Classification of undoped and 10% Ga2O3-doped LiTaO3 thin films based on electrical conductivity and phase characteristic

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Submission date: 14-Apr-2023 09:27PM (UTC+0700)
Submission ID: 2064439502
File name: 2_jeas_0617_6127.pdf (231.16K)
Word count: 2004
Character count: 11228

VOL. 12, NO. 12, JUNE 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

CLASSIFICATION OF UNDOPED AND 10% Ga_2O_3-DOPED $LiTaO_3$ THIN FILMS BASED ON ELECTRICAL CONDUCTIVITY AND PHASE CHARACTERISTIC

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ABSTRACT

This experiment aims to investigate the electrical conductivity and the resonance frequency of thin films. The materials of thin film made from 7059 corning glass substrate, lithium acetate, tantalum pentoxide, gallium oxide and also using 2-methoxyethanol as solvent. The growth of thin film is done by using the tool of spin coater at 7059 corning glass substrate with dimension 1×1 cm^2 and annealed in furnace for eight hours with a temperature of 550 ºC. Thin films also have been prepared by Metal Organic Chemical Vapor Deposition (MOCVD) technique to create the aluminum contacts at 7059 corning glass substrate and the thin film layer with dimension 2×2 mm^2. The thin film is measured by using LCR meter to found the data of conductance and phase in range frequency at 50Hz - 5MHz. The results of electrical conductivity curve shows in range 10^{-8} - 10^{-6} and $LiTaO_3$ with doping (10%) Ga_2O_3 shows increasing the number of resonance frequency. Based on these results, it can be concluded that the thin films classified into semiconductormaterial and 10% Ga_2O_3-doped $LiTaO_3$ generates the increasing number of resonance because of vibration from Ga_2O_3 ion.

Keywords: thin film, semiconductor, $LiTaO_3$, Ga_2O_3, the electrical conductivity.

INTRODUCTION

Ferroelectrics thin film has been used in variety of applications for electronic and optical electricity [1]. One of the chemical material could be used to making thin film layer is Lithium Tantalate ($LiTaO_3$). Based on the characteristic of ferroelectric material, one of the thin film which is made from $LiTaO_3$ material also could have the properties of piezoelectric, pyroelectric, electro-optical and nonlinear optical coefficients [2-4]. $LiTaO_3$also have the high dielectric constant and high load storage capacity [5, 6].

$LiTaO_3$ is a memberof alkali tantalatewithin the R3c space group ofperovskite crystal structure[7-10]. Based on the transport of electrons, the phenomenon of conductivity in materials is influenced by the ionization impurity and electron-hole pairs [11, 12] that related with the ability of conduction. Figure-1 shows the range of electrical conductivity for 3 materials (insulator, semiconductor and conductor) [13].

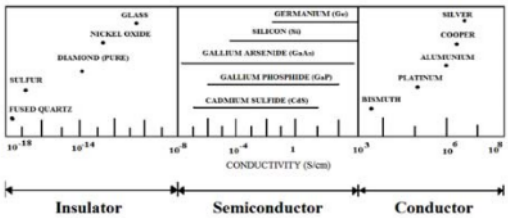

Figure-1. Range of electrical conductivity.

One of the methods that used to manufacture the thin film layer is Chemical Solution Deposition (CSD) [5, 14]. Chemical Solution Deposition (CSD) is the coating process of chemical solution on to the surface of substrate [2, 15]. In addition, this experiment also using spin coating technique to control stoichiometric movement of the chemical solution during the rotation process [6, 16]. The aims of this experiment are classify of thin films that have been made based on characteristic of electrical conductivity and also resonance frequency based on characteristic of phase.

METHODOLOGY

The equipments that used in this experiment are an analytical scale type ADAM equipment, a BRANSON 2510 ultrasonic device, a spin coater, a VULCAN ™ 3-130 furnace, a HIOKI 3532-50 LCR HiTESTER. The materials of thin film made from 7059 corning glass substrate, lithium acetate [$Li(CH_3COO)$, 99.99% purity], tantalum pentoxide [(Ta_2O_5), 99.8% purity], gallium oxide [(Ga_2O_3), 99.998% purity] and 2-methoxyethanol [$(CH_3OCH_2CH_2OH)$]. In this experiment, the substrate of 7059 corning glass was cutted by using a glass cutter with dimension 1×1 cm^2. The substrate washed by using aqua bidest for 30 seconds then drying with tissue.

The chemical formula of thin film layer at solubility of 1 M that has been produced by mixing:

a. Lithium acetate [$Li(CH_3COO)$, 99.99% purity] with a mass of 0.1650 gram.
b. Tantalum pentoxide [(Ta_2O_5), 99.8% purity] with a mass of 0.5524 gram.
c. Gallium oxide [(Ga_2O_3), 99.998% purity] with a mass of 0 gram as 0% doping and a mass of 0.0590 gram as 10% doping.
d. 2.5 ml of 2-methoxyethanol [$CH_3OCH_2CH_2OH$] as solvent.

The materials were weighed with an analytical scale type ADAM equipment. Next, the solution was sonicated with BRANSON 2510 as an ultrasonic device for 90 minutes to get a homogeneous $LiTaO_3$ solution.

The growth of thin film was done by using the tool of spin coater on speed of 3000 rpm for 30 seconds. The coating process of the thin film layer at 7059 corning glass substrate with dimension 1×1 cm^2 was repeated three times in each interrupt time for one minute by using Chemical Solution Deposition (CSD) method. The annealing process that were done by using furnace (type VULCAN ™ 3-130) intended to shaping crystal of $LiTaO_3$ solution (without and with doping (10%) Ga_2O_3) at 7059 corningglass substrate with a temperature of 550 ºC for eight hours.

The contacts of thin film were created by closing the substrate using aluminum foil with leaving a small hole dimensionless 2×2 mm^2 on sides 7059 corning glass substrate and the layer of thin film. The next process was continued by creating aluminum contacts using Metal Organic Chemical Vapor Deposition (MOCVD) technique, then installation of fine copper wire using a silver paste on the contacts surface. Finally, the thin filmswere measured by using LCR meter (HIOKI 3532-50 LCR HiTESTER) to found the data of conductance and phase at a range frequency of 50 Hz - 5 MHz (see Figure-2).

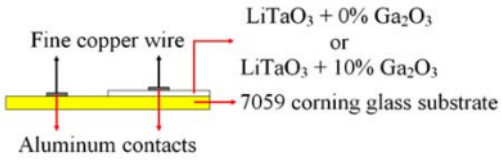

Figure-2. Layers of thin film.

RESULTS AND DISCUSSIONS

The conductance of thin films were measured by using LCR meter (HIOKI 3532-50 LCR HiTESTER) and displayed in the form of curve (see Figure-3) at a range frequency of 50 Hz - 5 MHz.

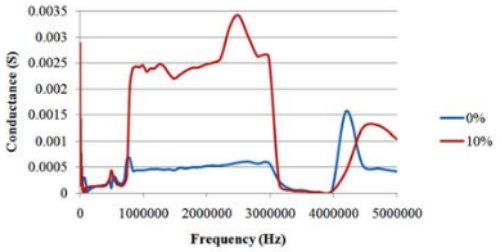

Figure-3. Curve of conductance.

From conductance data, the value of resistance (R) can be calculated by using the equation (1)[17] and displayed in the form of curve (see Figure-4) at a range frequency of 50 Hz - 5 MHz.

$$R = \frac{1}{G} \quad (1)$$

with:
R = resistance (unit: Ω)
G = conductance (from measurement data)

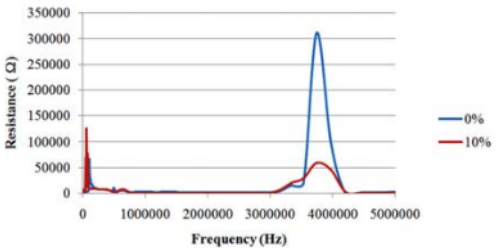

Figure-4. Curve of resistance.

The next calculation was continued by following the equation (2) to obtain the value of electrical conductivity [11, 17] and displayed in the form of curve (see Figure-5) at a range frequency of 50 Hz - 5 MHz.

$$\sigma = \frac{L}{RA} \quad (2)$$

with:
σ = electrical conductivity (unit: S/cm)
L = film thickness(1×10^{-4} cm)
R = resistance (unit: Ω)
A = aluminum contact surface area (4×10^{-2} cm^2)

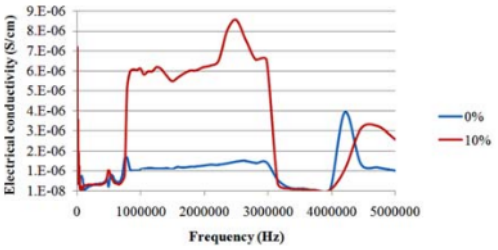

Figure-5. Curve of electrical conductivity.

Figure-5 shows the curve of electrical conductivity as a function of frequency according to calculation from equation (2) and it is seen that thin films shows in interval 10^{-8} - 10^{-6}. Based on Figure-1, it can be classified that thin films are semiconductor materials. The phase of thin films were measured by using LCR meter (HIOKI 3532-50 LCR HiTESTER) and displayed in the form of curve (see Figure-6).

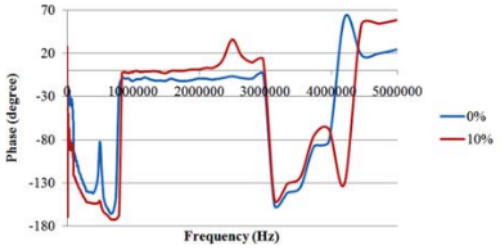

Figure-6. Curve of phase.

In Figure-6, the resonance frequency from $LiTaO_3$ without (0%) doping Ga_2O_3 is 4101779 Hz, but the resonance frequency from $LiTaO_3$ with (10%) doping Ga_2O_3 are 1801953 Hz, 2983979 Hz and 4241266 Hz. It can be concluded that $LiTaO_3$ with doping (10%) Ga_2O_3 afford increasing the number of resonance frequency compared with $LiTaO_3$ without (0%) doping Ga_2O_3.

CONCLUSIONS

In this experiment, the curve that describing electrical conductivity was used to classify the thin films, and the points of frequency on the curve of phase was used to describing the number of resonance frequency in specific point.Based on the results of this experiment, it can be concluded that the thin films are classified into semiconductor material and 10% Ga_2O_3-doped $LiTaO_3$ generates the increasing number of resonance which is indicate the vibration from Ga_2O_3 ion in specific frequency.

ACKNOWLEDGEMENT

This research work was supported by PEKERTI Research Grand 2016 No. 771/K3/KM/SPK.LT/2016. The authors would also like to acknowledge the contributions and financial support from Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

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