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Characterisation of Sputter Deposited of Thin Film Strain Sensors for Wearable Technology

Nur Ashikin Zulaikha Yulcifly[1], Ahmad Hadi Ali[1]*

[1] *Department of Physics and Chemistry, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 86400 Pagoh, Muar, Johor, MALAYSIA.*

*Corresponding Author: ahadi@uthm.edu.my
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Abstract

The increasing demand from industries in wearable technologies required a flexible and high sensitivity thin films. The study investigates the characterization and deposition of gold thin films on glass and polyethylene terephthalate (PET) samples as substrate for wearable technology applications. Sputtering method was applied to achieve uniform and high quality thin films, meanwhile four point probe, temperature testing, and flexibility testing used to determine electrical resistivity, thermal stability and mechanical performance. PET shows superior conductivity compared to glass and exhibited better flexibility under stress conditions. Temperature testing shows a linear resistance increase with rising temperatures, claimed thermal sensitivity. As result highlight the suitability of PET for flexible electronics due to its lower resistivity, mechanical stability, adaptability when stress applied, providing views for advancing thin film technology in wearable applications.

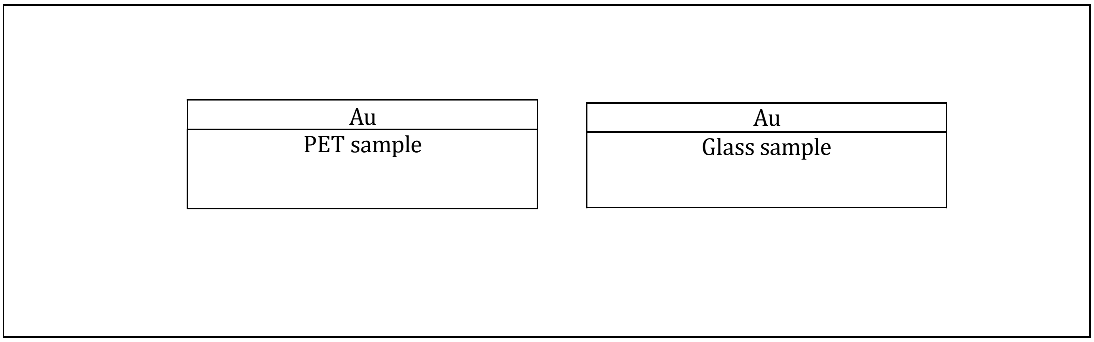
1. Introduction

The exploration of fundamental principles, electrical characterisations and applications of Thin Film Strain Sensors in wearable technology, the focus is on deposition and enhancement the thin film strain sensors, considering factors such as the sensitivity of the thin film, simplified the deposition process, and cost reduction [1]. It is important for wearable technology performance, appropriate samples selection, metal selection, with advantages found in metals like titanium, aluminium, nickel, copper, gold and platinum [3]. The power setting for sputtering technique is important where it will affect the deposition rate, film density and stress applied [2]. Therefore, to achieve a uniform thin film layer might be challenging due to the various deposition parameters like uneven power distribution which lead to non-uniform thin film thickness and affect the sensitivity and reliability for wearable technology [4].

Thin films, particularly it is composed of gold (Au), play the main role in electronics due to their characteristics [2]. Gold is unique due to its better electrical properties and stability [1]. With the increasing demand for high quality and performance sensors, appropriate flexible substrate and characterise the thin film based on its electronic properties. The choice of samples a substrate is important where it will affect the performance and applications of thin film strain sensors. In this deposition, polyethelene terephthalate (PET) and glass is used as a sample [4]. PET is mostly used for wearable technology and applications due to the flexibility, lightweight and compatibility. Commonly, PET used in health industries as health monitors [12]. Meanwhile, glass is used as a sample of substrate due to the high stability and durability which able to undergo temperature testing with changing in temperatures. Glass provides a smooth and defect free surface which ideal in achieving high quality deposition and consistent electrical properties [8]. The understanding behaviour when stress applied on the samples which crucial for the stability and its applications as it significantly affect sensors especially in health industries.

2. Methodology

Polyethelene terephthalate (PET) and glass sample precisely cut 2cm x 2cm by using scissors and glass cutter [2]. Alternatively, ensuring accuracy and ensuring the surface of samples free from contaminants, the samples underwent through chemical cleaning using acetone and isopropyl, then, rinse with distilled water [4]. Furthermore, samples underwent sputtering where depositing gold on the samples for 50 seconds with 40 mA current and base pressure is $1\text{x}10^3$ mBar [9].



a) b)

Fig. 1 Simple diagram of the Au layer deposited on a) PET substrate and b) glass substrate was presented

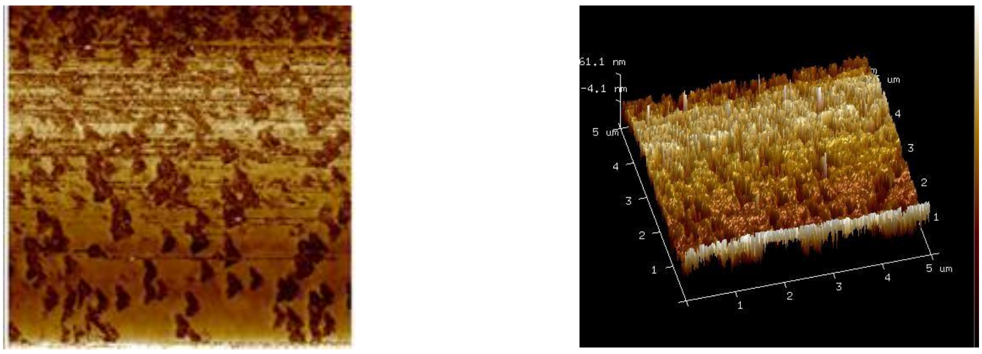
The characterisation surface topography of samples was analysed under Atomic Force Microscopy (AFM) to determine the grain size and the roughness of Au thin film. Then, Four Point Probe with current and voltage is -10mA to +10mA and -5V to +5V to determine the minimum, maximum and average resistivity of samples [12]. The samples underwent two different types of testing to determine the electrical properties. PET sample with deposited gold underwent flexibility testing. Load was hanged on the rubber band that attach to the sample and the resistance was measure. Besides, glass samples underwent temperature testing by putting the sample into the oven and increase the temperature consistently after 30 minutes and resistance was measured using multimeter.

3. Results and Discussion

The collected data were systematically processed to explore the behaviour of Au thin films deposited on PET sample and glass sample. Comprehensive characterisation was conducted using Atomic Force Microspcopy (AFM) and Four Point Probe. The PET/Au and glass/Au samples provide view into topographical properties and electrical characteristics.

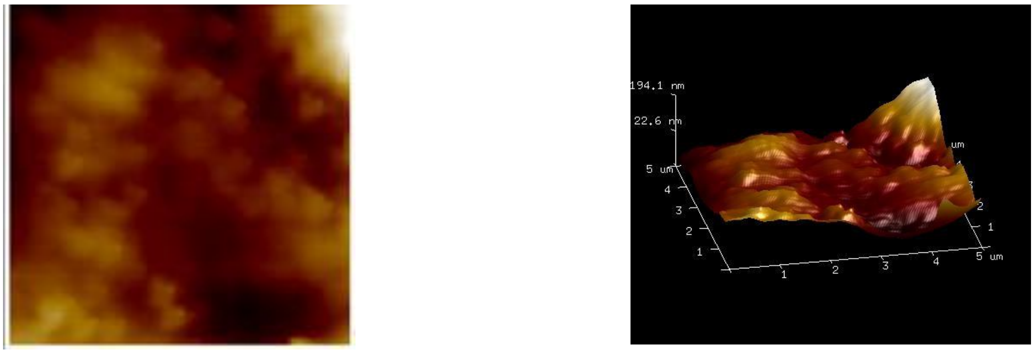
3.1 Surface Topography

Atomic Force Microscopy (AFM) used to determine the surface morphology of Au thin films. AFM techniques allowed to shows the properties of substrates. Fig. 2 and Fig. 3 display 2D and 3D AFM images of Au thin films on different types samples.



a) b)

Fig. 2 a) 2D AFM image b) 3D AFM images of Au thin film on glass sample



a) b)

Fig. 3 a) 2D AFM image b) 3D AFM images of Au thin film on PET sample

Based on the Fig. 2 and Fig. 3, the images results show the PET sample has a smoother and uniform surface compared to the glass substrate. The smoothness surface of sample affects the adhesion of thin film and the enhancement of conductivity. Meanwhile, the roughness on the surface of glass sample might cause from the increasing of resistivity due to the scattering of electrons at the irregular surface which limit the potential of consistency electrical performance [10].

3.2 Electrical Properties

The electrical properties of samples were assessed using the four point probe, measuring the minimum, maximum and average resistivity on two different types of samples which is PET and glass. Results of measurement shows that PET has consistently resistivity compare to glass which make PET more conductive and has potential that fit for wearable technology [4].

3.2.1 Resistance measurement for glass substrate under temperature testing

The resistance measurement for glass sample was measured by using multimeter. Temperature was changed every 10 minutes to indicate the change in resistance.

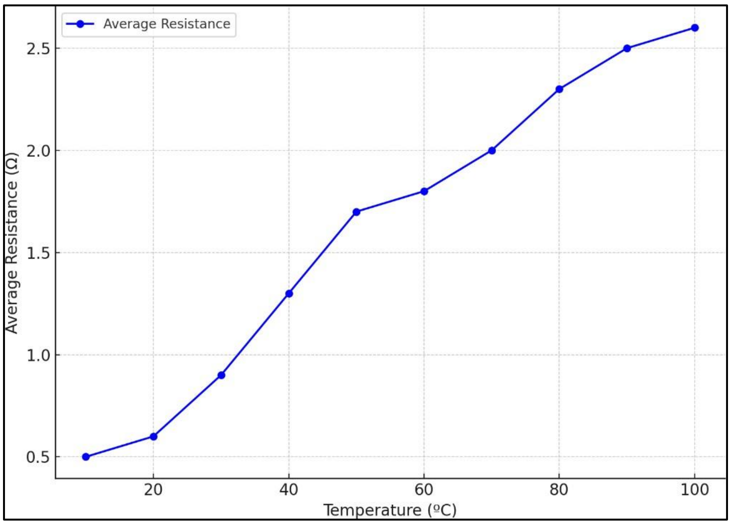


Fig. 4 Temperature vs Average Resistance

Fig. 3 shows the trends that align with the theory of relationship between resistance and temperature for metals, the resistance increases due to the thermal agitation of atoms. Besides, the inconsistency resistance value obtained shows the limitation for thermal stability in testing applications.

3.2.2 Resistance Measurement for PET Substrate Under Flexibility Testing

The change of resistance increases linearly with weight. When the weight is increase, the strain on the sample increase which will affect the resistance. This is to analyse the electrical and mechanical performance under stress.

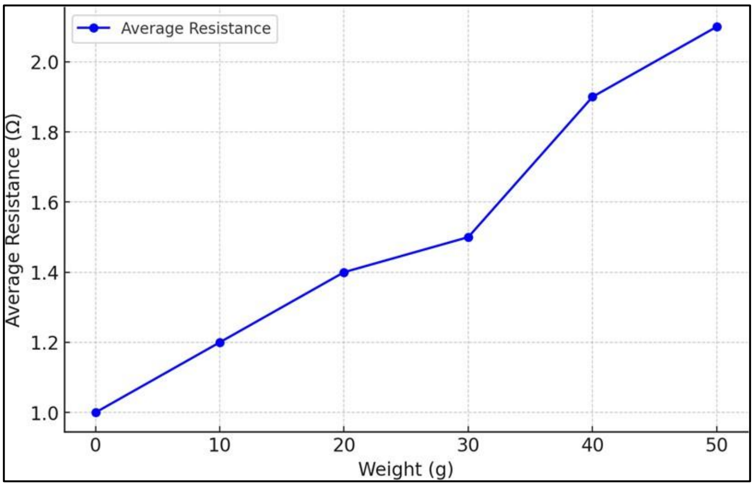


Fig. 5 Weight vs Average Resistance Graph

The surface of PET sample changed due to the stress applied. At the low weight, the sample underwent elastic deformation. Elastic deformation is a temporary change in the shape of sample. The increasing of weight that applied, the clearer change texture of surface. Plus, it is indicating the changes in electrical properties. This shows that PET able to maintain its electrical properties under moderate stress that will make it suitable for flexible and wearable applications.

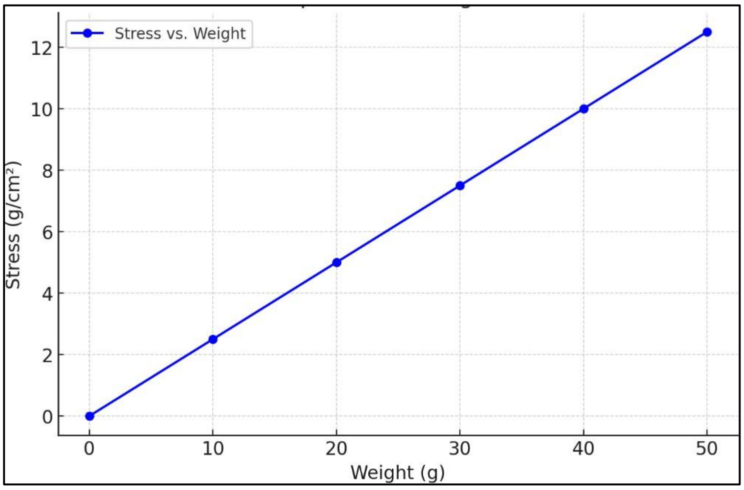


Fig. 6 Weight vs Stress Graph

Fig. 6 illustrates the stress applied to the PET sample during the flexibility testing which shows the relationship between weight and stress. As the number of weight increase, the sample enter a plastic deformation phase led to irreversible changes in surface morphology and electrical properties. Thus, PET sample exceed its mechanical stress limits.

4. Conclusion

This study shows the topographical, electrical, resistance measurement under temperature testing and resistance measurement under flexibility testing of Au films were investigated as a film performance under various types of stress. The objective of investigating suitable substrate materials by depositing gold thin films, and characterizing the electronic properties when stress applied. The difference minimum, maximum and average resistivity obtained from four point probe for two different types of substrates where the average resistivity for glass is $2.87\text{x } 10^{-2}$, meanwhile for PET is $1.43\text{x}10^{-2}$, highlighting the suitability for flexible electronics. Regarding the resistance measurement, there is two different types of stress that applied on the substrate which for glass substrate is temperature testing; change in temperature every 10 minutes and for PET is applying various weight of load with constant height. Characterisation through temperature and flexibility testing revealed that PET an excellent candidate for wearable technology applications. This shows the importance of substrate selection and thin film optimization to meet the requirements and demands for durability, flexibility, and sensitivity in wearable devices. Thus, based on the analysis, it is concluded that testing experiment to ensure the samples is fit for wearable technology.

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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, data collection, methodology, analysis and interpretation of results:*** *Nur Ashikin Zulaikha Yulcifly and Ahmad Hadi Ali. All authors reviewed the results and approved the final version of the manuscript.*

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