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The Effect of Cerium Doping on LiTaO3 Thin Film on Band Gap Energy

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Abstract

Lithium tantalite LiTaO3 was grown on a Si Type-P (100) substrate by chemical solution deposition and spin coating methods at a speed of 3000 rpm for 30 seconds with an annealing temperature of 800 ° C, 900 ° C. This study aims to determine the effect of temperature variations on the band gap energy. The results show that the energy band gap value of the thin film has a significant impact on the interpretation of annealing temperature. It can be seen that a high energy band gap peak occurs at an annealing temperature of 900 ° C and a time of 15 hours of the energy band gap of 1,49 eV. This shows the effect of temperature variations on the energy band gap to move from the valence band to the conduction band, which will produce current.

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INTRODUCTION

The development of ferroelectric materials, especially lithium tantalate, produces a new generation of devices [1],[2]. It is hoped that pyroelectric properties can be applied to infrared sensors, polarization properties can be applied as Non-Volatile Ferroelectric Random-Access Memory (NVRAM), and electro-optic properties can be used in infrared thermal switches [3]. The nature of a ferroelectric material is used for the needs of electronic devices [4]. The role of LiTaO3 ferroelectric material is exciting to study because, in its application, it can be used as an infrared sensor [5]. LiTaO3 is an object that has been intensively studied in recent years because it has unique properties [6],[7]. LiTaO3 is ferroelectric at room temperature. From several studies, LiTaO3 is an optical, pyroelectric, and piezoelectric material [8]. LiTaO3 has a high dielectric constant and a high charge storage capacity. In addition, LiTaO3 is a non-hygroscopic crystal that is not easily damaged by its optical properties. This property makes LiTaO3 superior to other materials [9].

Intrinsic semiconductors consist of only one element, such as Si only or Ge only. In Si semiconductor crystals, 1 Si atom, which has 4 valence electrons, is bonded to 4 other Si atoms [10],[11]. In the intrinsic semiconductor crystal Si, the primitive cell is cuboid. The bond that occurs between adjacent Si atoms is a covalent bond. This is due to the sharing of 1 electron by two adjacent Si atoms. According to the energy band theory, at T = 0 K, the valence band of a semiconductor is filled with electrons, while the conduction band is empty. The two bands are separated by a small energy gap in the range of 0.18 - 3.7 eV. At room

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temperature Si and Ge have energy gaps of 1.11 eV and 0.66 eV [12], [13].

In this study, a thin film of LiTaO3 was deposited on a silicon substrate using a chemical solution deposition technique. Thermal annealing was also carried out to obtain a better level of crystallinity with increasing temperature [14],[15],[16],[17]. Several characterization methods were used to see the experimental results. A spectrophotometer is used to know the absorbance, reflectance, and transmittance wavelength values to determine the band gap energy value in the thin film layer [18],[19]. Besides, it is used to analyze the sample structure of other elements as the effect of variations in thermal annealing. Therefore, the purpose of this study was to determine the effect of cerium doping on lithium tantalate thin films on band gap energy using the tauc plot method[20].

METHOD

The materials used in this research are Lithium Acetate [$LiO_2C_2H_3$] powder, Tantalum Oxide [Ta_2O_5] powder, 2-methoxy ethanol [$C_3H_8O_2$], Niobium [NiO_3], p-type Si (100) substrate, deionized water, acetone PA [CH_3COCH_3, 58.06 g/mol], cerium, methanol PA [CH_3OH, 32.04 g/mol], fluoride acid (HF), glass preparations, silver paste, fine copper wire, and aluminum foil.

In this study, $LiTaO_3$ thin films were made using the chemical solution deposition (CSD) method, which has long been developed for the growth of *perovskite* thin films [21],[22]. This method has the advantage that the procedure is easy, the cost is relatively economical, and it gets good results. The chemical solution deposition (CSD) method is a method of making films by depositing chemical solutions on the surface of the substrate, then prepared with a spin coater at a speed of 3000 rpm for 30 seconds each drop of a $LiTaO_3$ solution [23],[24], the step of this research can be seen in fig. 1.

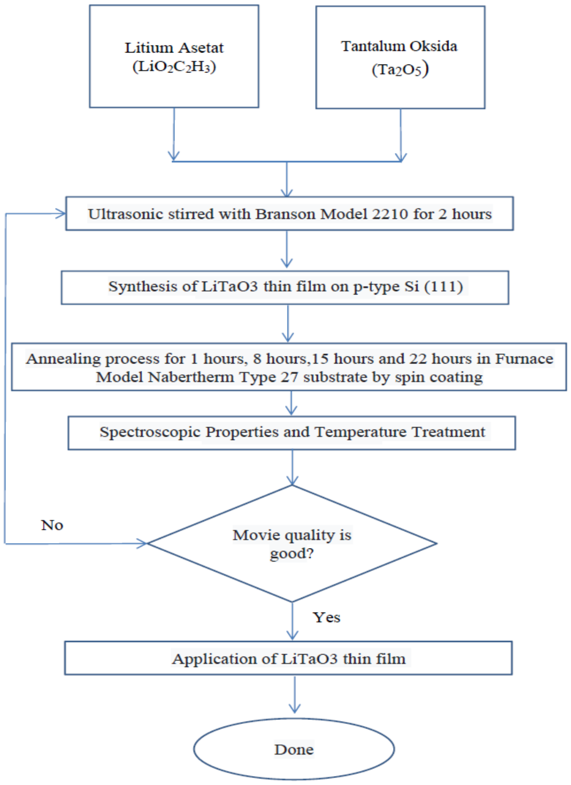

Figure 1. A flow chart

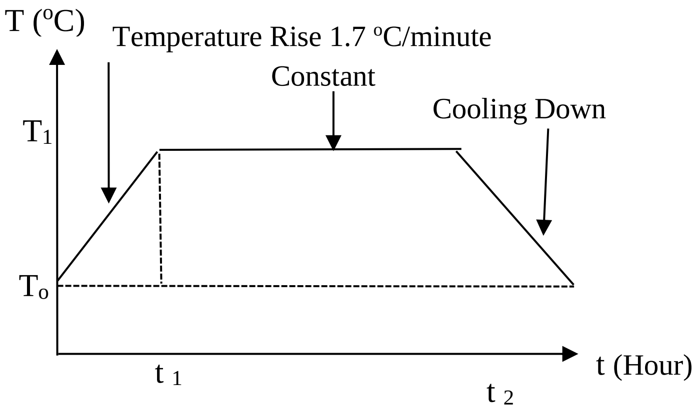

Figure 2. The Annealing Process

The annealing process is carried out in stages using Furnace Vulcan TM 3-130 [25],[26]. The purpose of annealing is to diffuse the $LiTaO_3$ solution with a silicon substrate starting at room temperature and then raised to the annealing temperature of 800°C, 900°C. With an increase in temperature of 1.7°C/ min [27] and held constant for 8 hours at the annealing temperature [28]. Further cooling is carried out until returning to room temperature.

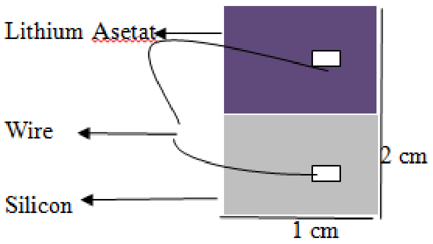

Figure 3. $LiTaO_3$ Thin Film Design

The energy gap is obtained by plotting the relationship between:

⍰*h* ⍰ = ⍰ (*h* ⍰ − ⍰⍰) ⍰ (1)

h ⍰ = [ln (⍰⍰⍰⍰−⍰⍰⍰⍰) /(⍰−⍰⍰⍰⍰)] 2 (2)

Description: ⍰ is the absorbance coefficient (cm^-1), h is the Planck constant (4.135669 x 10-15 eV · s), v is the light frequency (Hz), Egis the bandgap energy (eV), R is the reflectance value (%), and d is the film thickness (cm).

RESULTS AND DISCUSSION

The absorption spectrophotometer has five main components: the radiation source, monochromator, sample, detector, and recorder. The radiation source used is the xenon lamp which is commonly used in spectrophotometers, while the monochromator functions to produce a radiation beam with one wavelength. When radiation or white light is passed through a solution, radiation with a particular wavelength will be absorbed selectively, and other radiation will be transmitted or reflected.

The spectrophotometer is an analytical method based on the absorption of electromagnetic radiation. Light consists of radiation to the sensitivity of the human eye. Different wavelengths will produce different light, while a mixture of light with wavelengths will make up white light. White light covers the entire visible spectrum from 400 to 780 nm, while infrared light is in the spectrum above a wavelength of 780 nm.

The energy gap is a minimum energy gap that an electron must have to move from the valence band to the conduction band. The electrons in this valence band can move to the conduction band with external energy, which can come from the external electric field, thermal energy, and photon energy. Measurement of the optical properties of thin films uses wavelengths in the range of 340 nm to 1020 nm. The wavelength range includes ultraviolet, visible, and infrared light.

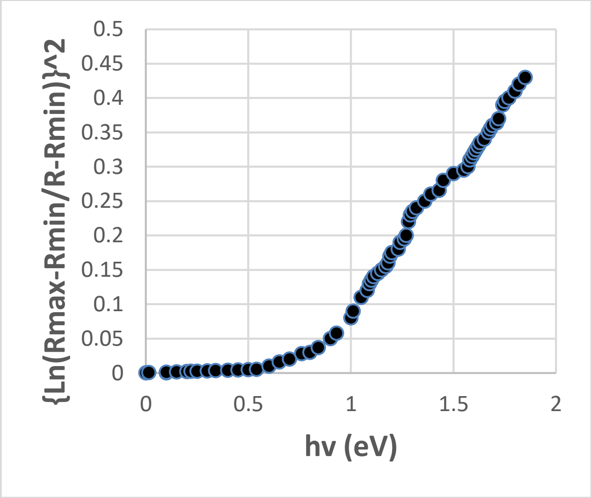

Figure 4. Band Gap Energy $LiTaO_3$ Thin Film doping cerium at Temperature 800 °C

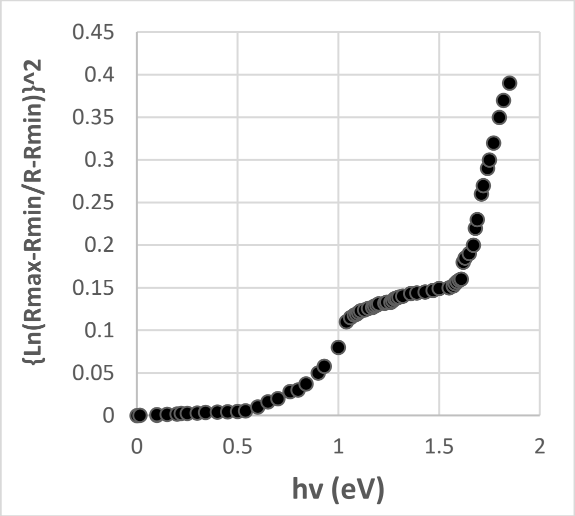

Figure 9. Band Gap Energy $LiTaO_3$ Thin Film doping cerium at Temperature 900°C

The resulting curve shows that the energy band gap value of the thin film has a significant effect with annealing temperature variations from 800 °C and 900 °C. Still, shown in the graph, the dominant peak energy band gap occurs at an annealing temperature of 900 °C. This happens when the electrons move towards the hole, it can be seen that a high band gap energy peak occurs at an annealing temperature of 900 °C and a 15-hour band gap energy time of 1.49 eV. This shows the effect of temperature variations on the energy band gap to move from the valence band to the conduction band, which will produce current.

CONCLUSION

Based on the results obtained, it is concluded that the energy band gap value of the thin film has a significant effect with variations in annealing temperature of 800 ° C and 900 ° C. High energy band gap occurs at an annealing temperature of 900 ° C and in 15 hours the energy band gap is 1,49 eV.

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