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The Deposition of Silver (Ag) on a Glass Substrate (SiO₂) using Direct Current Sputtering Method

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Abstract. The research's aims are to calculate the absorbance and the thickness value of the silver (Ag) thin layer formed on the glass substrate (SiO₂) at various visible wavelengths. The silver (Ag) thin layer was formed using Direct Current Sputtering method. The research showed that the highest absorbance value on the glass (SiO₂) substrate was 4.000 with wavelengths 287.50 nm. While, the lowest absorbance value on the glass (SiO₂) substrate was - 4.000 with wavelengths 262.50 nm and 243 nm. The lowest absorbance value is estimated because of the part of the substrate that has not been completely coated so that the part is not absorbed at all. Using Swanepoel equation we obtained the thickness value of the thin layer equal to 4.692663316 nm with sputtering time of 15 minutes.

1. Introduction

A thin layer or film is one of the many materials that called as nanomaterial. The thickness of a thin layer or film are usually between 10⁻⁶ m to 10⁻⁹ m [1]. It needs certain care or method to form a thin layer with desired characteristic that comply with its application [2]. A thin layer or film was made through a deposition process of target atom onto a substrate [3]. One of the many technologies used for deposition process of target atom onto a substrate was called Direct Current (DC) Sputtering.

DC Sputtering used an ionization process to release target's atoms onto a substrate material. A sputtering system could layer all kinds of metal, metal alloy or non-metal onto a substrate material [4]. Argon gas was use to sputter or deposition a target material onto the surface of substrate material. Argon was used because of its high sputtering energy on material such as titanium and aluminium and it is very effective to release the surface atom of a target material [5]. The substrate material used in this research was glass or silica (SiO₂).

Silica was used because it is easily acquired and relatively cheap. Silica was the main resource material in glass industry, ceramic, silicon and alloy [6]. The target material used in this research was silver (Ag). Silver was an easily forged metal. It has the highest electric conductivity of all elements and the highest thermal conductivity of all metals. It was reflective and non-reactive. It used in many electronic industries. It has relatively high price because of its rarity.

The research's aims are to calculate the absorbance and the thickness value of the silver (Ag) thin layer formed on the glass substrate (SiO₂) at various visible wavelengths. When polychromatic light emitted onto some material, some of the wavelengths will be absorbed by the material.

The transmittance value can be derived from the absorbance value equation:



$$A = \log \frac{I_0}{I} = -\log T \tag{1}$$

$$T = 10^{-A} \tag{2}$$

where I_0 is the incoming light intensity and I is the out coming light intensity [7].

Maximum transmittance value and minimum transmittance value can be used to calculate the reflective value of the thin layer formed using the Swanepoel equation :

$$N_1 = 2n_s \frac{TM_1 - Tm_2}{TM_1 Tm_2} + \frac{n_s^2 + 1}{2} \tag{3}$$

$$N_2 = 2n_s \frac{TM_2 - Tm_1}{TM_2 Tm_1} + \frac{n_s^2 + 1}{2} \tag{4}$$

$$n_1 = \sqrt{N_1 + \sqrt{N_1^2 + n_s^2}} \tag{5}$$

$$n_2 = \sqrt{N_2 + \sqrt{N_2^2 + n_s^2}} \tag{6}$$

where n_1 and n_2 is the reflective value of the thin layer in each wavelengths λ_1 and λ_2 , n_s is the reflective value of the substrate material, N_1 and N_2 is the reflective value of the thin layer, T_{M1} and T_{M2} is the maximum transmittance value, T_{m1} and T_{m2} is the minimum transmittance value.

The thickness value can be calculated using equation:

$$d = \frac{\lambda_1 \lambda_2}{2(\lambda_1 n_2 - \lambda_2 n_1)} \tag{7}$$

where d is the thickness value of the thin layer, λ_1 and λ_2 is the maximum and minimum wavelengths that absorbed by the substrate material, n_1 and n_2 is the reflective value of the thin layer in each wavelengths [8].

2. Materials and Methods

This research was done following the depiction of figure 1.

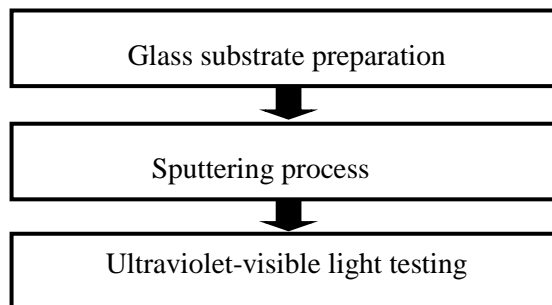


Figure 1. Research scheme

Glass substrate preparation process was done using Matsuzawa digital Micro Hardness Tester. UV-vis testing was done using UV-1800 UV-Vis Spectrophotometer by Shimadzu Scientific Instruments Inc. The ultraviolet wavelengths used in this research are between 190 nm to 400 nm and the visible light wavelengths used are between 400 nm to 1100 nm.

3. Results and Discussion

The result of this research was shown by table 1, table 2 and table 3.

Table 1. UV-vis testing of glass substrate before silver deposition

λ (nm)	absorbance	Chart
291.00	0.010	1
281.00	3.303	2
264.50	0.364	3
254.50	0.364	4
249.00	- 0.364	5
233.50	1.818	6
222.00	2.545	7
209.00	2.545	8
300.50	-0.002	9
289.00	0.001	10
275.00	-4.000	11
260.00	-4.000	12
252.50	-4.000	13
242.00	-4.000	14
229.50	-4.000	15
213.50	-4.000	16
201.50	-4.000	17

Table 2. UV-vis testing of glass substrate after silver deposition

λ (nm)	absorbance	Chart
770.00	3.090	1
563.50	3.154	2
533.50	3.183	3
341.50	3.828	4
287.50	4.000	5
251.50	2.545	6
226.00	3.653	7
846.50	3.071	8
764.00	3.084	9
559.50	3.147	10
523.50	3.169	11
318.50	1.824	12
262.50	-4.000	13
243.00	-4.000	14

Table 3. Transmittance value calculation result

λ (nm)	Absorbance	Transmittance
770.00	3.090	0,0008128305
563.50	3.154	0,0007014552
533.50	3.183	0,0006561452
341.50	3.828	0,0001485935
287.50	4.000	0,0001
251.50	2.545	0,0028510182
226.00	3.653	0,0002223309
846.50	3.071	0,0008491804
764.00	3.084	0,0008241381

λ (nm)	Absorbance	Transmittance
559.50	3.147	0,000712853
523.50	3.169	0,000677641
318.50	1.824	0,014996848
262.50	-4.000	10.000
243.00	-4.000	10.000

3.1 Glass substrate before silver deposition

The glass substrate was observed using Matsuzawa digital Micro Hardness Tester with 40 times magnification before the sputtering process. The result is presented in figure 2.

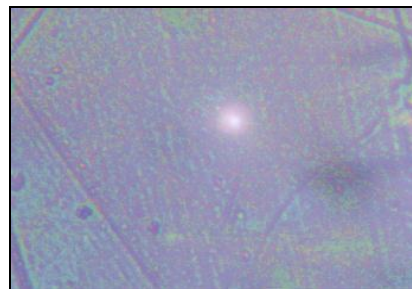


Figure 2. The surface of glass substrate before silver deposition

Figure 2 showed that the surface of glass substrate was smooth. It is shown by the contour-less line that observed on the surface of the glass substrate. The less the contour line observed on the surface of the glass substrate is the better the glass substrate preparation. The relation between the wavelengths and the absorbance value is shown by figure 3.

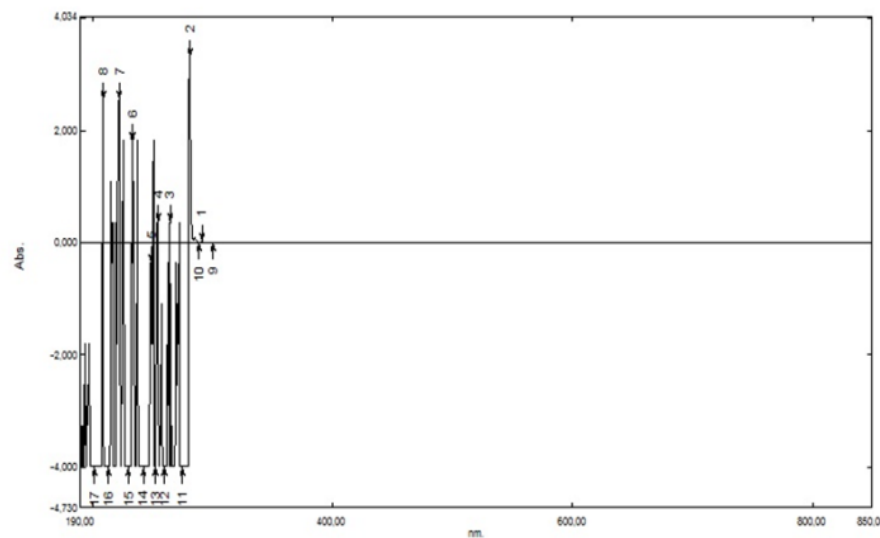


Figure 3. UV-vis testing result of glass substrate before silver deposition

Figure 3 shown that the maximum wavelength absorbed by the glass substrate is equal to 300.50 nm and has absorbance value of -0.0002. It is also shown that the minimum wavelength absorbed by the glass substrate is equal to 201.50 nm and has absorbance value of -4.000.

3.2 Glass substrate after silver deposition

The glass substrate was observed using Matsuzawa digital Micro Hardness Tester with 40 times magnification after the sputtering process. The result is presented in figure 4.

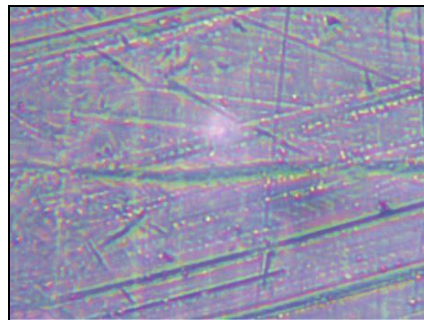


Figure 4. The surface of glass substrate after silver deposition, was captured using Optilab
The relation between the wavelengths and the absorbance value is shown by figure 5.

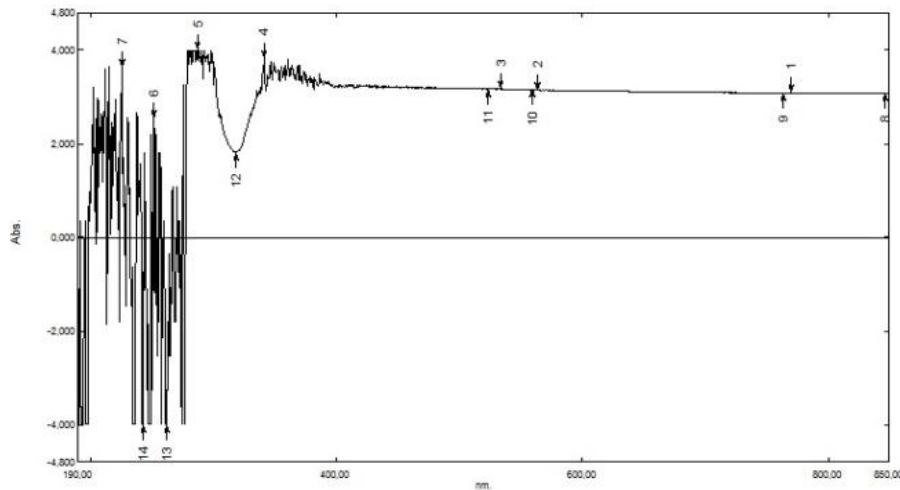


Figure 5. UV-vis testing result of glass substrate after silver deposition

Figure 5 shown that the maximum wavelength absorbed by the glass substrate is equal to 846.50 nm and has absorbance value of 3.071. It is also shown that the minimum wavelength absorbed by the glass substrate is equal to 243.00 nm and has absorbance value of -4.000. The difference of the absorbance value was caused by the roughness of the silver thin layer formed on the surface of the glass substrate.

3.3 Silver thin layer thickness

The calculation using equation (3), (4), (5) and (6) shown that the reflective value of N1 is equal to 20325.5436 and the reflective value of the silver thin layer n1 for wavelength/ λ_1 (243.00 nm) is equal to 201.624892. It is also shown that the reflective value of N2 is equal to 30201.6398 and the reflective value of the silver thin layer n2 for wavelength / λ_2 (262.50 nm) is equal to 245.773859. The calculation using equation (7) shown that the silver thin layer thickness d is equal to 4.692663316 nm.

4. Conclusions

The research showed that the absorbance value on the glass substrate was higher after the silver deposition. The research also showed that the smaller the wavelength emitted to the glass substrate, the greater the absorbance value changed. We obtained the thickness value of the silver thin layer on the glass substrate was equal to 4.692663316 nm.

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