 | 10 | 280,448 | 300 | 6,517 |

Cara menghitung nilai % degradasi pada konsentrasi 65 ppm

Nilai absorbansi pada konsentrasi 65 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 65 ppm

Konsentrasi akhir ($C_e$)

y = 3,4

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{3{,}4 - 0{,}014}{0{,}058}$$

x = 58,379 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{65 - 58{,}379}{65} \times 100\%$$

= 10,186 %.

**Lampiran 31**. Data penentuan kapasitas fotodegradasi fenol merah oleh katalis ZnO

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 1,86 | - | 35,553 | 60 | 40,745 |
| 0,219 | 10 | 41,887 | 70 | 40,162 |
| **0,246** | **10** | **47,069** | **80** | **41,164** |
| 0,284 | 10 | 54,363 | 90 | 39,597 |
| 0,318 | 10 | 60,889 | 100 | 39,111 |
| 0,36 | 10 | 68,950 | 110 | 37,318 |
| 0,404 | 10 | 77,395 | 120 | 35,504 |
| 0,526 | 10 | 100,812 | 150 | 32,792 |

Cara menghitung nilai % degradasi pada konsentrasi 80 ppm

Nilai absorbansi pada konsentrasi 80 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 80 ppm

Konsentrasi akhir ($C_e$)

y = 2,46

y = ax + b

$$x = \frac{y-b}{a}$$

$$= \frac{2,46 - 0,0077}{0,0521}$$

x = 47,069 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100\%}$$

$$= \frac{80 - 47,069}{80} \times 100\%$$

= 41,164 %

**Lampiran 32.** Data penentuan kapasitas fotodegradasi fenol merah oleh katalis Cu/ZnO

| Absorbansi | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|
| 0,34 | 6,378 | 60 | 89,370 |
| 0,41 | 7,722 | 70 | 88,969 |
| **0,42** | **7,914** | **80** | **90,108** |
| 0,552 | 10,447 | 90 | 88,392 |
| 0,651 | 12,347 | 100 | 87,653 |
| 0,82 | 15,591 | 110 | 85,826 |
| 0,954 | 18,163 | 120 | 84,864 |
| 1,982 | 37,894 | 150 | 74,737 |

Cara menghitung nilai % degradasi pada konsentrasi 80 ppm

Nilai absorbansi pada konsentrasi 80 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 80 ppm

Konsentrasi akhir ($C_e$)

y = 0,42

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0{,}42 - 0{,}0077}{0{,}0521}$$

x = 7,914 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{80 - 7{,}914}{80} \times 100\%$$

= 90,108 %

Data penentuan konsentrasi optimum fotodegradasi fenol merah tanpa penambahan katalis

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| **0,283** | **10** | 54,171 | **60** | **9,715** |
| 0,334 | 10 | 63,960 | 70 | 8,629 |
| 0,387 | 10 | 74,132 | 80 | 7,334 |
| 0,441 | 10 | 84,497 | 90 | 6,114 |
| 0,493 | 10 | 94,478 | 100 | 5,522 |
| 0,547 | 10 | 104,843 | 110 | 4,689 |
| 0,601 | 10 | 115,207 | 120 | 3,994 |
| 0,757 | 10 | 145,150 | 150 | 3,234 |

Cara menghitung nilai % degradasi pada konsentrasi 60 ppm

Nilai absorbansi pada konsentrasi 60 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 60 ppm

Konsentrasi akhir ($C_e$)

y = 2,83

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{2{,}83 - 0{,}0077}{0{,}0521}$$

x = 54,171 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{60 - 54{,}171}{60} \times 100\%$$

= 9,715 %.

**Lampiran 33.** Data penentuan kapasitas fotodegradasi fenol merah oleh katalis $TiO_2$

| Absorbansi | FP | $C_e$ (ppm) | $C_o$ (ppm) | % Fotodegradasi |
|---|---|---|---|---|
| 0,218 | 10 | 41,695 | 60 | 30,509 |
| 0,26 | 10 | 49,756 | 70 | 28,920 |
| **0,287** | **10** | **54,939** | **80** | **31,327** |
| 0,34 | 10 | 65,111 | 90 | 27,654 |
| 0,383 | 10 | 73,365 | 100 | 26,635 |
| 0,434 | 10 | 83,154 | 110 | 24,406 |
| 0,498 | 10 | 95,438 | 120 | 20,469 |
| 0,642 | 10 | 123,077 | 150 | 17,949 |

Cara menghitung nilai % degradasi pada konsentrasi 80 ppm

Nilai absorbansi pada konsentrasi 80 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 80 ppm

Konsentrasi akhir ($C_e$)

y = 2,87

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{2{,}87 - 0{,}0077}{0{,}0521}$$

x = 54,939 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{80 - 54{,}939}{80} \times 100\%$$

= 31,327%

**Lampiran 34**. Data penentuan kapasitas fotodegradasi fenol merah oleh katalis Ag/$TiO_2$

| **Absorbansi** | **FP** | **$C_e$ (ppm)** | **$C_o$ (ppm)** | **% Fotodegradasi** |
|---|---|---|---|---|
| 0,58 | - | 10,985 | 60 | 81,692 |
| 0,68 | - | 12,904 | 70 | 81,566 |
| **0,743** | **-** | **14,113** | **80** | **82,358** |
| 0,932 | - | 17,741 | 90 | 80,288 |
| 1,13 | - | 21,541 | 100 | 78,459 |
| 1,32 | - | 25,188 | 110 | 77,102 |
| 1,52 | - | 29,027 | 120 | 75,811 |
| 0,234 | 10 | 44,766 | 150 | 70,156 |

Cara menghitung nilai % degradasi, misal pada konsentrasi 80 ppm

Nilai absorbansi pada konsentrasi 80 ppm dimasukkan dalam persamaan regresi kurva standar

y = 0,0521x + 0,0077

$R^2$ = 0,9994

Konsentrasi awal ($C_o$) = 80 ppm

Konsentrasi akhir ($C_e$)

y = 0,743

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0,743 - 0,0077}{0,0521}$$

x = 14,113 ppm

$$\textbf{Persentase Degradasi} = \frac{\mathbf{C_o - C_e}}{\mathbf{C_o}} \times \mathbf{100}\%$$

$$= \frac{80 - 14,113}{80} \times 100\%$$

= 82,358%.

**Penentuan % efektivitas campuran zat warna TK dan FM**

**Lampiran 35.** Data penentuan % efektivitas campuran zat warna TK dan FM

| Katalis | Absorbansi | | $C_o$ (ppm) | | $C_e$ (ppm) | | % Efektivitas | |
|---|---|---|---|---|---|---|---|---|
| | TK | FM | TK | FM | TK | FM | TK | FM |
| ZnO | 1,23 | 1,480 | 50 | 50 | 20,966 | 28,2591 | 58,069 | 43,4818 |
| **Cu/ZnO** | **0,136** | 0,247 | 50 | 50 | 2,103 | 4,5931 | 95,793 | 90,8138 |
| $TiO_2$ | 1,437 | 1,75 | 50 | 50 | 24,534 | 33,4415 | 50,931 | 33,1171 |
| $Ag/TiO_2$ | 0,23 | 0,42 | 50 | 50 | 3,724 | 7,9136 | 92,552 | 84,1727 |
| Tanpa katalis | 0,24 (FP 10) | 0,236 (FP 10) | 50 | 50 | 41,138 | 45,1497 | 17,724 | 9,7006 |

Cara menghitung nilai % efektivitas pada Cu/ZnO TK
Nilai absorbansi pada Cu/ZnO TK dimasukkan dalam persamaan regresi kurva standar
y = 0,058x + 0,014

$R^2$ = 0,998

Konsentrasi awal ($C_o$) = 50 ppm

Konsentrasi akhir ($C_e$)

y = 0,136

y = ax + b

$$x = \frac{y - b}{a}$$

$$= \frac{0,136 - 0,014}{0,058}$$

x = 2,103 ppm

**Efektivitas =** $\mathbf{\frac{C_o - C_e}{C_o}}$ **x 100%**

$$= \frac{50 - 2,103}{50} \text{ x } 100\%$$

= 95,793%