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The Effect of Electrical Conductivity of $LiTaO_3$ Thin film to Temperature Variations

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Abstract

Lithium tantalite has the chemical formula $LiTaO_3$, with Si Type-P (100) substrate with chemical solution deposition and spin coating methods with a speed of 3000 rpm for 30 seconds. $LiTaO_3$ has a concentration of 2.5M and annealing temperatures of 550 ° C, 600 ° C, 650 ° C, 700 ° C, 750 ° C, 800 ° C. $LiTaO_3$ thin films are characterized by LCR meters. The value of the electrical conductivity of a material can increase because it conducts an electric current. The electrical conductivity value of $LiTaO_3$ films obtained ranged from 10^{-6} S/cm to 10^{-5} S/cm. The effect of annealing temperature on the value of optimal electrical conductivity when the annealing temperature is 800 °C but the value of electrical conductivity decreases when the annealing temperature is carried out at 750 °C. The decrease in the value of electrical conductivity is related to the annealing temperature caused by the evaporation experienced by the thin film $LiTaO_3$. The value of the electrical conductivity obtained from the $LiTaO_3$ films ranged from 1.90 - 9.95 μS/cm, this results indicate that the thin film $LiTaO_3$ made is a semiconductor material.

Keywords: *Litium, Conductivity, Spin coating, Semiconductor.*

1. Introduction

Semiconductors are materials with electrical conductivity between the insulator and the conductor. This material is very useful in the electronics field, because its electrical conductivity can be changed by injecting other material (commonly called a container) [1], [2]. Semiconductors are the basic elements of electronic components such as diodes, transistors, and ICs (integrated circuits) [3]. Semiconductors are very widely used, especially since the discovery of transistors in the late 1940s, germanium (Ge), and Gallium Arsenide (GaAs) .E recently, silicon became famous after it was discovered how to extract silicon material from nature [4], [5]. Ferroelectric materials, especially those based on lithium tantalate ($LiTaO_3$) [6] mixture, have pyroelectric properties that can applied to infrared sensors [7], polaryzability can be applied as Non Volatile Ferroelectric Random Access Memory (NVRAM), and electro-optic properties can be used in infrared thermal switches [8], [9].

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The nature of a $LiTaO_3$ ferroelectric material is very interesting to study because in its application it can be used as an infrared sensor [10]. $LiTaO_3$ is an object of intensive research over the past few years because it has unique properties. $LiTaO_3$ is ferroelectric at room temperature [11], [12]. From several studies, $LiTaO_3$ is an optical, optoelectric and piezoelectric material, which has a Currie temperature of (601 ± 5.5) ° C [13]. In addition, $LiTaO_3$ is a non-hygroscopic crystal which is not easily damaged by its optical properties, this characteristic makes $LiTaO_3$ superior to other materials. The lithium tantalate film ($LiTaO_3$) has a higher diffusion coefficient speed with increasing temperature [14]. The dielectric properties of a material are determined by including its crystal structure and stoichiometric composition [15]. The dielectric constant value of $LiTaO_3$ increases with increasing temperature, which is caused by an increase in the quality of its crystallinity [16], [17].

In this study, the $LiTaO_3$ thin film layer was deposited on a silicon substrate using chemical solution deposition. Thermal annealing is also carried out to get a better level of crystallinity with rising temperatures. Several characterization methods were carried out to see the results of the experiments. LCR meter is used to see the electrical conductivity value of thin film layers. And analyze the structure of the sample that has been doped with other elements as the influence of thermal annealing variation. The purpose of this study was to determine the effect of temperature variations on electrical conductivity using an LCR meter.

2. Methodology

This research was conducted at the Basic Physics Laboratory, Faculty of Mathematics and Natural Sciences, Pakuan University. The materials used in this research are Lithium Acetate [LiO2C2H3] powder, Tantalum Oxide [Ta_2O_5] powder, 2-methoxyethanol [C3H8O2], Niobium [NiO3], Rubidium [RuO_2] powder, p-type Si (100) substrate, deionized water , acetone PA [CH3COCH3, 58.06 g/mol], methanol PA [CH3OH, 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 [18]. This method has the advantage that the procedure is easy, the cost is relatively economical, and get good results. Chemical solution deposition (CSD) method is a method of making films by depositing chemical solutions on the surface of the substrate [19], then prepared with a spin coater at a speed of 3000 rpm for 30 seconds each drop of a $LiTaO_3$ solution.

The annealing process is carried out in stages using Furnace Vulcan TM 3-130. The purpose of annealing is to diffuse the $LiTaO_3$ solution with a silicon substrate starting at room temperature and then raised to annealing temperature of 800ºC with an increase in temperature of 1.7ºC/ min and held constant for 8 hours at the annealing temperature. Further cooling is carried out until returning to room temperature [20].

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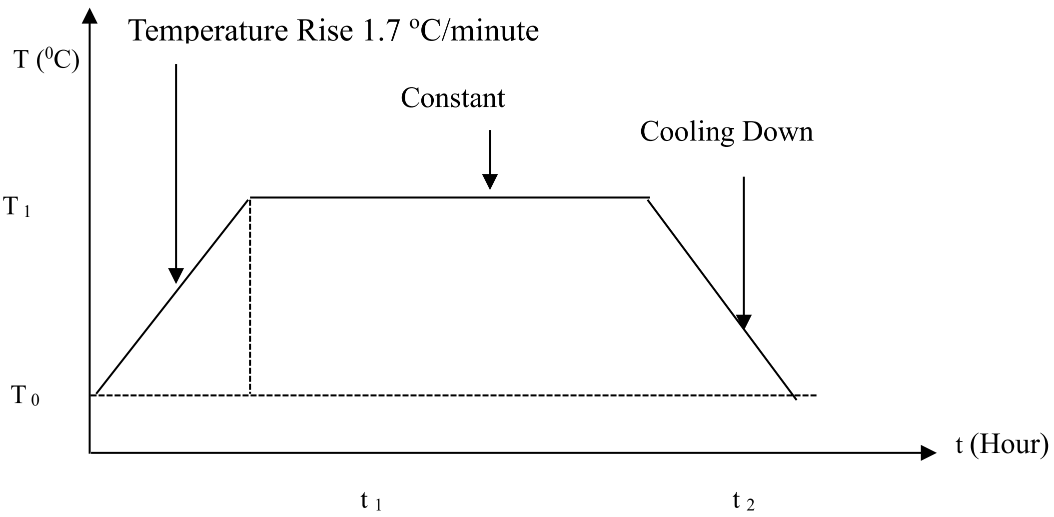

Figure 1. Annealing Process

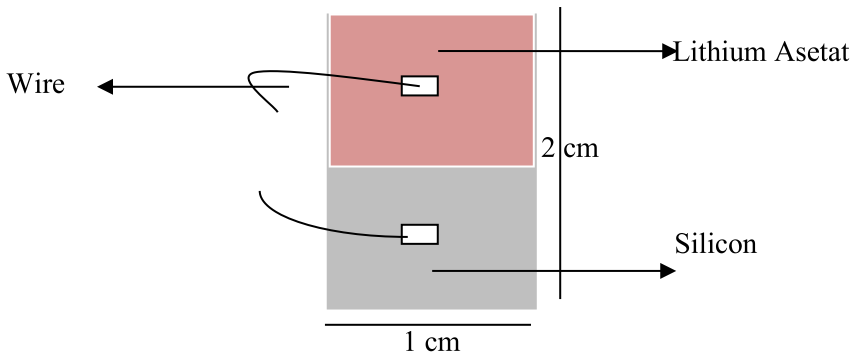

Figure 2. $LiTaO_3$ Thin Film Design

2.1. Characterization of Electrical Conductivity

Electrical conductivity is measured using LCR meters with various intensity variations, namely at 0 lux (dark), 1000 lux, 2000 lux, 3000 lux, and 4000 lux. From the instrument the conductance value (G) is obtained. This conductance data is used to calculate the value of electrical conductivity. The value of electrical conductivity can be found from equation (3.1). The electrical conductivity data of the films obtained will be compared with the literature data whether the film formed includes conductor, semiconductor or insulator material.

One of the characteristics of the p-n connection is the thin film electrical conductivity test. Based on the value of the electrical conductivity of a material can be divided into three parts, namely conductors, semiconductors and insulators. Figure 3. Shows that for insulators the material is in the range of 10^{-18} S/m -10^{-8} S/m, the semiconductor is in the interval of 10^{-8} S/cm - 10^{3} S/cm and the conductor is in the interval of 10^{3} S/cm - 10^{8} S/cm [21], [22].

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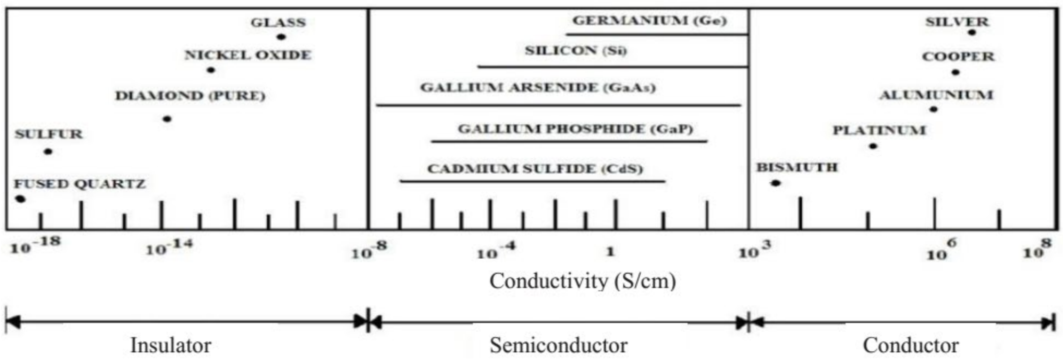

Figure 3. Spectrum of Electrical Conductivity [21], [25]

Semiconductor materials have electrical conductivity values between (10^{-8}to10^{3}) S/cm [23]. Electrical conductivity values can be found from equation (2.1):

$$\sigma = Gl\ A \qquad (2.1)$$

Where σ, l, G, and A are respectively the electrical conductivity of the material, the distance between contacts, the conductance, and the cross-sectional area [24].

The value of electrical conductivity at high temperatures occurs due to ion diffusion and almost no electron contribution. Therefore the electrical conductivity is proportional to the diffusion coefficient according to equation (2.2):

$$\sigma = kd\ [Cq2\ kT]\ D \qquad (2.2)$$

σ is the electrical conductivity by ion conduction, C and qd are the concentration and charge of imperfections that play a role, k depending on the type of imperfection; kd = 1 for interstitial ions, k and T are boltzman constants and Temperature [25], [26].

3. Result and Discussion

Measurement of the electrical conductivity value of thin films was carried out in 5 different conditions namely dark (0 lux), with lamps 1000 lux, 2000 lux, 3000 lux, and 4000 lux. Figure 4. Shows that the value of electrical conductivity increases with increasing light intensity. The increase in electrical conductivity is due to the electrons in the valence band being activated to the conduction band. The electrons in the free conduction band move under the influence of the electric field so that more electrons are excited into the conduction band due to irradiation of light which causes the current to increase, thus the electrical conductivity also increases and vice versa the resistance value will decrease because the electrical conductivity and resistance have an inverse relationship.

The value of the electrical conductivity of a material depends on the material. Temperature affects the resistance value and electrical conductivity of a material. The value of the electrical conductivity of a material indicates that it is an insulator, a semiconductor or a conductor. The magnitude of the value of electrical conductivity is inversely proportional to the resistance. Electrical conductivity will increase if the resistance of a material decreases. Materials which are electrical conductor insulators will

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increase if the temperature is increased. On the contrary conductor material if the temperature is increased the conductivity value decreases.

The electrical conductivity of each sample with annealing temperature variation can be calculated using equation (2.1). The contact area (A) and the distance between contacts (1) in each sample affect the calculation of electrical conductivity. Semiconductor material has an electrical conductivity value in the interval between (10^{-8}to10^{3}) S/cm. The electrical conductivity value of $LiTaO_3$ films obtained ranged from 10^{-6} S/cm to 10^{-5} S/cm. This shows that the $LiTaO_3$ film is a semiconductor material. Semiconductors are materials with electrical conductivity between the insulator and the conductor. The material properties of both conductors, insulators, and semiconductors lie in the structure of the path or energy bands of the atoms, which distinguishes whether the material includes conductors, insulators, or semiconductors is energy gap.

The influence of temperature on the value of electrical conductivity has a directly proportional relationship, meaning that an increase in annealing temperature causes an increase in the value of electrical conductivity. This occurs due to an increase in annealing temperature causing an increase in evaporation of the thin film so that the thickness of the thin film layer decreases and the structural defects decrease. The increase in electrical conductivity due to flowing electrons will increase due to scattering with crystal defects that tend to decrease. In the measurement of electrical resistance and conductivity beforehand it was known that the thin film $LiTaO_3$ used was a semiconductor material. Semiconductor material that forms a p-n junction makes it possible to produce currents and voltages when given the appropriate energy for electrons and diffused holes.

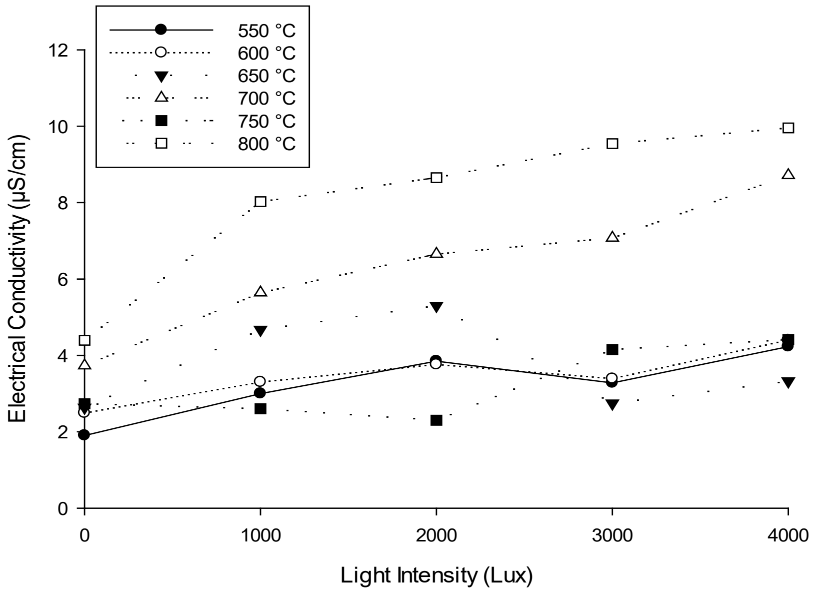

Figure 4. Relationship Electrical Conductivity and Light Intensity

Figure 4. Shows the electrical conductivity curve of $LiTaO_3$ thin films as a function of light intensity. The electrical conductivity curves show that electrical conductivity is relatively rising as a function of light intensity which will increase the value of electrical conductivity. The electrical conductivity value of a material depends on the nature of the material. The value of the electrical conductivity of a material can increase because it conducts an electric current. The electrical conductivity value of $LiTaO_3$ films obtained ranged from 10^{-6} S/cm to 10^{-5} S/cm. This shows that the $LiTaO_3$ film is a semiconductor

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4. Conclusion

Based on the results it was concluded that the electrical conductivity value of thin films increases with increasing light intensity and the electrical conductivity value obtained by $LiTaO_3$ films obtained ranges from 1.90 - 9.95 μS/cm. These results indicate that the $LiTaO_3$ thin films made are semiconductor materials. $LiTaO_3$ thin films obtained are the forerunners of infrared sensors.

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