Australian Journal of Basic and Applied Sciences, 8(2) February 2014, Pages: 87-92

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Prospects of molybdenum thin film for solar cell application from AFM analysis

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ARTICLE INFO

Article history:
Received 1January 2014
Accepted X January 2014
Available online February 2014

Keywords:
CdTe, CIGS, Molybdenum, RF Sputtering.

ABSTRACT

Molybdenum (Mo) was grown on soda lime glass by the radio frequency (RF) magnetron sputtering deposition method to characterize the prospect feature to be used as solar cell back contact. 10 samples were sputtered with different suitable parameter by varying RF target power, argon gas pressure and growth temperature. Then all the samples were analyzed by atomic force microscopy (AFM) to determine their features and specification. The results include molybdenum thin film characteristics of roughness, grain size and root mean square (RMS) is obtained. From these characterization results the paramount parameter condition is obtained which at 200 °C, 6.6 mTorr and 75 Watt. These optimized results can be used in future work for fabricating of molybdenum as back contact layer for solar cell application. In conclusion, this study has obtained the optimized parameter in term of growth temperature, argon (Ar) gas pressure and radio frequency (RF) power for molybdenum growth on thin films that compatible and can be integrated not only for solar cell application but with wide variety of MEMS/NEMS devices.

To Cite This Article: Faiz Arith, Nowshad Amin, Puvaneswaran Chelvanathan, M. Idzdihar Idris., Prospects of molybdenum thin film for solar cell application from AFM analysis. ***Aust. J. Basic & Appl. Sci.,*** *8(2): 87-92, 2014*

INTRODUCTION

World population growth over the years causing the need of electricity is becoming vital. With the increasing cost of electricity from conventional sources and the effect of global warming it is essential to shift to renewable energies to meet the global energy demand. Photovoltaic (PV) solar cell technology is one of the most promising options of all the renewable technologies that can convert sunlight into electricity (Faiz *et al*., 2014; Green, 2000). Among the various PV technologies, such as Si based, a-Si:H and thin film; CIGS and CdTe solar cell which belonging to thin film solar cell group have the large potential for cost reduction with respect to power generation efficiency. The highest reported efficiencies of a CIGS and CdTe solar cell are 19.6% and 18.3%, respectively (Green *et al*., 2013).

Researchers and scientists all over the world are performing a variety of work over the past few years on the growth process and the features characterization of Molybdenum thin films (Pethe *et al*., 2012; Takahashi *et al*., 2010; Assmann *et al*., 2005; Scofield *et al*., 1995). The reason behind this enormous interest is the some specific features shown by molybdenum thin film such as low resistivity, excellent adhesiveness, high thermal stability, and mechanical hardness (Löhmann *et al*., 1999; Kuo *et al*., 2009). Molybdenum has a capability to be used as a surface electron collector layer because of its high electronic conducting capabilities (Esmaeili-Rad and Salahuddin, 2013). There are many applications of Molybdenum such as interconnection in very large scale integration (VLSI) technology (Singh *et al*., 1985) highly protective coating (Zhao and Ye, 2013; Barrera *et al*., 2010), and fabrication process where high temperature is required such as thin film solar cells (Hossain *et al*., 2011: Khatri *et al*., 2008). There are also device applications cover by multilayer films of molybdenum like X-ray optical devices and X-ray detectors. The application of Mo/Si multilayer for soft X-rays needs more thermal stability of the layered structures (George *et al*., 2009). Hence main objective of this study is to grow, fabricate, characterize and evaluate the performance of the molybdenum thin films as a solar cell back contact by using radio frequency (RF) magnetron sputtering and the effect of this deposition specification. Furthermore by combining solar cell device technology with the operational system (hybrid), the optimization of usage energy can be obtain and enhance the performance in term of economical and efficiency (Faiz *et al*., 2013).

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MATERIALS AND METHODS

Fabrication of Molybdenum Thins Films:

In this study, molybdenum is grown on a 10 soda lime glass (SLG) with different parameter by using radio frequency (RF) magnetron sputtering method. Hence, RF sputtering process is a very important thin film deposition method in this study. Sputtering deposition process is a physical vapor deposition (PVD) process whereby thin film layers are produced from the bombardment of energetic particles onto a target, knocking off the atoms of the target material. Film growth occurs on the substrate usually placed on the bottom of the deposition chamber as shown in the figure 1 below.

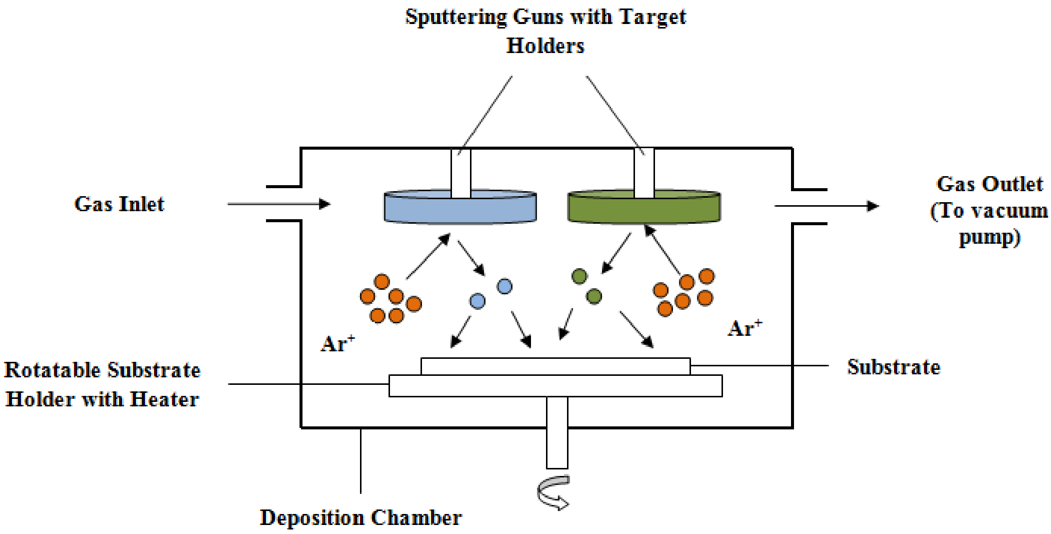


Fig. 1: Schematic diagram of sputtering deposition chamber layout

The energetic particle that is often used in sputtering process is ionized argon gas atoms which are supplied into the deposition chamber via the gas inlet. The sputtering gun has its own power supply with operating frequency of 13.56 MHz During deposition process, initially the argon gas atoms which are introduced are neutral and collide with each other creates argon gas ions which are positively charged (argon atoms loses an electron). The alternating polarity of the electric field induced by the RF frequency will attract and repel the argon ions repeatedly against the target material, causing the target material atoms to be knocked off. To promote a uniform film growth, substrate is rotated with the rotatable substrate holder and the rotation speed can be varied. Substrate can also be heated to enhance the nucleation process during the film growth. Sputtering process offers a flexible platform for thin film deposition research as there are numerous variables that can be manipulated and varied in order to observe the effects on the film growth condition (Davidse, 1967).

Parameter variables:

In this research, sputtering parameters for the buffer layer deposition process that are varied are operating pressure (correlates with argon gas flow rate, sccm), RF sputtering power, and substrate deposition temperature. Table 1 below shows the sputtering parameters that are investigated in this study.

Table 1: RF magnetron sputtering parameter

Sputtering Parameter	Range
Operating Pressure	6.6– 20 [mTorr]
RF Power	50 – 125 [Watt]
Growth Temperature	Room Temperature (RT) – 300 [°C]

AFM characterization produces the results of surface morphology in term of roughness, RMS and grain size. These results play as a main factor consider for the best condition to deposit molybdenum thin film and suitable for solar cell application

RESULTS AND DISCUSSION

Atomic Force Microscopy (AFM):

Atomic Force Microscopy (AFM) is an important probe in the characterization of nanometer-scale structure. The produced force from AFM such as van der Waals forces, electrostatics forces or etc. is reflected by cantilever then measured as scanned surface structure (Gross *et al*., 2009). In this research, the AFM test is performed to the molybdenum sputtered layer to determine the roughness and grain size. Figure 2 to figure 4 show the 3-D view of the molybdenum layer by using AFM with different parameter.

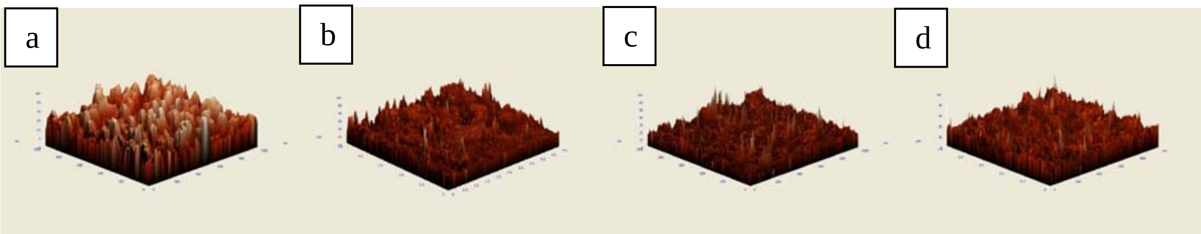


Fig. 2: 3-D view of surface roughness with growth temperature variable using AFM
(a) 25 °C (b) 100 °C (c) 200 °C (d) 300 °C.

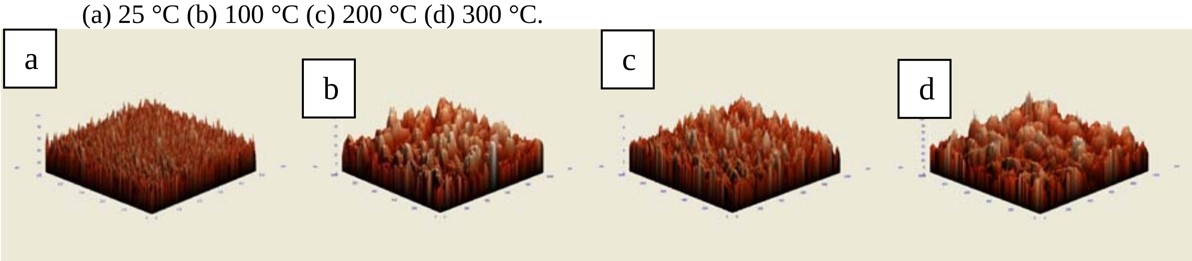


Fig. 3: 3-D view of surface roughness with argon gas pressure variable using AFM
(a) 6.6 mTorr (b) 10 mTorr (c) 15 mTorr (d) 20 mTorr

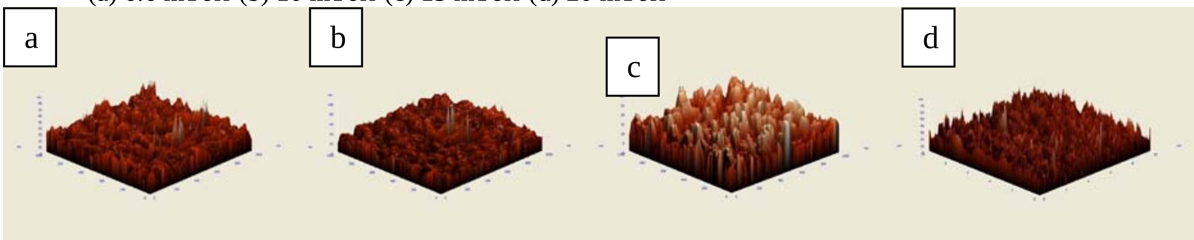
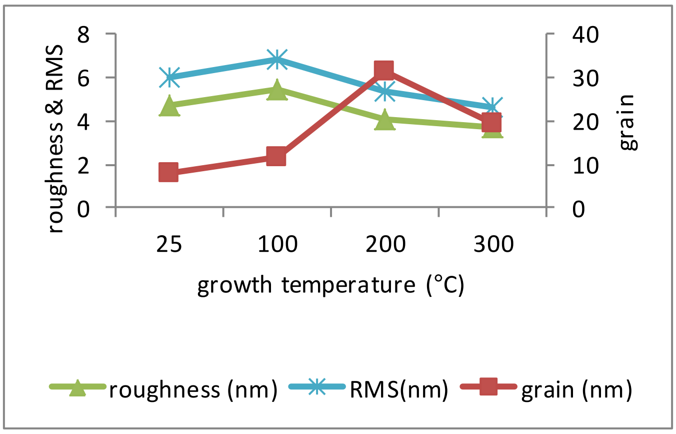


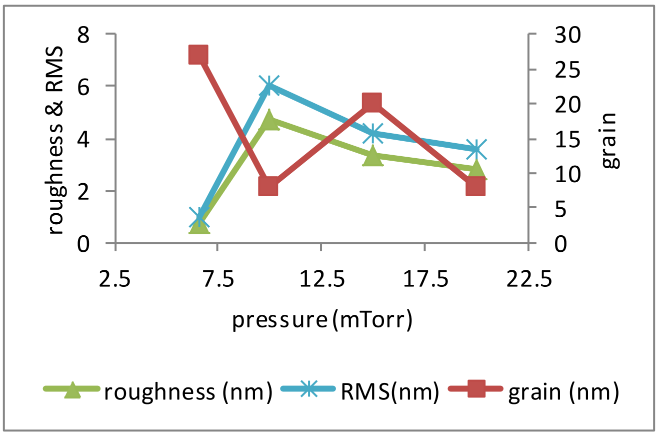
Fig. 4: 3-D view of surface roughness with RF power variable using AFM
(a) 50 Watt (b) 75 Watt (c) 100 Watt (d) 125 Watt

Roughness and Root Mean Square (RMS):

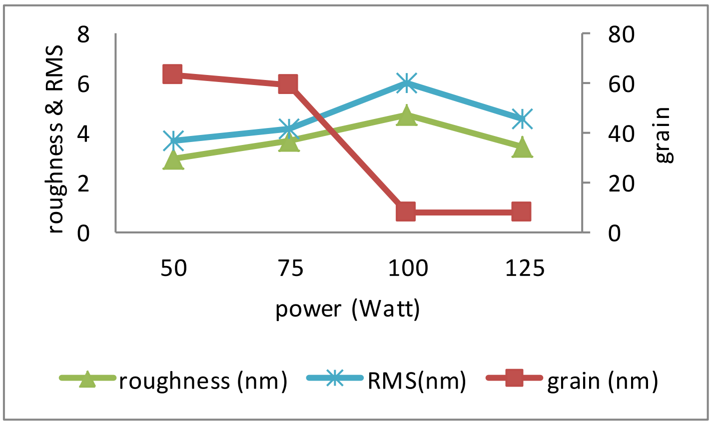
From the AFM test, the roughness, RMS and grain size is obtained. Figure 5 below shows that by varying the growth temperature, argon gas pressure and RF power, the results are significantly different. Surface roughness and RMS show that results are almost same as function of growth temperature and RF power, but abruptly low at low argon gas pressure. Roughness and RMS plays as important role in determining the interaction between samples and environment in term of forming cracks and corrosion (Black and Kohser, 2013; Den Outer *et al*., 1995). These factors are considered for solar cell application as crack and corrosion will reduce the solar cell efficiency in long period. On the other hand, higher roughness may promote better adhesion.



(a)



(b)



(c)

Fig. 5: Surface roughness, RMS and grain size as function of (a) Growth temperature (b) Argon gas pressure (c) RF power

Grain size:

The grain size can be seen higher at 200 °C, below 75 Watt and fluctuated as function of argon gas pressure in Fig. 5. The higher grain size leads to be low resistivity that explains the current flow of the molybdenum thin films (Gordillo *et al.*, 2006). The resistivity is the most important factor to be considered where lowers resistivity produce higher efficiency for solar cell application.

Conclusion:

Molybdenum thin films are deposited on soda lime glass by using RF magnetron sputtering method. It was proved that growth temperature, Ar gas pressure and RF power play as a main influence to the physical, electrical and structural of the films. From surface roughness, RMS and grain size results, we concluded that the best optimized condition for molybdenum deposition is at 200 °C, 6.6 mTorr and 75 Watt. Moreover all this research results properties show that the films is compatible and can be integrated not only for solar cell application but with wide variety of MEMS/NEMS devices and energy harvesters.

ACKNOWLEDGEMENT

This work was financially supported by Ministry Of Higher Education (MOHE), Malaysia through Universiti Teknikal Malaysia Melaka (UTeM) under research grant PJP/2012/FKEKK(7B)/S01099.

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