# Fabrication of $TiO_2$ Nanoparticles Slab Waveguide by Spin-coating Method with 2-Propanol Solvent

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***Abstract*—The slab waveguide $TiO_2$ nanoparticles by spin-coating method was fabricated with solvent 2-propanol. Component of $TiO_2$ phase anatase is obtained using the old method of coprecipitation with time stirring 5 h. The Slab waveguide fabrication process using the spin-coating method with a rotation speed of 3000 rpm for 60 s and thermally treated at 100 $^0$C for 15 min. Heating temperature used should be higher than the boiling point of the solvent (2-propanol) is 82.2 $^0$C. This research was intended to determine the thickness of the film of the waveguides that have been fabricated and examination absorbance and transmittance. From the test results of absorbance and transmittance using UV-Vis known that the highest absorption (262 nm) and average transmittance (91%). The thickness of the film obtained 131.6 µm.**

***Keywords*— Slab waveguide, $TiO_2$, Spin-coating, Absorbance, and Transmittance.**

## I. Introduction

The development of the modern era is possible to designed, fabricated and characterized a system super thin [1]. For example is the slab waveguide. The slab waveguide technology has enable to produce a solid device, monolithic, and multi sensor [2]. Selection of appropriate materials to guide the waveguide is required because it deals with the transmitted loss power [3].

Furthermore, Titanium Dioxide ($TiO_2$) is a semiconductor material that has a melting point and a high dielectric constant. Besides $TiO_2$ has a refractive index of nonlinear 30 times greater than silica. Several polymorphs consist of anatase, brookite and rutile (the thermodynamical stable phase). Each crystalline structure exhibits specific physical properties, band gap, surface states, etc governing their applications and uses. With the highest refractive index, rutile has found extensive use in painting and inks as a white pigmen. Anatase nanoparticles are effective in catalysis and photocatalysis application. It is also cosidered as the best candidate for photovoltaic devices. Brookite has not yet. A commercial interest, but a dye-sensitized solar cell was recently reported, with encouraging results. The particle size has also an important impact on the surface properties. The research uses polycrystalline anatase of $TiO_2$. It has a refractive index of 2.4 to 2.8, good transparency of the wavelength region range infrared to visible light and propagation loss of planar waveguide less than 0.4 dB/cm ($\lambda$=826 nm) [4].

$TiO_2$ has developed many applications today, such as Dye Sensitized Solar Cell (DSSC) [5][6][7], Photo-catalyst [8], and thin film on the slab waveguide [9][10][11] that applied in this research. Several methods have been used to prepare $TiO_2$ nanoparticles films are Chemical Vapor Deposition (CVD), Pulse Laser Ablation Deposition (PLAD), Solution gelation (Sol-Gel), and Spin coating [12]. This research using a spin-coating method which is a method of deposition solution to the center of the substrate and then rotated at a certain speed, so the solution will spread and acquired the film deposition on the substrate. Fabricated using this method relatively easy, but has been able to produce a waveguide and can produce a minimum thickness of 0.5 µm [1].

In this research slab waveguide fabrication consists of corning glass substrates, the film of $TiO_2$ and air cover are deposited by spin-coating method and then determined thickness in the film. At this research, a solvent used in the manufacture of solution $TiO_2$ is 2-propanol ($(CH_3)_2CHOH$) because it has a low boiling point at 82.2 ºC. So later expected will be more pure $TiO_2$ produced due to remove the solvent does not require high temperatures.

## II. Method

### A. Synthesis of $TiO_2$

$TiO_2$ material used is the result of synthesis using the old method of coprecipitation with stirring 5 h. This synthesis using $TiCl_3$ 15% Merck solution 20 ml and 100 ml distilled water and then stirring for 5 hours. Titration $NH_4OH$ until the solution reaches a pH of 9-10. The measurement of pH using pH meter, and then the solution was stirred until the solution becomes white color. The white color on this solution indicates that the solution has dissolved perfect and homogeneous. The solution was precipitated overnight, after the white precipitate was washed by distilled water. Precipitation and washing processes performed until pH 7 and then calcination in temperature

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400 ºC for 3 h. The synthesis of $TiO_2$ phase anatase shown in Figure 1.

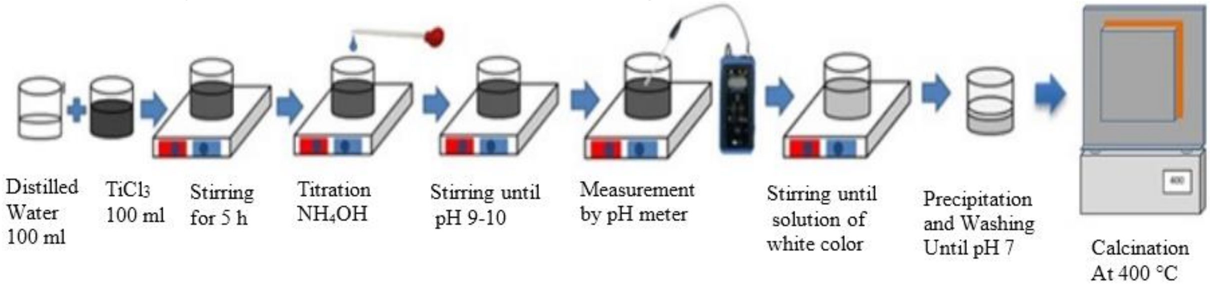


Figure 1. The process of synthesis TiO2 phase anatase

### *B. Preparation of the solution $TiO_2$*

The solution $TiO_2$ prepared by dissolving 0.25 grams of Ethyl cellulose ([$C_6H_7O_2(OH)_3$-x $(OC_2H_5)_x$]n) and 10 ml of 2-propanol using the magnetic stirrer hotplate, and then 0.5 grams $TiO_2$ powder inserted and rotated for 1 h. The length of time stirring indicated with a solution which started dissolved and can't distinguish between the solute and solvent. In this process, 2-propanol is a solvent of $TiO_2$ and Ethyl cellulose is a binder.

### *C. Preparation of the glass substrate*

The substrate used is a Corning Glass Eagle XG with a refractive index of 1.5078 (λ = 643.8 nm) and the dimensions of 2 x 1 cm with a thickness of 1 mm. The substrate was cleaned by distilled water and alcohol 96% and then heat treated at 50 °C. The preparation of the glass substrate shown in Figure 2.

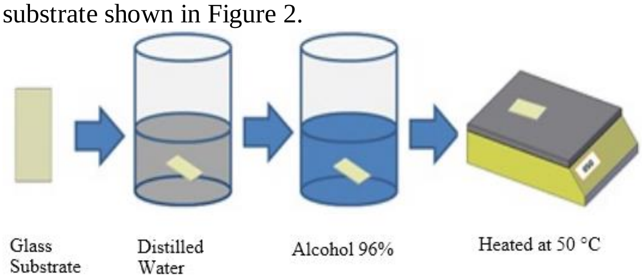


Figure 2. The preparation of the glass substrate

### *D. Fabrication of the slab waveguide*

The as-prepared solution $SnO_2$ was spin coated on a glass substrate with a rotation speed of 3000 rpm for 60 sec. After process coating, glass substrates were then heat treated at 100 ºC for 15 min, to remove residual organic solvent. Fabrication of slab waveguide shown in Figure 3.

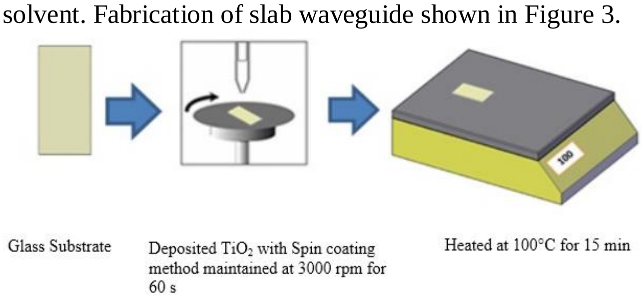


Figure 3. Fabrication of slab waveguide

### *E. Characterization of the slab waveguide*

The optical absorption and transmittance of the films were characterized using UV-Vis spectroscopy, this measurement used for the wavelength region range. The thickness of the layer was measured using a microscope connected to a computer and the pixel shift method.

To show propagation of the waveguide used the same circuit by measuring the thickness, but given the addition of the input source is a He-Ne laser (λ = 632.8 nm) that is transmitted by using a single-mode optical fiber. The output of this device was observed with a microscope webcam connected to a PC. The measurement set up for slab waveguide shown in Figure 4.

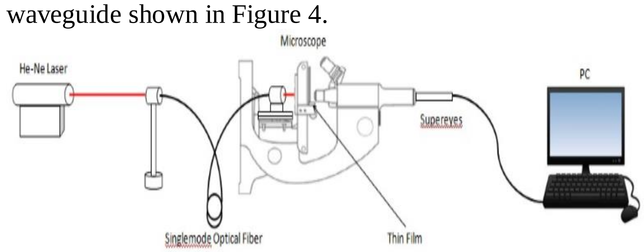


Figure 4. Measurement setup for slab waveguide

## III. Result and Analysis

Fabrication of the slab waveguide was done using $TiO_2$ nanoparticles with a solvent 2-propanol and is shown in Figure 5. In Figure 5, the film has been formed between the air cover and the glass substrate. The choice combination for substrates, film and cover consider of propagation electromagnetic waves.

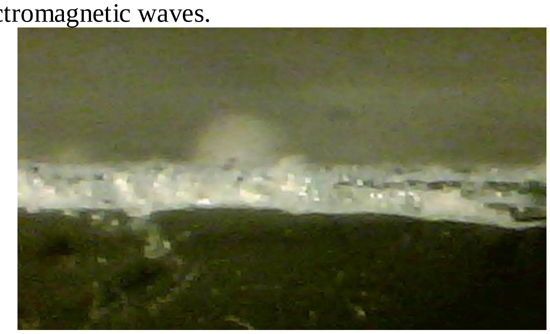

Figure 5. Put the caption for figure 1 here. Use an appropriate and as clear as possible caption for the figure.

The propagation electromagnetic waves occurs if the refractive index film greatest than substrates and cover ($n_f > n_s \geq n_c$). In this research, refractive index film $TiO_2$ anatase (λ = 589 nm) is 2.489; 2.562, refractive index substrate corning glass (λ = 643.8 nm) is 1.5078 and refractive index cover air is 1.

The UV-Vis, absorption spectra for spin coated $TiO_2$ slab waveguide were shown in Figure 6. UV absorption peaks were observed at 262 nm and can be absorption in the wavelength range ±300-1000 nm (visible wavelength).

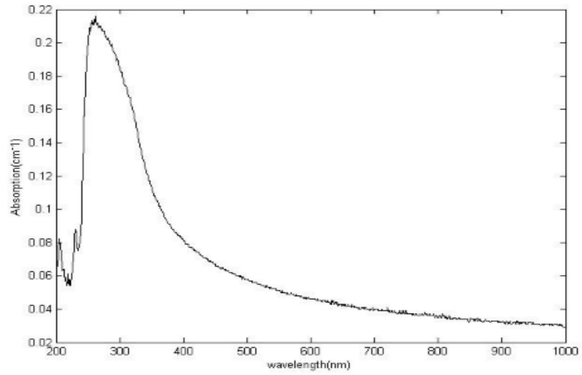


Figure 6. The absorption spectra of $TiO_2$

The UV-Vis, transmission spectra of the $TiO_2$ thin films were shown in Figure 7. The sample show an optical average transmittance 91% in the visible region, which is in good range for many optoelectronics application. The transmittance in the He-Ne laser ($\lambda$=632.8 nm) is 95.345 %.

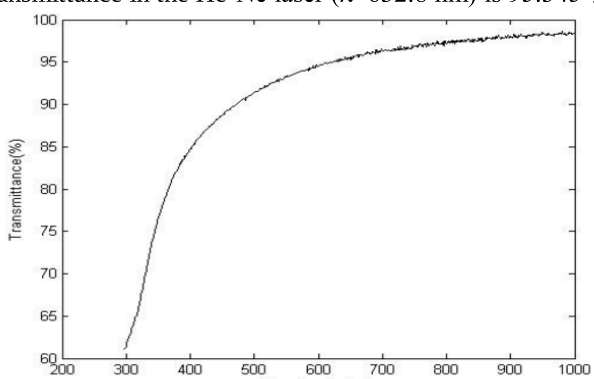


Figure 7. The transmission of $TiO_2$

In this research, input of slab waveguide was taken from a He-Ne laser. It has transmitted by single-mode optical fiber propagation of the waveguide. The light coming from single-mode optical fiber and then propagation of the waveguide was observed in cross section area by a microscope webcam which is connected to a PC.

The propagation of He-Ne laser in the slab waveguide shown in Figure 8. In Figure 8 it can be seen that the laser beam is guided in the slab waveguide which is a singlemode. The surface of slab waveguide is not flat, because the process of spin-coating with 3000 rpm is not stable. The result of fabrication slab waveguide can be use as an optical power transfer (switchhed), the power devider, time measuring devices, etc.

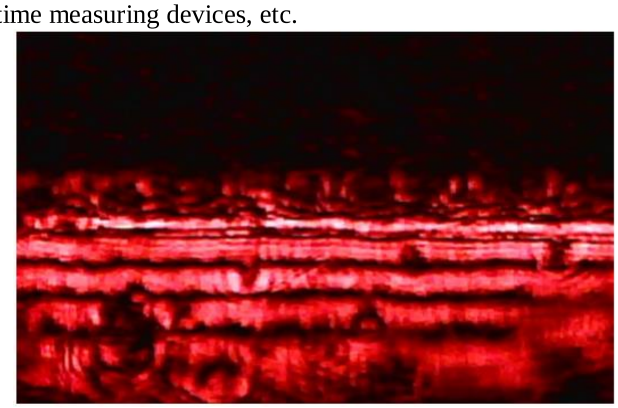

Figure 8. The propagation of He-Ne laser in the slab waveguide

The thickness of the layer was measured using a microscope connected to a computer using pixel shift method. Thickness measurement done to convert the pixel values in units of 1 μm using the equation.

$$\frac{friction}{|X_2 - X_1|} = \frac{50\mu m}{|120-106|} = \frac{50\mu m}{14\,pixel} = 3{,}57\,\mu m./\,pixel \quad (1)$$

In order to obtain the conversion value is 1 pixel = 3.57. Results are incorporated into the software conversion *Supereyes* and then measurements are made by dragging the mouse cursor along a thick layer to be measured and the obtained value of 131.6 μm that shown in Figure 9.

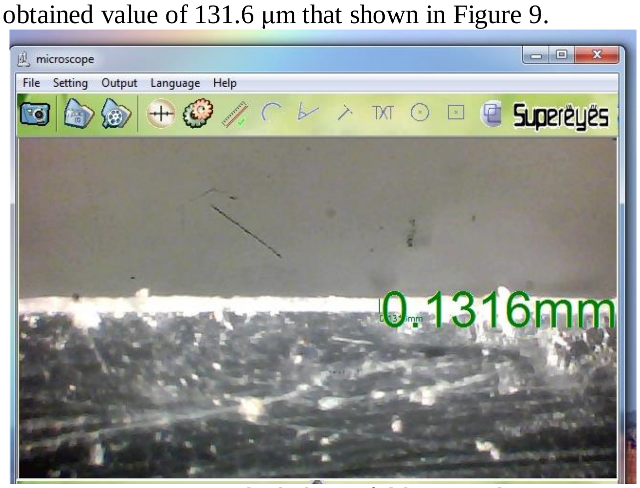


Figure 9. The thickness of slab waveguide

## IV. Conclusion

Fabricated slab waveguide were successfully prepared on corning glass substrate and $TiO_2$ nanoparticles as films using spin coating method with 2-propanol solvent. From the test results of absorbance and transmittance using UV-Vis known that the highest absorption (262 nm) and average transmittance (91%). The thickness of the film obtained 131.6 μm.

## V. Acknowledgements

The authors are thankful to LPDP (the scholarship thesis program).

## References

[1] R. D. Harris and J. S. Wilkinson, "Waveguide surface plasmon resonance sensors," *Sensors Actuators B Chem.*, vol. 29, no. 1–3, pp. 261–267, Oct. 1995.

[2] N. M. Kassim, M. H. Ibrahim, A. B. Mohammad, and M. Yacob, "Polymer Based Multimode Interfence Optical Couplerol," in *Recent Developments in Polymer Waveguides and Devices*, Johor: Universiti Teknologi Malaysia, 2008, p. 41.

[3] T. Touam *et al.*, "Low Loss Sol-Gel TiO2 Thin Films for Waveguiding Applications," *Coatings*, vol. 3, no. 1, pp. 49–58, 2013.

[4] J. D. B. Bradley *et al.*, "Submicrometer-wide amorphous and polycrystalline anatase TiO 2 waveguides for microphotonic devices," *Opt. Express*, vol. 20, no. 21, pp. 8336–8346, 2012.

[5] R. T. Ako *et al.*, "DSSCs with ZnO@TiO2 core–shell photoanodes showing improved Voc: Modification of energy gradients and potential barriers with Cd and Mg ion dopants," *Sol. Energy Mater. Sol. Cells*, vol. 157, pp. 18–27, 2016.

[6] A. Hegazy, N. Kinadjian, B. Sadeghimakki, S. Sivoththaman, N. K. Allam, and E. Prouzet, "TiO2 nanoparticles optimized for photoanodes tested in large area Dye-sensitized solar cells (DSSC)," *Sol. Energy Mater. Sol. Cells*, vol. 153, pp. 108–116, 2016.

[7] N. Tasić *et al.*, “Mesoporous films prepared from synthesized TiO2 nanoparticles and their application in dye-sensitized solar cells (DSSCs),” *Electrochim. Acta*, vol. 210, pp. 606–614, 2016.

[8] V. Nguyen *et al.*, “A CdS/ZnSe/TiO2 nanotube array and its visible light photocatalytic activities,” *J. Colloid Interface Sci.*, vol. 462, pp. 389–396, 2016.

[9] S. A. Yasin, “Characterization Prototype Multimode Interference Device (MMI) For Optical Power,” Institut Teknologi Sepuluh Nopember, 2013.

[10] Y. R. Meifina, “Study About Application of Slab Waveguide Based on Polymethyl Methacrylate (PMMA) Using Spin Coating Technique As Mass Gaug,” Institut Teknologi Sepuluh Nopember, 2013.

[11] Rinawati, “Fabrication and Characterization Directional Coupler Slab Structure Based on Polystyrene and Polymethyl Methacrylate (PMMA) Polimer,” Institut Teknologi Sepuluh Nopember, 2009.

[12] N. Bsiri, M. A. Zrir, A. Bardaoui, and M. Bouaïcha, “Morphological, structural and ellipsometric investigations of Cr doped TiO2 thin films prepared by sol–gel and spin coating,” *Ceram. Int.*, vol. 42, no. 9, pp. 10599–10607, 2016.