EVOLUTION IN ELECTRICAL AND ELECTRONIC ENGINEERING
e-ISSN: 2756-8458

EEEE

Vol. 5 No. 1 (2024) 230-235
https://publisher.uthm.edu.my/periodicals/index.php/eeee

Aluminium Nitride Thin Film Deposition Using Magnetron Sputtering on Silicon and Microscopic Glass Substrate for IDE Applications

Mugilesh Samynathan[1], Riyaz Ahmad Mohamed Ali[1]*

[1] *Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: riyaz@uthm.edu.my
DOI: https://doi.org/10.30880/eeee.2024.05.01.029

Article Info

Received: 14 January 2024
Accepted: 12 February 2024
Available online: 30 April 2024

Keywords

Aluminium Nitride, AlN, Thin film deposition, Microscopic Glass, Silicon, Magnetron Sputtering, IDE

Abstract

This work aims to investigate the potential of magnetron sputtering to deposit thin aluminium nitride films on microscopic glass and silicon substrates. The objective is to examine the advantages and limitations of magnetron sputtering and its potential challenges for healthcare applications and other fields. Magnetron sputtering is a promising technique that produces high-quality, uniform films with good adhesion and low defect density. The findings suggest that magnetron sputtering has significant potential to improving the sensitivity of medical diagnostic tools, enhancing drug delivery systems, and enabling the development of advanced biosensors. The study also investigates the impact of magnetron sputtering on the thickness, roughness, and electric conductivity of aluminium nitride (AlN) thin film deposited on silicon and microscopic glass substrates. The results show that increasing the duration of sputtering leads to thicker and smoother aluminium nitride film deposition. Additionally, the use of silicon and microscopic glass as substrates to deposit thin aluminium nitride film for IDE (interdigitated electrode) applications helps to study which substrate can eliminate the influence of the substrate on the electric conductivity reading of the thin aluminium nitride film.

1. Introduction

The field of global health is facing several challenges, and the need for innovative solutions to address pressing issues is more significant than ever. Material science has recently gained attention for its potential to revolutionize healthcare (Remes et al., 2020). One promising area is the application of magnetron sputtering to deposit thin aluminum nitride (AlN) films on various substrates. This technique has been widely used in electronic device manufacturing for many years, and it is now gaining attention in the medical field (Alyousef et al., 2023). The application of magnetron sputtering in healthcare could revolutionize the sector by enhancing drug delivery systems, improving the sensitivity of medical diagnostic tools, and enabling the development of advanced biosensors (Cicha et al., 2022). Ultimately, this technology will significantly improve the accuracy and effectiveness of medical treatments and diagnosis, leading to better health outcomes for individuals worldwide (Bhatia et al., 2024). Magnetron sputtering is an effective technique for depositing thin films utilized for various materials science applications. During the process, material is ejected from a target onto the surface of a substrate by high-energy particles that bombard the target (Stoner, 2024). Several variations of the process include direct current (DC) magnetron sputtering, pulsed DC sputtering, and radio frequency (RF) magnetron sputtering. RF magnetron sputtering is a versatile method that accommodates a wide range of materials. It yields high-quality results and expands the capabilities of the sputtering process, making it an excellent choice for precise material deposition (Green, 2023). The use of magnetron sputtering to deposit thin films of aluminum nitrite (AlN) has the potential to bring about innovative solutions that can address global health challenges (Fredrick et al., 2020). The future of magnetron sputtering systems seems promising, as the demand for this technology continues to expand, showing potential for healthcare applications and other fields.

2. Materials and Methods

2.1 Materials

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

Table 1 *List of material and substrate*

Material	Substrate
Aluminium Nitride (AIN)	N-type Silicon, Microscopic Glass

2.2 Methods

The method involves conducting a comprehensive investigation of the deposition of thin films using Magnetron sputtering with aluminium nitride as the material shown in Fig. 1. The study comprises three phases that focus on specific aspects of the work. In the first phase, the thin film of AlN will be deposited using Magnetron Sputtering at a sputtering power level of 100W and time at 30 and 60 minutes. During the second phase, we will evaluate the effect of sputtering time on the performance of interdigitated electrodes. In the third and final phase of the study, we will characterize the thin aluminium film using Surface Profiler, Atomic Force Microscopy (AFM), and 4-point Probe on silicon and microscopic glass substrates.

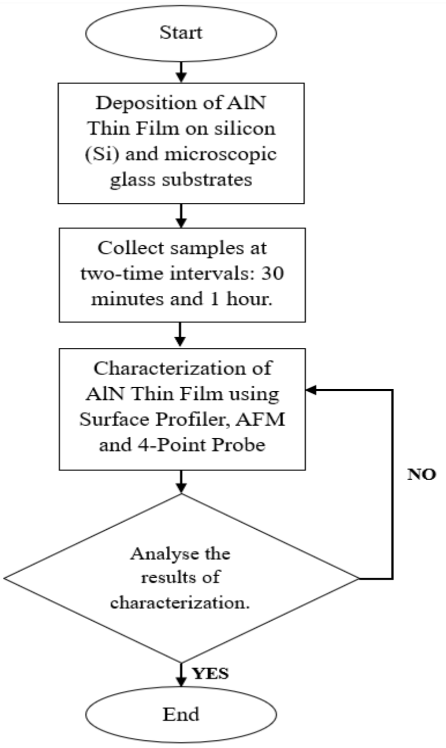

Fig. 1 *The flowchart of the research design*

Single-sided polished silicon wafers and microscopic glass with dimensions of 1cm x 1cm were used for substrate preparation. The silicon wafer and microscopic glass were cut into approximately 2cm x 2cm pieces using RS Pro Scribe to prepare them into substrates. Before deposition, it was essential to clean the substrates thoroughly. An ultrasonic bath was filled with deionized water for about 3 minutes to clean the substrates. After cleaning, the substrates were rinsed with deionized water, and nitrogen gas was used to blow dry the silicon wafer and glass substrates. Then, a thin layer of aluminium nitride was deposited on the substrate using RF magnetron sputtering by inlet Argon (Ar) gas at the capacity of 100 sccm and Nitrogen gas at the capacity of 50 sccm. To perform a deposition process, the system should be turned ON, samples should be loaded, pumped for high vacuum, pre-sputter, the sample, and turned OFF the system—the substrate should be collected at two intervals, which are 30 minutes and 60 minutes. There are a few main parts to a deposition process. Finally, characterize the thin aluminium film on silicon and glass substrates. Measure thickness using a Surface Profiler, analyze surface morphology using AFM, and measure resistivity using a 4-point probe. This characterization will provide insights into the quality and potential applications of the aluminium layer.

3. Results and Analysis

3.1 Thickness Analysis

Thickness analysis was conducted for aluminium nitride (AlN) thin film deposition on silicon and microscopic glass substrates using magnetron sputtering shown in Table 2. At 100W Power and 30 Minutes Duration, the AlN film deposited on the silicon substrate was found to have a thickness of 172.51 nm, while on the microscopic glass substrate, the thickness was slightly less at 166.43 nm. When the duration was increased to 60 minutes, there was a significant increase in thickness for both substrates, with the thickness of the AlN film deposited on the silicon substrate found to be 343.06 nm, and an even higher value of 430.76 nm on the microscopic glass substrate.

Table 2 *Thickness data from Surface Profiler*

Power (W)	Duration (min)	Sample	Thickness (nm)
100	30	Silicon	172.51
	60	Silicon	343.06
	30	Microscopic Glass	166.43
	60	Microscopic Glass	430.76

3.2 Roughness Analysis

The surface roughness of Aluminium Nitride (AlN) thin film deposition on silicon and microscopic glass substrates using magnetron sputtering was analyzed as shown in Fig. 2. Atomic force microscopic analysis was utilized for quantitatively measuring the nanometric dimensional surface roughness. Based on the data obtained from atomic force microscopy, the roughness of the samples varied depending on the duration and substrate type. The longer the duration of sputtering, the smoother the roughness of the deposited AlN thin film onto a substrate (Bakri et al., 2021). The roughness parameters of a deposition process are influenced by various factors such as power, duration, and substrate material.

There are several factors that affect the roughness of a deposition process. Two of the most influential factors are the power and duration of the sputtering process and the type of substrate material used. As the power and duration of the process increase, the surface roughness also increases as shown in Table 3. Additionally, different substrate materials react differently to the deposition process, which can also cause variations in roughness. In this experiment, both factors had a significant impact on the observed surface roughness results. The data also suggests that negative Rsk values indicate that surface valleys are more pronounced than peaks. Moreover, Rku values greater than three suggest a leptokurtic distribution, which means that the surface has a higher frequency of extreme values or outliers (Bashevskaya et al., 2017).

Table 3 *Roughness parameters of deposited AIN Thin Film on silicon and Microscopic Glass with various durations*

Power (W)	Duration (min)	Sample	R_{pv} (nm)	R_q (nm)	R_a (nm)	R_z (nm)	R_q/R_a	R_{sk}	R_{ku}
100	30	Silicon	23.562	3.094	2.453	22.987	1.261	-0.210	3.129
	60	Silicon	31.797	3.943	3.131	31.437	1.259	-0.420	3.246
	30	Microscopic Glass	25.060	3.357	2.636	24.796	1.274	-0.370	3.430
	60	Microscopic Glass	28.648	3.906	3.100	27.611	1.260	-0.245	3.115

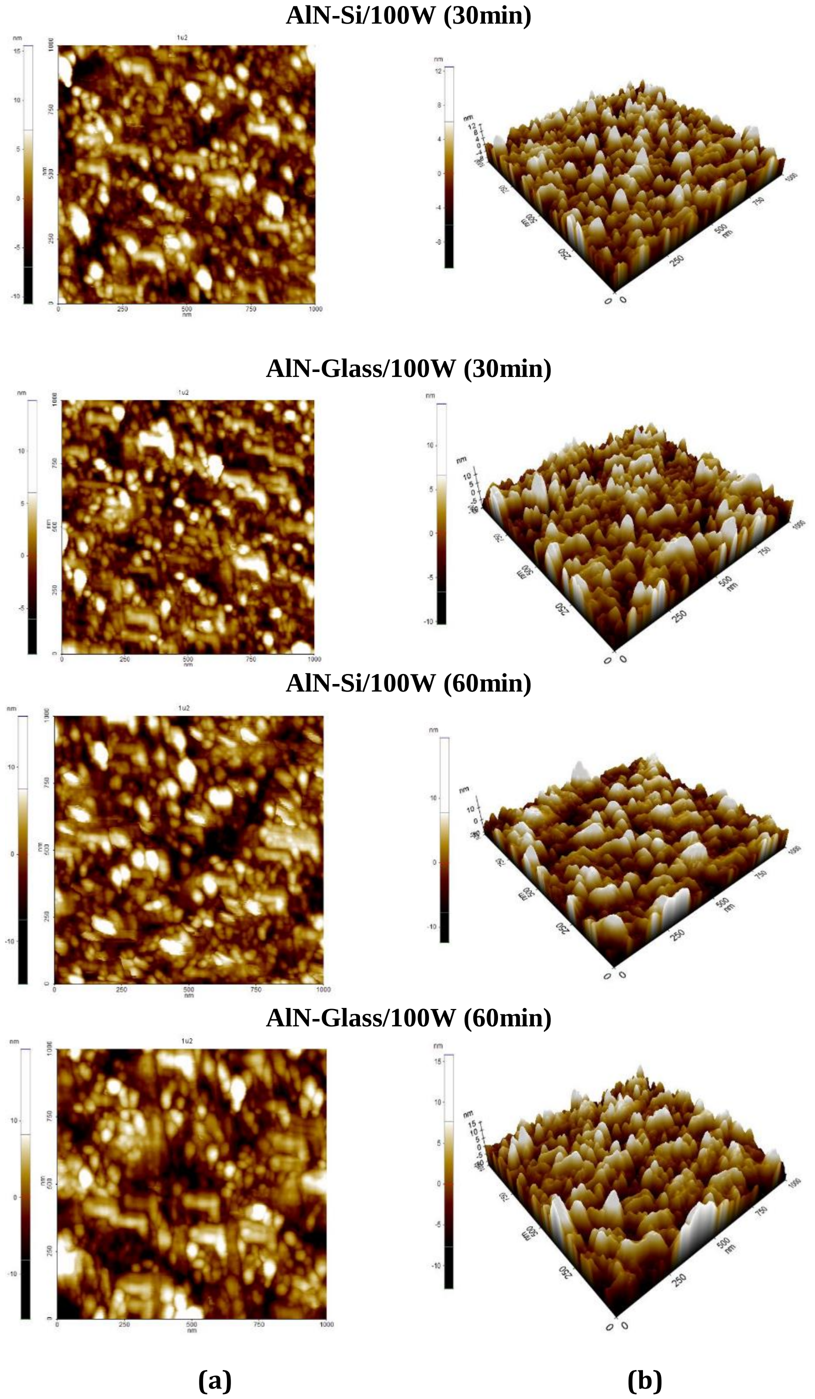

Fig. 2 *AFM (a) 2D and (b) 3D images of Deposited AlN Thin Film on Silicon and Microscopic Glass with various durations*

3.3 Electrical Analysis

The conductivity of AlN thin film deposited on Silicon and Microscopic Glass substrates was measured using a 4-point probe technique shown in Fig. 4. The resistivity and sheet resistance of these substrates were hypothesized to vary depending on the duration of sputtering at a constant power of 100W. A low resistivity indicates that a material has a high electric current flow (Libretexts, 2021).

It was observed that the sheet resistance of silicon decreased from 1450.3517 Ω/sq at 30 minutes to 761.4702 Ω/sq at 60 minutes, which shows a reduction of approximately 47.5%. On the other hand, the sheet resistance of microscopic glass decreased from 621.2495 Ω/sq at 30 minutes to 581.5943 Ω/sq at 60 minutes, indicating a decrease of around 6%. This suggests that the sheet resistance is inversely proportional to the thickness of the film. As the thickness of the film increases, the sheet resistance decreases. Conversely, the thinner the film, the greater the sheet resistance.

Table 4 *Four – Point Probe Calculated Average Data*

Power (W)	Duration (min)	Sample	Resistivity (Ω/cm)	Sheet resistance (Ω/sq)	V/I	Thickness (um)
100	30	Silicon	0.10326	1450.3517	321.5141	0.172
	60	Silicon	0.02611	761.4702	168.8028	0.343
	30	Microscopic Glass	0.01031	621.2495	137.7187	0.166
	60	Microscopic Glass	0.02501	581.5943	128.9279	0.43

4. Conclusion

In conclusion, this research work successfully achieved the objectives of sputtering thin film aluminium nitride deposition on silicon and microscopic glass substrates using magnetron sputtering. The aluminium nitride films were characterized on both substrates using a surface profiler, atomic force microscopy (AFM), and a 4-point probe, and comparing the thickness and conductivity of aluminium nitride on silicon and microscopic glass substrates that were sputtered for various durations. The discussion revealed that longer sputtering duration leads to thicker and smoother AlN films, and the type of substrate used has a significant impact on the electric conductivity of the AlN thin film. The use of microscopic glass as a substrate for IDE applications can be advantageous due to its low dielectric constant and high thermal stability and as an insulator, it is an ideal substrate for IDE applications as it does not affect the electrical characteristics of the AlN thin film.

Acknowledgement

This research work is supported by Universiti Tun Hussien Onn Malaysia Research Grant (Q186). The authors would like to thank the Faculty of Electrical and Electronic Engineering, University Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mugilesh Samynathan, Riyaz Ahmad Mohamed Ali;* ***data collection:*** *Mugilesh Samynathan;* ***analysis and interpretation of results:*** *Mugilesh Samynathan;* ***draft manuscript preparation:*** *Mugilesh Samynathan, Riyaz Ahmad Mohamed Ali. All authors reviewed the results and approved the final version of the manuscript.*

References

A. S. Bakri et al., "Structural and mechanical properties of a-axis AlN thin films growth using reactive RF magnetron sputtering plasma," Microelectronics International, vol. 38, no. 3, pp. 99–104, Jun. 2021, doi: 10.1108/mi-02-2021-0015.

D. Bhatia, S. Paul, T. Acharjee, and S. S. Ramachairy, "Biosensors and their widespread impact on human health," Sensors International, vol. 5, p. 100257, Jan. 2024, doi: 10.1016/j.sintl.2023.100257.

H. A. Alyousef, A. Hassan, and H. M. H. Zakaly, "Reactive magnetron sputtered AlN thin films: structural, linear and nonlinear optical characteristics," Journal of Materials Science: Materials in Electronics, vol. 34, no. 13, May 2023, doi: 10.1007/s10854-023-10459-x.

I. Cicha, R. Priefer, P. Severino, E. B. Souto, and S. Jain, "Biosensor-Integrated drug delivery systems as new materials for biomedical applications," Biomolecules, vol. 12, no. 9, p. 1198, Aug. 2022, doi: 10.3390/biom12091198.

J. Green, "An overview of magnetron sputtering | Stanford Advanced Materials," Global Supplier of Sputtering Targets and Evaporation Materials | Stanford Advanced Materials, May 05, 2023. https://www.sputtertargets.net/blog/an-overview-of-magnetron-sputtering.html

J. Remes et al., “Ten innovations that can improve global health,” McKinsey & Company, Jul. 15, 2020. https://www.mckinsey.com/industries/healthcare/our-insights/ten-innovations-that-can-improve-global-health

J. Stoner, “What is Magnetron Sputtering and How Does it Work | Korvus Technology,” Korvus Technology, Jan. 08, 2024. https://korvustech.com/magnetron-sputtering/

Libretexts, “Resistivity,” Engineering LibreTexts, Jul. 06, 2021. https://eng.libretexts.org/Bookshelves/Materials_Science/Supplemental_Modules_%28Materials_Science%29/Electronic_Properties/Resistivity

Mwema, Fredrick & Akinlabi, Esther & Oladijo, Philip. (2020). A systematic review of magnetron sputtering of AlN thin films for extreme condition sensing. Materials Today: Proceedings. 26. 10.1016/j.matpr.2020.02.317.

O. S. Bashevskaya, S. V. Bushuev, A. A. Никитин, E. V. Romash, and Yu. V. Poduraev, “Assessment of surface roughness using curvature parameters of peaks and valleys of the profile,” Measurement Techniques, vol. 60, no. 2, pp. 128–133, May 2017, doi: 10.1007/s11018-017-1161-z.