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THE EFFECT OF NANO SURFACE TOPOGRAPHY ON ELECTRICAL PROPERTIES OF ALUMINIUM FILMS DEPOSITED ON PLASTIC SUBSTRATE BY DIFFERENT TECHNIQUE

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Abstract

Aluminium films have been prepared by two different techniques namely direct current (DC) sputtering and thermal evaporation on polyethylene terephthalate (PET) substrates. Effects of techniques types on the structural and electrical characteristics of the films were studied. The effect of nano surface topography on electrical properties of Aluminium films was studied. Sets of experiments were conducted to optimize the deposition of Aluminium films with appropriate deposition parameters. The deposited films were analyzed with atomic force microscopy and four-point probe technique to determine their structural and electrical characteristics. Film characteristics such as electrical resistivity and surface roughness have been determined.

Keywords: Aluminium; polyethylene terephthalate; sputtering; evaporation

Introduction

Recently, there is a growing interest in the deposition of several thin films materials on polymers using different techniques such as DC sputtering and evaporation methods (Faraj et al., 2010 ; Faraj and Ibrahim, 2012 ; Faraj et al., 2011 ; Guille´n and Herrero, 2005 ; Zhou et al., 2007) . A special attention was given to aluminum thin layers due to numerous of applications. In the development of highly demanding future product applications, for example efficient portable devices with light-weight and flexible display technologies have been needed. The aluminum thin layers have been used extensively in cell phone, remote control units, digital cameras, smart cards, personal digital assistants (PDAs), camcorders and the future “electronic paper” (Suo et al., 1999 ; Yanaka et al., 1999).

The aluminium thin layers have been used as back contact in layer in thin film silicon solar cells (Popovich et al., 2009; Amick et al., 1994). Therefore, it is important to deposit the aluminum thin layers with the desired substrate materials such as polyethylene terephthalate (PET) (Kale et al., 1975; Nasef, 2002). PET, is a thermoplastic polyester resin. PET may exist both as an amorphous (transparent) and as a semi-crystalline material initiated by various techniques (Awaja et al., 2005; Lee, 1990; Jabarin, 1998). As PET is widely used in complex multilayered systems, the nature of their interface with other metal materials plays a major role in determining the mechanical, electrical and chemical properties of the whole system. However, PET chemical inertness, together with other physical properties, has made it particularly suitable for several applications. PET finds application in a wide array of fields, because it combines low cost with good chemical resistance and good spinnability (Miller, 1966).

Until recently, there is little information concerning the effect of sputtering and evaporation of aluminum thin films on plastic substrates. In this study aluminum thin films have been deposited on PET substrate with DC sputtering and evaporator apparatus. The structural and electrical properties of aluminum thin layers deposited on PET were measured. Film characteristics such as electrical resistivity, sheet resistance and surface roughness have been determined.

2. Experimental details

2.1. Target preparation

The cleaning of contaminants from the PET substrate is a crucial step and must be performed with great care as it has a direct impact on the performance of the device. A 250 mm-thick PET from Penfibre Film Division was used. The PET substrates were first cleaned by full immersion in Decon 90 for 10 min to remove contamination. After the cleaning process, all of the substrates were rinsed with deionized water (DIW) to remove the Decon 90 residue. The samples were then dipped in isopropyl alcohol (IPA) and agitated with moderate ultrasonic power for 10 min. The samples were again dipped in DIW and then dried off with nitrogen (N_2) gas after the ultrasonic cleaning. An aluminium (Al) film was deposited on the PET plastic substrate using DC sputtering (model: AUTO306). The substrate is placed in a vacuum chamber with the source material (target). The residual gas pressure in the chamber was evacuated to $8x10^{-3}$ torr by a rotary and diffusion pump arrangement. The chamber was back filled with argon. Gas plasma is struck using a DC power source, causing the gas to become ionized. The ions are accelerated towards the surface of the target, causing atoms of the source material to break off from the target in vapour form and condense on all surfaces including the substrate. The target was pre-sputtered for 10 minutes to remove contaminations, if any, from the surface and then the shutter was displaced to expose the substrates in the sputtering plasma for 30 minutes. The power used was 250 watts. The sputtering was done in room temperature of 298 K. The distance between the target and PET substrate is an approximately 6 cm.

The evaporator system, Edwards Auto 306 utilizes a common diffusion and rotary pump to evacuate the high vacuum chamber that was made of an enclosed bell jar. Wafers were loaded on top of the vacuum chamber while tungsten boat was used to hold the molten aluminum for evaporation. Source of aluminum (99.99% pure) in the form of long rod was cut into small pieces and loaded onto tungsten crucible in the vacuum. Prior the deposition, the aluminum and tungsten boat were clean in alcohol to remove any contamination and dried with nitrogen gas. The vacuum chamber was evacuated to 3.0 $x10^{-5}$ torr before the source was heated. The tungsten boat was heated with 3.0 amperes direct current for 10 seconds to melt the aluminium. The current was increased slowly to 7.0 amperes until all aluminium was evaporated. The PET substrate was removed after waiting for a few minute to cool down the chamber.

2.2. Characterization of the Aluminium Films

The thicknesses of the Al on the PET substrates are of the order of 500 nm, which were measured with an optical reflectometer (Model: Filmetrics F20). The electrical resistivity and sheet resistance of the deposited Al films were measured by four point probe technique (Changmin Tech CMT-SR2000N Resistivity Measurement System). The surface morphology of the Al films were studied by atomic force microscopy (AFM) (Model: ULTRAlObjective model) at the School of Physics, Universiti Sains Malaysia.

3. Results and discussions

3.1. Structural properties

AFM topographic images were done in non contact mode over 5 um x 5 um area for both samples. **Fig.1 (a)** and **(b)** shows non contact mode images of PET metalized with Al using DC sputtering and evaporation respectively. Evaporation techniques show many spike compare to DC sputtering. The average grain height for both methods is likely to be the same range 12.51 nm and 12.97 nm respectively.

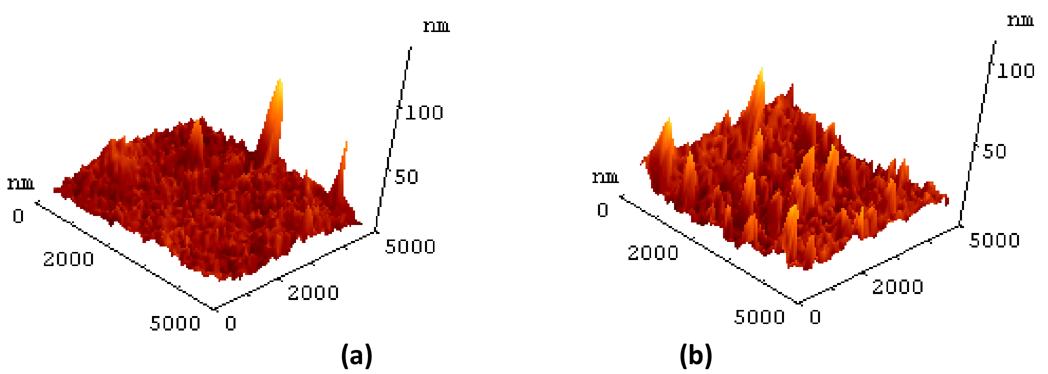

Fig. 1: AFM pictures of Aluminum deposited on PET: **(a)** DC sputtering method, **(b)** evaporation method.

Table 1: Statistical data on Aluminum deposited on PET using DC sputtering and evaporation methods.

	DC sputtered Al	**Evaporated Al**
Max. height different	74.48 nm	57.39 nm
Mean	12.51 nm	12.97 nm
Root mean square	5.66 nm	6.49 nm
Average deviation	3.43 nm	4.69 nm
Skewness	4.28	1.60
Kurtosis	33.33	4.53

The root mean square (RMS) for DC sputtering and evaporation are 5.66 nm and 6.49 nm respectively. This indicates DC sputtering techniques shows better quality compare to evaporation techniques. In the table (1), another parameter that is skewness is a measure of symmetry, or more precisely, the lack of symmetry. The skewness for DC sputtering and evaporation techniques are 4.28 and 1.60 respectively. The DC sputtering techniques, **Fig. 1 (a)** have higher skewness compared to evaporation techniques because the overall distribution have several high peaks on the majority flat surface. However, evaporation techniques, **Fig. 1 (b)** show that the peaks scattered over the substrate tend to be equally distributed.

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. Al deposited by DC sputtering has higher kurtosis value, 33.33 than Al deposited by evaporator, 4.53. **Fig. 1 (a)** shows a very sharp peak out of majority flat area. **Fig. 1 (b)** shows that majority surface area is the same heights indicate low kurtosis value. Obviously, sputtering method shows smoother surface than evaporation technique.

3.2. Electrical properties

Electrical resistivity of the Al films deposited on PET substrates using DC sputtering and evaporation techniques were measured by four point probe system. **Table 2** shows the comparison between electrical resistivity using DC sputtering and evaporation techniques. DC sputtering has much lower resistivity around 2.54×10^{-5} Ω.cm compared to evaporation method 3.40×10^{-5} Ω.cm. It has quite significant difference of 0.86×10^{-5} Ω.cm. Sheet resistance for DC sputtered and evaporated Al are 131.68 mΩ/ sq. and 167.30 mΩ/ sq. respectively. The difference between both techniques is 35.62 mΩ/ sq. This indicates DC sputtering has better electrical conductivity. This indicates with increasing the roughness, increase the electrical resistivity of the films prepared by direct current (DC) sputtering and thermal evaporation. In the present work a comparison took place between the electrical resistivity of Al deposited on PET using DC sputtering and Al deposited on PET using evaporation. These results due to low resistivity, suggest that it would be possible to use Al as a back contact layer in thin film silicon solar cells.

Table 2: Comparison between electrical resistivity and sheet resistance using DC sputtering and evaporation techniques

	DC sputtered Al	Evaporated Al
Resistivity (average)	2.54×10^{-5} Ω.cm	3.40×10^{-5} Ω.cm average
Sheet resistance (average)	131.68 m Ω/ sq.	167.30m Ω/ sq.

4. Conclusions

It is possible to deposit Al films on PET by means of sputtering and evaporating. The deposition of films with good characteristics does not require the unpractically long "presputtering" periods which had been found necessary in the case of the DC sputtering of Al. Films produced by DC sputtering have characteristics which are comparable to the characteristics of films deposited by evaporation. The resistivity ratio of the best films deposited by DC sputtering is somewhat smaller than that of the best films deposited by evaporation. DC sputtering has much lower resistivity around 2.54×10^{-5} Ω.cm compared to evaporation method 3.40×10^{-5} Ω.cm. This indicates with increasing the roughness, increase the electrical resistivity of the films prepared by direct current (DC) sputtering and thermal evaporation. The results of electrical properties of Al/ PET substrate can be used as back contact layer in thin film silicon solar cells.

References

Amick, J.A., Bottari, F. J., Hanoka, J. I. (1994) The Effect of Aluminum Thickness on Solar Cell Performance. Journal of The Electrochemical Society, 141 (6) p.1577-1585.

Awaja, F., Pavel, D. (2005) Recycling of PET. European Polymer Journal, 41(7) p.1453–1477.

Faraj, M. G., Ibrahim, K., Ali, M. K. M., Azhari, F. (2010) Investigation on Molybdenum Thin Films Deposited by DC-Sputtering on Polyethylene Terephthalate Substrate. International Journal of Polymeric Materials, 59 (8) p. 622-627.

Faraj, M. G., Ibrahim, K. (2012) Comparison of cadmium sulfide thin films deposited on glass and polyethylene terephthalate substrates with thermal evaporation for solar cell applications. Journal of Materials Science: Materials in Electronics, 23 (6), p.1219-1223.

Faraj, M. G., Ibrahim, K., Eisa, M. H. (2011) Investigation of the optical and structural properties of thermally evaporated cadmium sulphide thin films on polyethylene terephthalate substrate, Journal of Materials Science in Semiconductor Processing, 14(2) p. 146–150.

Guille´n, C., Herrero, J. (2005) Comparison study of ITO thin films deposited by sputtering at room temperature onto polymer and glass substrates. Journal of Thin Solid Films, 480–481(1) p. 129– 132.

Jabarin, S. A. (1998) PET technology and processing Textbook, University of Toledo.

Kale, P. D., Lokhande, H. T., Rao, K. N., Rao, M. H. (1975) Grafting on polyester fibers. Journal of Applied Polymer Science.19 (2) 461-480.

Lee, N. C.(1990) Plastic Blow Molding Handbook; Chapman and Hall, NewYork.

Miller, M. L. (1996) The Structure of Polymers, Reinhold Publishing Corporation, New York.

Nasef, M., M. (2002) Structural Investigations of Poly (ethylene terephthalate)-graft polystyrene copolymer Films. Journal of Applied Polymer Science, 84 (1) p.1949–1955.

Qiang, Qiang, Ji, Zhou Zhenguo, Hu, BinBin Chen, Chen, Zhao, Lina, Wang, Chao (2007) Low resistivity transparent conducting CdO thin films deposited by DC reactive magnetron sputtering at room temperature. Journal of Materials Letters, 61(2) p. 531–534.

Popovich, V.A., Janssen, M., Richardson, I.M., Van Amstel, T., Bennett, I. J.(2009) Microstructure and Mechanical Properties of Aluminium Back Contact Layers. 24th European Photovoltaic Solar Energy Conference, 21-25 September 2009, Hamburg, Germany, p.1453-1458.

Suo, Z., Ma, E.Y., Gleskova , H., Wagner, S.(1999) Mechanics of rollable and

foldable film-on-foil electronics. Journal of Applied Physics Letters, 74 (8), 1177- 1179.
Yanaka, M.-A., Kato, Yutaka, Tsukahara, Y., Takeda, N.(1999) Effects of temperature on the multiple cracking progress of sub-micron thick glass films deposited on a polymer substrate. Thin Solid Films, 355–356 (1) p.337-342.

تاثير الخشونة السطحية النانوية على الخواص الكهربائية لغشاء الالمنيوم المرسبة على قاعدة بلاستيكية بطرق مختلفة

الخلاصة

تم تحضير اغشية الالمنيوم بطريقتين الترسيب المختلفة تدعى تقنية الترذيذ بالتيار المستمر وتقنية التبخير الحراري على قواعد البولي إيثيلين تيرفثالات(PET) . تمت دراسة تاثير طريقة الترسيب على الخصائص التركيبية والكهربائية لاغشية المحضرة, وكذلك تاثير الخشونة السطحية النانوية على التوصلية الكهربائية لغشاء الالمنيوم المرسبة . تم تحديد الخصائص الكهربائية والتركيبية لاغشية المحضرة كالمقاومية الكهربائية وخشونة السطح بواسطة مجهر القوة الذرية (Atomic Force Microscopy) وتقنية تحقيق اربع Four-Point Probe

كاريگەری زبرە ڕووی نانۆیي لەسەر تواناى گەیاندنی کارەبايي چينە تەنکەکاني ئەلەمنیۆم کە بە ڕێگای جیاواز ڕووپۆش کراون لەسەر بنچینەی پلاستیکی

پوختە

چینە تەنکەکانی ئەلەمنیۆم لە ڕێگەی دوو تەکنیکي سەرەکییەوە ئامادەکران بۆ ڕووپۆشکردن لەسەر بنچینەی پۆلي ئەسیلین تێریفسالەیت (PET) ، ئەوانیش بریتي بوون لە ڕێگەی پرژاندن بە تەزووی نەگۆڕ و تەکنیکي هەڵماندن بە گەرمي . کاریگەری ئەم تەکنیکە جیاوازانە لەسەر پێکهاتەو سیفەتە کارەبایيەکانی چینە تەنکەکان تاوتوێ کرا ، بەمەش لێکۆڵینەوە کرا سەبارەت بە کاریگەری زبرە ڕووی نانۆیي لەسەر تواناى گەیاندنی کارەبايي چینە تەنکەکانی ئەلەمنیۆم . چەند تاقیکردنەوەیەك ئەنجامدرا بۆ هاوگونجاندن کردن لە ڕووپۆشکردنی چینەکانی ئەلەمنیۆم لە ڕێگەی هاوکۆلکەی شیاوی ڕووپۆشکردنەوە . شیکردنەوەی ڕوویي و سیفەتە کارەبایيەکان بۆ چینە ڕووپۆشکراوەکان ئەنجامدرا لە ڕێگەی تەکنیکي مایکرۆسکۆپي (Atomic Force Microscopy) و تەکنیکي چوار پنت (Four Point Probe) ، لە ئەنجامدا بەربەستی کارەبايي و ڕووە زبری چینە تەنکەکان ئەژمارکران.