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Fabrication of Al Electrodes on Si Substrate with Good Ohmic Contact

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Abstract:

The paper mainly focuses on the fabrication of Al electrodes on Si substrate with good ohmic contact based on the experimental studies. The main aim is to fabricate Al electrodes on the Si substrate. The objectives are as to know how to deposit Al by using thermal evaporation method, to learn the concept of native oxide on Si substrate and to test the conductivity and resistivity of two kinds of specimens. The experimental studies are completed in the semiconductor laboratory. The deposition of metal on semiconductor was successfully accomplished to observe the good ohmic contact for fabrication process of semiconductor crystal growth. The results confirm that the developed electrodes have met the high performance applications for metal/semiconductor stripe structure for future power electronic devices.

Keywords:

Fabrication, Nonostructure, Semiconductor Materials, Measurement, Thin Film

1. Introduction

Recently, semiconductor materials have been of great interest due to application for optical devices such as light emitting diodes (LEDs) and laser diodes (LDs). Semiconductor Materials have enthralled extensive consideration due to its superior physical properties and wide technological applications [1,2,3].

Fabrication is the process of creating and depositing of thin-film electrodes on the substrate under a high vacuum condition. Thermal evaporation is a commonly used method in micro-fabrication process. After deposition, native oxide is a highly affecting factor to fluctuate the conductivity of electrodes on the substrate and it is the worst case to get good Ohmic contact. In this system, hydrofluoric acid is used to overcome the native oxide effect [4,5,6].

The production technology for silicon materials consequently improved in relation to increasing demand for sources and detectors of short-wavelength light. Another imperative area where optoelectronic devices are used, along with the beforehand developed crystal for optoelectronic devices, is light sources which may replace ordinary incandescent lamps to save energy (since the energy is finished in the production of light rather than heat) and money (the lifetime of optoelectronic devices is drastically longer than that of the spirals in ordinary incandescent lamps or in fluorescent lights). Short-wavelength light has wide ranging uses in medicine [7,8,9,10].

The paper is organized as follows. The required materials and equipment section is very important for fabrication process. The research procedures based on research problems are mentioned. The research methodology and tests in experimental studies are done. The discussions of the results and conclusion of this study are given in the last section.

2. Required Materials and Equipment

The required materials and equipment for fabrication processes are mentioned in this section according to the respective physical nature. There are several materials for developing the fabrication in the semiconductor laboratory. They are (1) ***Si wafer.*** It is used as the substrate to hold and deposit Al on it and needed to cut to desired size. (2) ***Aluminum metal.*** It is used as target material to deposit on Si substrate and cut into a desired weight about 2mg. (3) ***Ethanol.*** It is used to clear the impurities on Al, Si and others. (4) ***HF acid (dil.).*** It is used to treat the oxide on Si substrate before deposition process. (5) ***Air blower.*** It is used to blow air for the removal of unwanted particles.

There are some equipment for developing the fabrication in the semiconductor laboratory. They are (1) ***Vacuum coater.*** It is the heart of the experiment because deposition using thermal evaporation is done in this equipment. To be deposit, it is needed to be the vacuum within this equipment and it is done with the help of rotary pump and diffusion pump. Chiller and liquid nitrogen are used to support diffusion pump to be in moderate condition. (2) ***Chiller.*** It is used to support the diffusion pump of the vacuum coater. (4) ***Digital microscope.*** It is used to examine the condition of the result specimens after the deposition process. (5) ***Fume hood.*** It is used during the treating of Si substrate with dilute HF acid before the deposition of Al. (6) ***Digital multi-meter.*** It is used to test the conductivity and resistivity of the result specimens.

2.1. Procedure of Fabrication

Figure 1 gives the block diagram of fabrication procedure.

The followings are the detail steps of the Fabrication.

Step 1- Cut the Si wafer and Al into the desired size

Step 2- Clean Si and Al with ethanol

Step 3- One Si is treated with HF acid and another Si is not

Step 4- Sep up the two specimens and Al is put in the boat

Step 5-Open the bell jar of the vacuum coater and clean this chamber

Step 6- Put the specimens and target material in bell jar

Step 7- Start the operating procedures of the vacuum coater to create the vacuum chamber with the help of rotary pump and diffusion pump

Step 8- Wait until 10-4 Pa pressure in the chamber

Step 9- Start applying current of 5A after every 2 minutes up to 70A

Step 10- Check the rate of deposition and thickness

Step 11- Start the stopping procedures if deposition rate is nearly decreased to 0.00nm/s and increasing of thickness is stopped

Step 12- Take out the specimen from the chamber

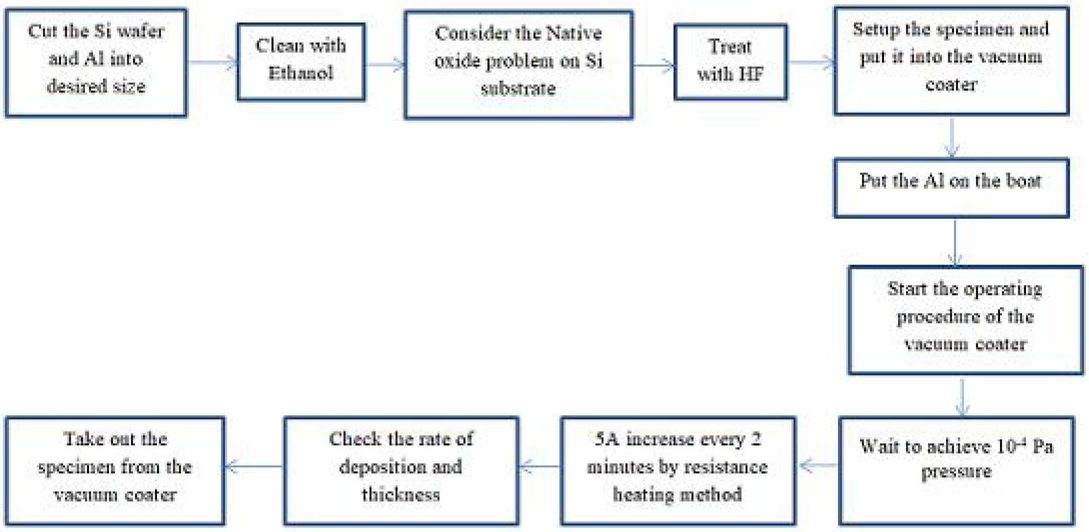
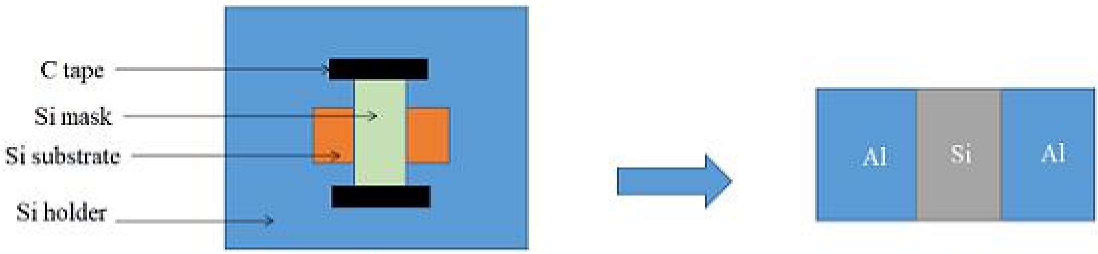
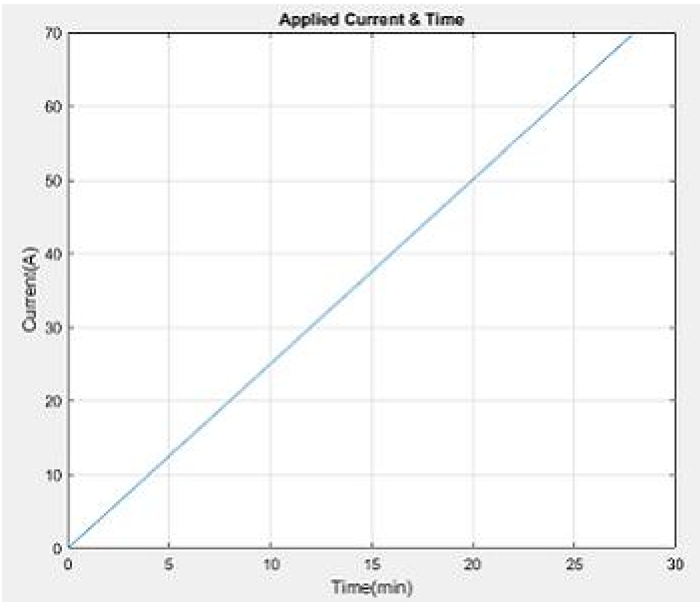


Figure 1. *Block Diagram of Fabrication Procedure.*

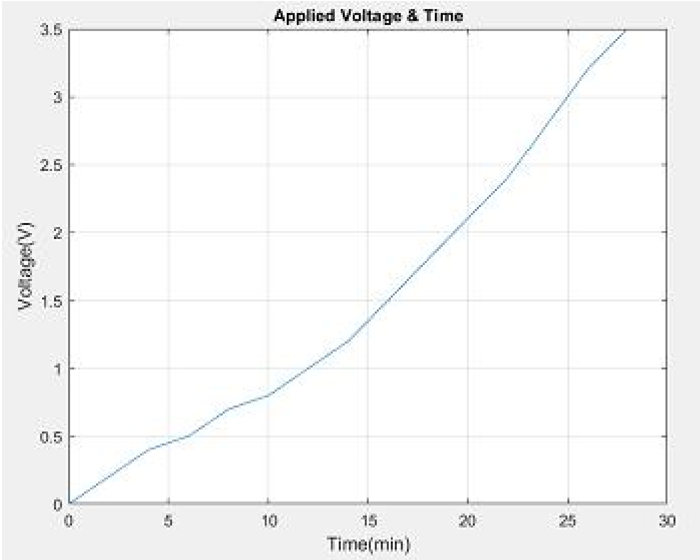


(i) (ii)

Figure 2. *(i) Specimen Setup before Deposition, (ii) Desired Result Specimen after Deposition.*



(i)



(ii)

Figure 3. *Graph of (i) Apply Current and Time, (ii) Apply Voltage and Time.*

Set up the specimen as shown in Figure 2(i) in order to achieve the desired specimen as shown in Figure 2(ii) after deposition. In this experiment, all of the substrate, holder and mask are Si and then carbon tape is used to attach and fix two terminals of Si mask on top of the Si substrate and holder.

During deposition process, thermal evaporation method is used and the applied current and its related voltage in time are also shown in Figures 3(i) and (ii).

2.2. Research Problem Statement

In this experiment, the native oxide on the Si Substrate is highly affecting the conductivity to be fluctuated and this effect is like three resistors connected one after another after depositing of Al on the Si substrate as shown in Figure 4. Also, native oxide on the Si substrate will greatly be affecting the Ohmic contact of the result specimen. Therefore, it is needed to remove the native oxide on Si substrate in order to get the stability of conductivity. To solve this problem, dilute Hydrofluoric acid is the best solution and it is used to avoid the oxide effects.

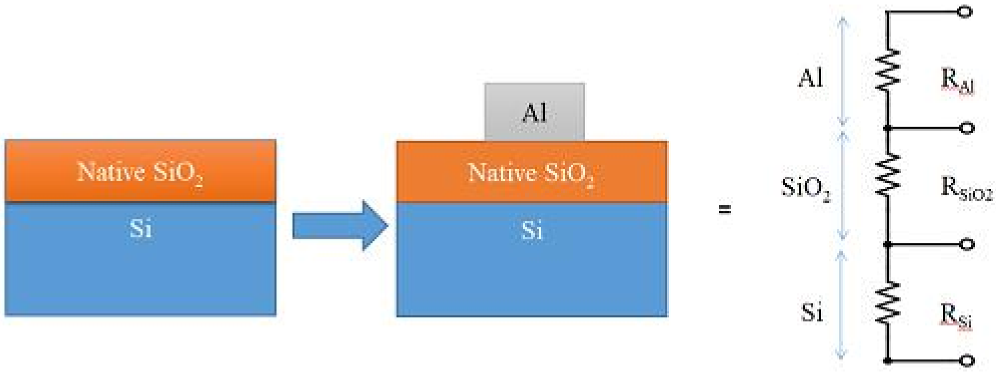


Figure 4. *Problem of Native Oxide.*

3. Methodology

There are two methods of fabrication process in the vacuum coater: thermal evaporation and electron beam heating methods. Thermal evaporation is suitable to

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the materials that have lower and normal melting points whereas electron beam heating is suitable to ones that have higher melting point. In this experiment, thermal evaporation method (also known as resistance heating method) is used to deposit Al on the Si substrate. Thermal evaporation is the most commonly used method of thin-film deposition to the substrate holder. The metal target material, Al is evaporated in a condition of vacuum to travel vapor particles directly to the Si substrate and then Al is condensed again back to solid state. Applied current is also important the target material to be successfully evaporation and accumulation on the substrate. Also to solve the problem statement mentioned above, dilute HF acid is the best solution and it is used to overcome the oxide effects on the result specimen. Because HF acid is a very strong, reactive and corrosive acid, it readily reacts with bases, acids, and oxidants.

One of its best known reaction is its corrosive, dissolving effect on glass and ceramic. Therefore, it is used to treat Si substrate before deposition process. For creating the dilute HF acid, it is needed to use the general dilution theorem in equation(1) in order to get the desired molarity and volume.

Before dilution = After dilution

$$M_1V_1 = M_2V_2$$

4. Test and Result

These are the result specimens after the deposition process as shown in Figure 5. The size of the Si substrate and electrode thickness will be different according to the manual needed. In this experiment, Al electrode thickness on the Si substrate is 0.009 µm.

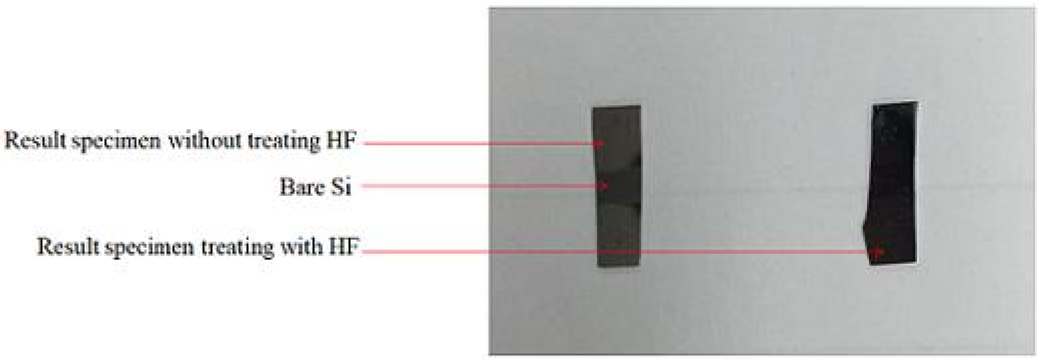

Figure 5. *Results of two Specimens after Fabrication.*

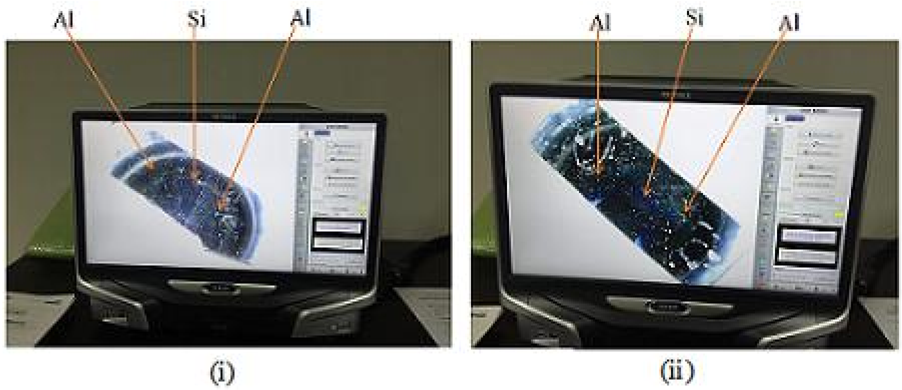

Figure 6. *Examining the Result specimen (i) without Treating HF Acid (ii) Treated with HF Acid.*

By examining these two result specimens with digital microscope in Figure 6, the specimen treated with HF is assumed to be more Al deposited than the one without treating HF. Consequently, the regions of Al and Si are more clearly seen on the HF treated specimen. Hence, treating with HF is essential before the deposition process for better result.

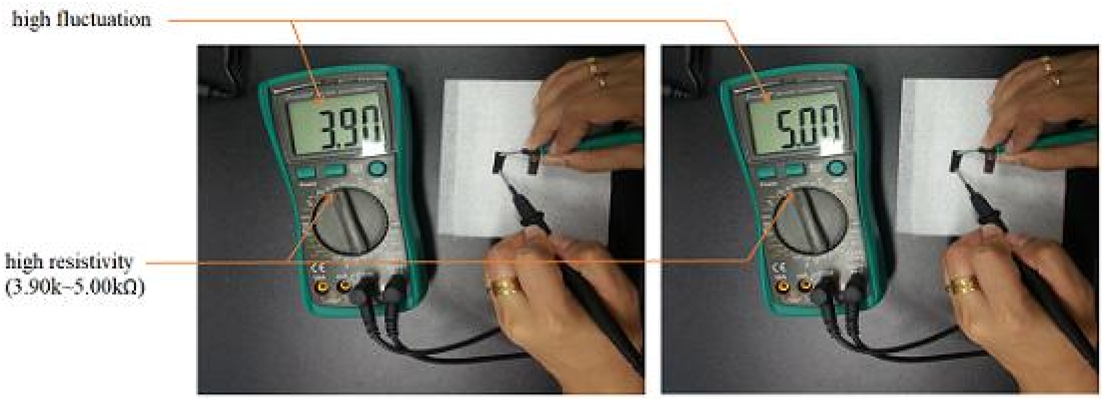

Figure 7. *Test of Specimen Treated without HF Acid.*

Test of specimen without treating HF acid using digital multi-meter is shown in Figure 7. It is shown that the conductivity is greatly fluctuated from time to time and then the resistivity value is in the range of 3.90kΩ to 5.00kΩ. Therefore, we can say that high resistivity and fluctuation will exist in the result specimen if it is not treating with HF acid so it is poor Ohmic contact.

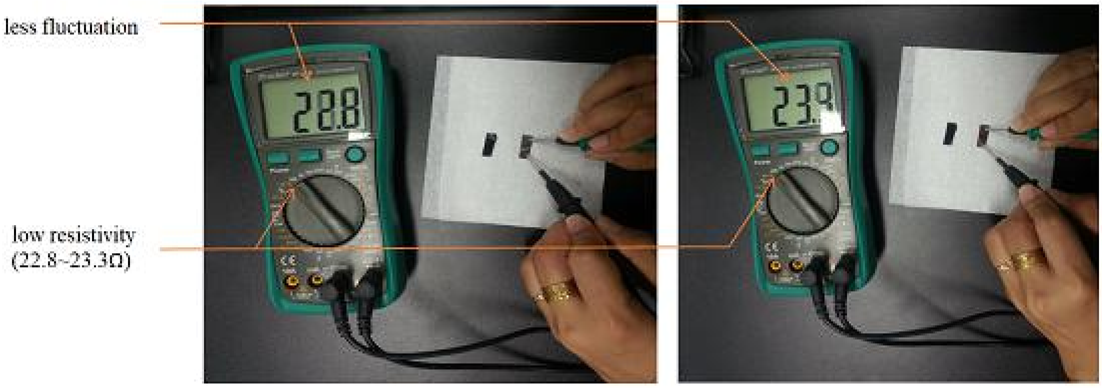

Figure 8. *Test of Specimen Treated with HF Acid.*

On the other hand, Figure 8 shows test of specimen treated with HF acid using digital multi-meter. It is proved that the conductivity is a little fluctuating from time to time and then the resistivity value is in the range of 22.8Ω to 23.3Ω. Therefore, we can say that low resistivity and less fluctuation will appear on the result specimen if it is treating with HF acid so it means good Ohmic contact. Table 1 shows the all of the conditions during the deposition process.

Table 1. *Condition of Thickness of Electrode during Deposition.*

Deposition Time	Applying Current	Applying Voltage	Deposition Rate	Electrode Thickness
2 min	5 A	0.2 V	0.01-0.02 nm/s	0
4 min	10 A	0.4 V	0.01-0.02 nm/s	0
6 min	15 A	0.5 V	0.01-0.02 nm/s	0
8 min	20 A	0.7 V	0.01-0.02 nm/s	0
10 min	25 A	0.8 V	0.01-0.02 nm/s	0

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12 min	30 A	1 V	0.01-0.02 nm/s	0
14 min	35 A	1.2 V	0.01-0.02 nm/s	0
16 min	40 A	1.5 V	0.01-0.02 nm/s	0
18 min	45 A	1.8 V	0.01-0.02 nm/s	0
20 min	50 A	2.1 V	0.01-0.02 nm/s	0.002μm
22 min	55 A	2.4 V	0.01-0.02 nm/s	0.003μm
24 min	60 A	2.8 V	0.01-0.02 nm/s	0.008μm
26 min	65 A	3.2 V	0.01-0.02 nm/s	0.009μm
28 min	70 A	3.5 V	0.01-0.02 nm/s	0.009μm

According to Figure 9, we can see that Al starts melting after applying 45A and all Al are melting completely at 65A. The thickness of electrodes depends on the added amount of Al but we have to notice that different materials have different melting points.

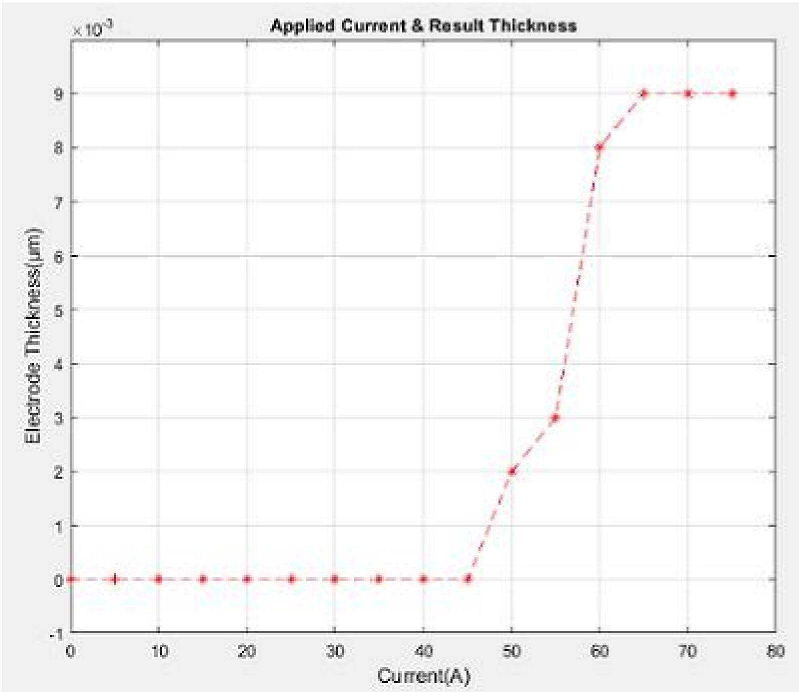

Figure 9. *Condition of Thickness of Electrode due to Applied Current.*

(i) (ii)

Figure 10. *(i) Setup the Specimen (ii) Result Specimen using Metal Mask.*

We can fabricate the specimen using the various forms of metal mask as shown in Figure 10(i). In this experiment, Si is used as a substrate, Al is used as target material to deposit, glass is used as a holder and metal mask is used to create the desired form. After deposition process, we achieved the specimen as shown in Figure 10(ii) by following the ways and procedures of previous experiment.

5. Discussion on Results

During the deposition process, applied current to the vacuum coater chamber is vital to be successfully deposited. If applied current is enough, evaporation is effectively done so that the result specimen may be in desired thickness. If not, the evaporation of Al may not be effectively accumulated on the specimen and then may spread out the whole chamber but not mostly on the specimen. Consequently, the thickness of electrodes will not be in desired thickness condition. Therefore, the applied current should be in enough. In this process, the current is applied up to 70A and 5A increased after every 2 minutes. But it is noted that the amount of applied current is greatly dependent both on the melting point and purity of target metal material. And also it is more suitable to give the amount of current gradually after every same period but not immediately the maximum value. Before applying the current, we should check the maximum allowable current of the vacuum coater chamber to be save the equipment and environment.

6. Conclusion

The research outcomes have been reported based on the experimental studies in the laboratory. By examining the results of two specimens, there are low resistivity and absolutely stable conductivity of Al electrodes on the Si substrate by treating HF acid prior to the process. On the other hand, there are very in high resistivity and unstable conductivity or fluctuation result of Al electrodes on the Si substrate without treating HF acid. Because of thickness variation, variation of refractive index will be characterized. And also, huge dielectric constant will lead to be greater capacitance values to the specimen. Upon the experiment, treating HF acid on Si substrate is better for the case of resistivity, conductivity, dielectric constant and desired thickness. Therefore, it can be concluded that removing native oxide is very important on every substrate of semiconductor materials before deposition process to get the best result.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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Author Contributions

Kyaw Swar Thu Rein and Wai Mar Thet have equally contributed for experimental studies in this research work. Pa Pa Aye, Khine Thandar Nyunt Swe and Khaing Zin Nway have equally highlighted to complete this study in the laboratory. Hla Myo Tun emphasized the correspondingly emphasized to prepare the research paper based on the experimental studies at YTU. This study mainly focuses on the fabrication of Al electrodes on Si substrate with good ohmic contact based on the experimental studies for designing the optoelectronics devices. The theoretical analyses on semiconductor fabrication process and measurements are vital role to enhance the high performance electronics devices for future semiconductor fabrication technology. This work could be provided to find the solution for research problems in high performance phonics device fabrications.

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