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Aluminum Thin Film on Various Substrates using Magnetron Sputtering

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Abstract: Many sectors employ aluminum (Al) thin films, however further study is required to improve their value and performance. In order to achieve the necessary qualities, these films are made that use deposition processes such as physical vapour deposition, chemical vapour deposition, and electrochemical deposition. Al thin films have properties like structure, electrical conductivity, optical conduct, mechanical stability, and adhesion strength that can be improved by alloying, using new deposition techniques, patterning, integrating them into devices, conducting stability studies, and taking cost-effectiveness into account. The purpose of this experiment is to determine the conductivity, morphology, topology, and thickness of the Al thin film on various substrates, in order to compare which substrates offered the better results. Studying these aspects will help Al thin film technology improve for a variety of applications. The use of aluminum (Al) thin films in semiconductors, optoelectronic, and energy storage applications is substantial, and further study is required to improve their functionality and look into new integration opportunities in advanced technologies. In conclusion, the FTO glass substrates offer good electrical conductivity, thickness, morphology, and topology compared to Si wafers.

Keywords: Aluminum (Al), Thin Film, Deposition, FTO Glass, Si Wafer

1. Introduction

Due to their outstanding properties which include high conductance, low resistivity, high reflectance, better adhesion and resistance to oxidation and corrosion, pure aluminum (Al) is used in the optical, microelectronics, telecommunication, and construction or structural sectors [1]. Successful depositions have been made on a variety of substrates, including glass, mild steel, stainless steel, titanium, silver, silicon (100), polyethylene terephthalate (PET), and polycarbonates, aluminum thin films continue to be of significant interest in both industry and research [1, 2]. Higher adhesion, lower substrate temperatures, and cleaner environmental effects are all produced via physical deposition techniques [3]. Additionally, physical deposition techniques allow for the deposition of thinner and metastable films as well as the control of stress states [3]. Due to these benefits, there is a significant

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amount of research being carried out on the physical deposition of thin Al film. Magnetron sputter deposition has significant benefits over conventional PVD processes [4]. In the PVD process, sputtering is the common deposition process. This is because of the advantages of its simplicity, low thermal temperature, low cost and ability to produce good quality films. In the sputtering techniques, it includes the diode sputtering, ion-beam sputtering and magnetron sputtering [5]. Magnetron sputtering is a high-rate vacuum coating technique that allows the deposition of many types of material, including metals and ceramics, onto as many types of substrate materials by the use of a specially formed magnetic field applied to a diode sputtering target [5]. The advantages of magnetron sputtering are simple equipment, easy control, large coating area, and strong adhesion [6]. Magnetron sputtering is a dominant technique to grow thin films because a large quantity of thin films can be prepared at relatively high purity and low cost [7].

2. Materials and Methods

2.1 Materials

In this project, the material and substrates shown in Table 1 have been used to deposit the Al thin film. This project used RF Magnetron Sputtering to develop the Al Thin film.

Table 1: List of materials and substrates

Material	Substrates
Aluminium (Al)	Si wafer, FTO glass

2.2 Methods

The experiment of deposition of Al thin films consists of three important processes which are substrate preparation, deposition process, and thin film characterization. The first process is the preparation of the substrate which is FTO glass and Si wafer for the experiment. Following that, Al is deposited using the RF magnetron sputtering with optimized sputtering parameters such as sputtering power, working pressure, deposition time, gas composition, and temperature. In the next step of the research, thin films will be characterized. X-ray Diffraction (XRD) will be used to analyse the structural aspects of thin films. The surface morphology, topography, roughness, and grain sizes, thickness and microstructure of Al films will be characterized using atomic force microscopy (AFM), surface profiler, and the electrical properties of thin film using a Four-point probe.

For the first process, the substrates will be single-sided polished silicon wafers and FTO glass. The substrates that will be used are 1cm x 1cm and need to be cleaned carefully before the deposition process. First, cut the Si wafer and FTO glass substrates into 2cm×2cm approximately. Next, the substrates will be ultrasonically cleaned for 3 minutes with deionized water. After that, the substrate will be rinsed with deionized water. Lastly, blow with nitrogen gas to dry the Si wafer and glass substrates. Then, the Al thin film is deposited using the RF Magnetron Sputtering with the parameters that have been set. There are a few main parts to a deposition process. It starts by turning ON the system, loading the sample, pumping the procedure for high vacuum, pre-sputter, depositing the sample and turning OFF the system. Lastly, the thin films will be characterized by several characterization machines such as X-ray diffraction (XRD), Atomic Force Microscope (AFM), surface profiler, and 4-point probe to investigate the properties of Al thin films such as structural, morphology, and optical properties. To investigate the uniform of Al on the substrate.

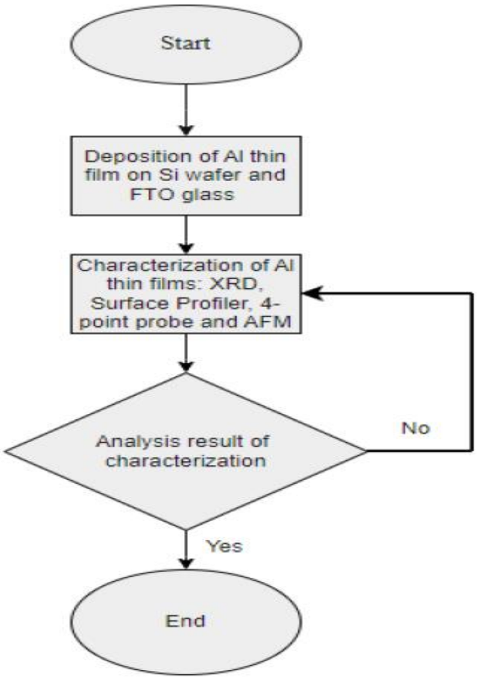

Figure 1: The flowchart of the experimental

3. Results and Discussion

3.1 Thickness Analysis

The thickness of the sample was determined by using a surface profiler. Surface profiler is a method that uses optical interfaces. This method that used widely in industry because of its non-contact and non-destructive method that quickly and accurately measures the profile of the microscopic surface [8]. Table 2 shows the data of the thickness of two samples of Al thin film deposited on Si and FTO glass substrates that had analysis by surface profiler. The thickness for sample A (Al-FTO glass) is higher compared to sample B (Al-Si) which is 415.6nm. Sample A shows a higher thickness during the deposition could be due to the material's properties. This is because Si wafer and FTO glass substrates have different material characteristics. Si wafers are semiconducting materials while FTO glass is an insulating substrate that is covered with a conductive FTO layer. The adhesion and growth properties of the deposited film might be impacted by the variation in material properties. A stronger tendency to produce a thicker film may be seen in the FTO glass as a result of compatibility and surface properties.

Table 2: Thickness data from Surface Profiler

Sample	Thickness (nm)
A	438.34
B	415.6

3.2 Structural Analysis

The X-ray Diffraction allowed insight into the thin film structure of the sample deposited. The sample was deposited on the different types of substrates at the same sputtering power. Figure 2 illustrates the XRD patterns of the Al on Si and Al on FTO glass substrates. The output patterns are compared. The result of XRD shows that different substrates influence the degree of crystallization and size of crystallization.

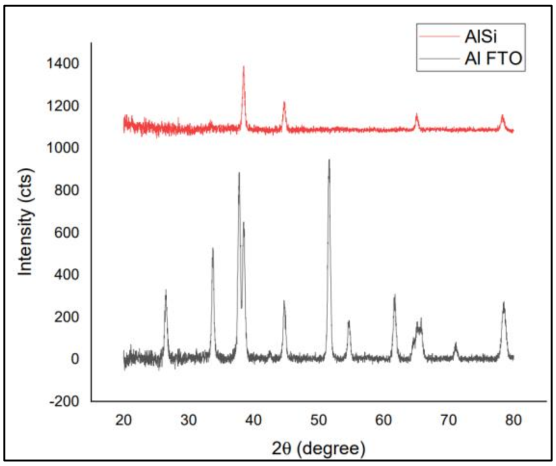

Figure 2: XRD patterns of Al thin films on Si and FTO glass substrates

Table 3:XRD Data for Al thin film on different substrates

Sample	Plane (hkl)	2θ (degree)	FHWM	Crystalline Size (Å)
A	111	51.6573	0.3936	196.5783
B	111	38.4515	0.2755	72.3554

3.3 Surface Topology Analysis

The surface roughness of Al thin film was analysed using AFM, which enables the characterization of the film surface topology evolution with the growth of Al in the experiment. Al thin film with different thickness were grown on Si substrate and FTO glass substrates in order to analyze the film quality. AFM images were obtained from the substrates. At times the substrate effect is not considered [9]. However, recent research has shown that there is a statistical association between the roughness of certain surfaces, plays a significant part in describing the evolution of the film's roughness. Figure below shows the AFM images of the samples with different substrates which are Si wafer and FTO glass.

Table 4: AFM data of Al thin film

Sample	Average roughness (nm)	Grain size (nm)
A	20.593	119.941
B	18.846	122.918

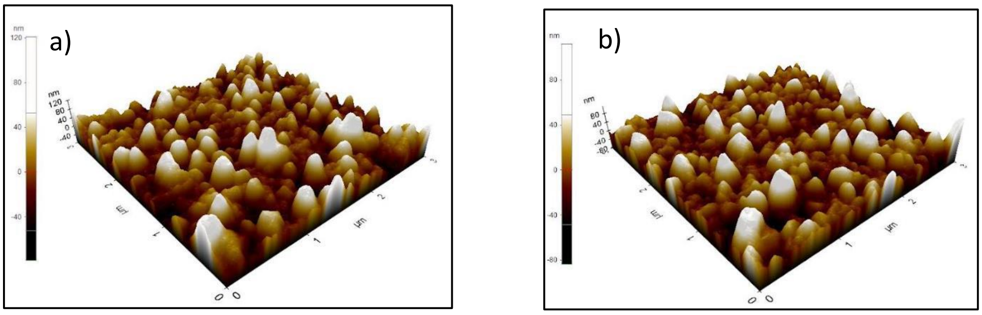

Figure 3: a) AFM image of Al thin film on FTO glass substrate, b) AFM image of Al thin film on Si wafer substrates

Based on the table and figure above it is clearly seen that the substrate with the lowest surface roughness had a grain size of 122.918nm. The highest roughness was observed for the FTO glass substrates. The grain size of the FTO glass substrates was 119.941. Based on this result it clearly shows that the surface roughness may influence on the grain growth process.

3.4 Electrical Analysis

The electrical properties of Al thin film were determined by using a four-point probe. Four-point probe is a measurement technique used to determine the sheet resistance or resistivity of Al thin film. The method consists of using four evenly spaced probes to apply a known current to a sample while measuring the voltage drop that occurs. Table below shows the result of resistivity of Al thin film on different substrates which is Si and FTO glass substrates.

Table 5: Four-point probe data

Sample	Resistivity (Ω/cm)	Sheet resistance (Ω/sq)	Thickness (um)
A	8.8622	202332.4	0.438
B	4.6732	112608.2	0.415

Due to variations in their intrinsic material characteristics and doping levels, FTO glass generally has a greater resistivity than a Si wafer. Other than that, to improve its conductivity, Si wafers used in electrical devices are frequently rigorously doped with impurities. Both boron (p-type) and phosphorus (n-type), which are frequently used as dopants in silicon, considerably reduce the material's resistivity.

4. Conclusion

The Al thin film is successfully deposited by using the RF Magnetron Sputtering technique that uses the Al as the single target to achieve the objective of this study which is to deposit Al thin film in various substrates, analyze the thickness between the thin film with different substrate and characterize the Al thin film by using surface profiler, XRD, AFM, and 4-point probe. Other than that, we can conclude that depending on the specific use and required film qualities, the thickness of an Al thin film might vary. An important factor that must be carefully managed and optimized for every particular use is the thickness of the Al thin film. The ideal deposition thickness is greatly determined by the required properties, performance requirements, substrate materials, and the function of the Al film for any applications.

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References

[1] Bordo, K. and H.G. Rubahn, *Effect of deposition rate on structure and surface morphology of thin evaporated al films on Dielectrics and Semiconductors.* Medziagotyra, 2012. **18**(4): p. 313-317.

[2] Abedi Esfahani, E., et al., *Study of Corrosion Behavior of Arc Sprayed Aluminum Coating on Mild Steel.* Journal of Thermal Spray Technology, 2012. **21**(6): p. 1195-1202.

[3] Waliin, E., *Alumina Thin Films.* 2008.

[4] Engineering, A. *Magnetron Sputtering Overview*. 1992.

[5] Swann, S., *Magnetron sputtering.* Physics in Technology, 1988. **19**(2): p. 67.

[6] Falk, H., *Interdigital Sensors and Transducers.* Proceedings of the IEEE, 2004. **92**(5): p. 806-807.

[7] Shi, F., *Introductory Chapter Basic Theory of Magnetron Sputtering.* 2016.

[8] Feng Gao, X.Q.J., Hussam Muhamedsalih, *Surface and Thickness measurement of a transparent film using wavelength scanning interferometry*. 2012.

[9] Nanda, K.K., S.N. Sarangi, and S.N. Sahu, *Measurement of surface roughness by atomic force microscopy and Rutherford backscattering spectrometry of CdS nanocrystalline films.* Applied Surface Science, 1998. **133**(4): p. 293-297.