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The effect of annealing temperature variation on the optical properties test of LiTaO₃ thin films based on Tauc Plot method for satellite technology

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8

Abstract. The purpose of the present research is to observe the energy gap of thin films made from LiTaO₃ in 1 M-solubility deposited on n-type Si (111) substrates with annealing temperature variation. The manufacture of thin films has been formed by Chemical Solution Deposition (CSD) method using spin coater on 3000 rpm speed for 30 seconds and performed annealing process using furnace (Nabertherm type B180) at a temperature of 750°C, 800°C and 850°C for 15 hours. The absorbance of thin films is measured by using an Ocean Optics USB2000 device and processed into the energy gap curve using Tauc Plot method. The result shows that the energy gap of thin films associated with indirect transitions are increased from 2.78 eV to 2.93 eV with the rise of annealing temperature. The research shows that the thin films on n-type Si (111) substrates made of LiTaO₃ produces sensitivity to violet light spectrum and have the potential to be developed as a sensor on satellite technology.

3

1. Introduction

Ferroelectric thin films are used for a variety of devices such as ferroelectric memories, infrared pyroelectric sensors and other integrated technologies [1-3]. Lithium tantalate (LiTaO₃) is currently one of the most interesting ferroelectric materials due to the high dielectric constant and high load storage capacity [4, 5]. LiTaO₃ is the object studied intensively over the last few years because it has unique properties [6].

Due to the excellent ferroelectric and pyroelectric characteristics, LiTaO₃ ferroelectric materials are used in electronic devices and optical devices, such as high temperature transducers, lasers, electronic filters and non-linear optical crystals [7, 8]. Ferroelectric materials also have a special



characteristic as they are spontaneously polarized dielectric and able to change the direction of the internal electricity [9, 10].

LiTaO₃ thin film can be created with a number of techniques, e.g. Chemical Solution Deposition (CSD), Pulsed Laser Deposition (PLD), sputtering and Metal Organic Chemical Vapour Deposition (MOCVD), combustion method [11], the Czochralski method [10] and liquid phase epitaxy [12]. These techniques have demonstrated that LiTaO₃ thin films are prepared by the CSD method on n-type Si (111) substrate can function as a sensor [4, 6, 9]. The purpose of the present research determines the energy gap of thin films made from lithium tantalate (LiTaO₃) on n-type Si (111) substrate with the annealing temperature of 750°C, 800°C and 850°C.

2. Experimental Method

The thin film preparation was started by cutting the n-type of Si (111) substrate using a glass cutter with the size of 1×1 cm², then it was cleaned using aqua bidest and then dried [13]. In this experiment, an analytical scale type AND GR-200, Branson 2510 ultrasonicator device, a spin coater, furnace Nabertherm type B180 and an Ocean Optics USB2000 were used as the research devices. LiTaO₃ solution was obtained by mixing chemicals according to reaction equalization [14, 15]:



Based on the reaction equalization, the chemical solution of LiTaO₃ at 1 M-solubility can be produced from a mass composition (by weighing with an analytical scale type AND GR-200) of lithium acetate (Li(CH₃COO), 99.5%) with 0.1650 gram, tantalum pentoxide ((Ta₂O₅), 99.9%) with 0.5524 gram and also using 2.5 ml of 2-methoxyethanol (CH₃OCH₂CH₂OH) as solvent. The procedure was continued with sonication the chemical solution of LiTaO₃ for 60 minutes by using BRANSON 2510 as the ultrasonicator device to obtain the homogeneous solution.

The Chemical Solution Deposition (CSD) method is the coating process of LiTaO₃ on the surface of n-type Si (111) substrates which is placed on the rotatable disc [14, 15]. The coating process on the surface of each substrate and rotating process (using a spin coater device) at speed of 3000 rpm during 30 seconds were repeated three (3) times with one (1) minute interruption time [14, 15]. The annealing process (by furnace Nabertherm type B180) with a temperature of 750°C, 800°C, 850°C for 15 hours was used to shape crystal of LiTaO₃ solution on n-type Si (111) substrates [16].

In this research, Ocean Optics USB2000 was used to measure the absorption spectrum of visible light of thin films. The results of measurement obtained in form of the recorded of absorbance data at a wavelength of visible light which indicates electron excitation in the crystal structure of LiTaO₃. Related to it, the Tauc Plot method was used to estimate the magnitude of energy band by withdrawing the line with a sloping curve from the relationship between $h\nu$ (x-axis) and $(\alpha h\nu)^n$ (y-axis).

3. Result and Discussion

The absorbance data at a wavelength of visible light of thin film was obtained through measurement using spectroscopy (Ocean Optics USB2000) and presented in the curve form (see Figure 1). The result shows the values shown as seen in Figure 2 (x-axis and y-axis) which were determined from the following formula [4, 17, 18]:

$$\alpha = 2.303 \frac{\text{absorbance data}}{d} \quad (2)$$

$$y\text{-axis} = (\alpha h\nu)^{0.5} \quad (3)$$

$$x\text{-axis} = h\nu \quad (4)$$

with: d = thickness of LiTaO₃ on substrate (cm)

absorbance data = the values from measurement by using spectroscopy

α = absorption coefficient (cm⁻¹)

$h\nu$ = photon energy (eV)

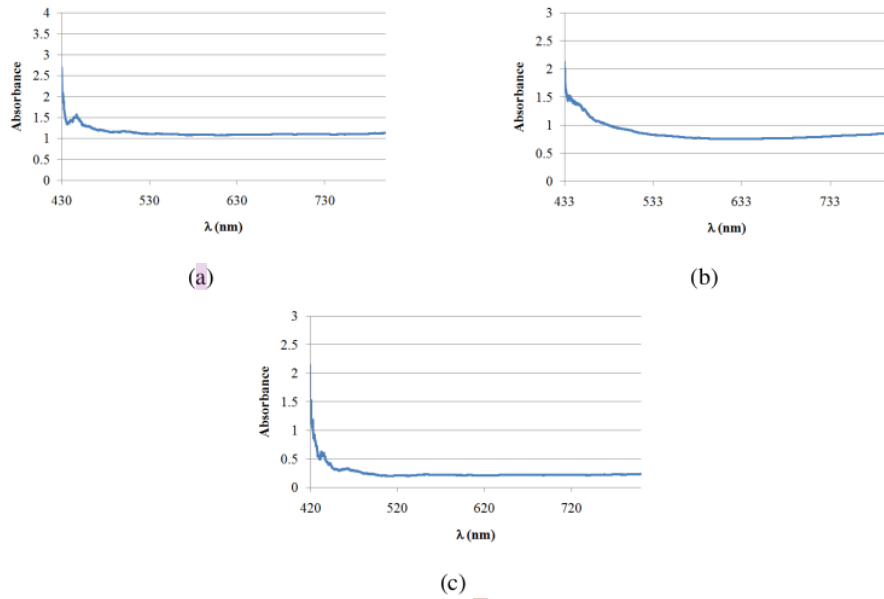


Figure 1. Absorption spectrum: (a) 750°C (b) 800°C (c) 850°C

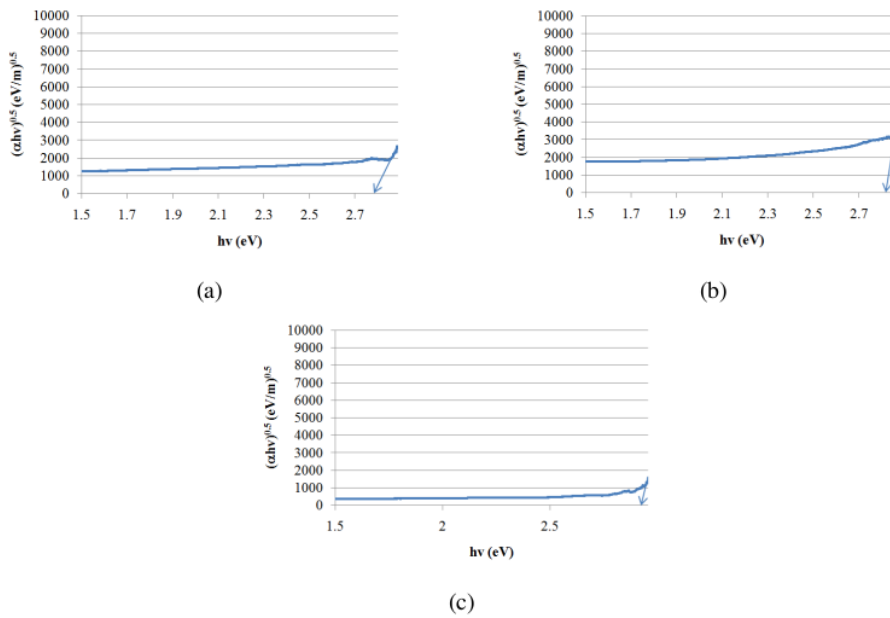


Figure 2. Energy gap: (a) 750°C (b) 800°C (c) 850°C

The energy gap values (Table 1) were estimated from Tauc Plot method by withdrawing the line with a sloping curve which was in correspondence between x-axis and y-axis (see Figure 2). The wavelength refers to energy gap value of thin films were determined from the following formula [17, 19]:

$$\lambda = \frac{h c}{(1.602 \times 10^{-19} \text{ J})(\text{energy gap})} \quad (5)$$

with: h = Planck's constant ($6.626 \times 10^{-34} \text{ J}\cdot\text{s}$)
 c = speed of light ($2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$)
 energy gap = the values from Table 1

Table 1. The energy gap of thin films

Annealing temperature (°C)	Energy gap (eV)
750	2.78
800	2.82
850	2.93

Table 2. The wavelength and sensitivity to specific light spectrum on each thin film

Annealing temperature (°C)	Wavelength of light (nm)	Spectrum color of light (Based on literature [20])
750	446	Violet
800	440	Violet
850	424	Violet

4. Conclusion

In this research, LiTaO₃ thin films was successfully made with spin coating. The energy gap of thin films associated with indirect transition shows increasing from 2.78 eV to 2.93 eV with the rise of annealing temperature. The absorbance of thin films was obtained by using an Ocean Optics USB2000 device in the wavelength of visible light in the range between 424 nm and 446 nm. The research concludes that the thin films on n-type Si (111) substrates made from LiTaO₃ produce sensitivity to violet light spectrum and have the potential to be developed as a sensor on satellite technology.

6. Acknowledgment

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