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SIGNIFICANCE OF SUBSTRATES AND BUFFER LAYERS IN CDTE THIN FILM SOLAR CELL FABRICATION

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ABSTRACT

CdTe is considered as a viable absorber material for the thin film solar cell because of its excellent material characteristics as well as simple, low cost manufacturability. Despite a theoretical 29% efficiency prediction of the cell, its high work function and coefficient of thermal expansion (CTE) have limited its efficiency to around 17%. One of the remedies of the problem is using a pseudo contact layer, which is called buffer layer in its back contact structure. In this study, different types of buffer layers have been investigated for possible application. Sb_2Te_3 and ZnTe have been deposited on top of different substrates (Mo, PI) by RF magnetron sputtering and the effects on the deposited films were studied in terms of their structural and morphological forms. In both cases, Sb_2Te_3 and ZnTe show better performance on top of molybdenum (Mo) sputtered on polymide (PI) rather than molybdenum (Mo) sputtered on molybdenum (Mo) substrate. SEM characterization reveals larger grain sizes as found in Mo sputtered on PI and some cracks were observed in case of Mo sputtered on Mo. However, after $CdCl_2$ treatment CdS surface exhibits larger grain size on top of Mo substrate. While using ZnTe as the buffer layer making it much more advantageous for CdTe solar cells.

Key Words: Thin film solar cells, CDTE, Buffer layer, Molybdenum, Polyimide.

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INTRODUCTION

Renewable energy sources are the most favorable choices to meet the global energy demands. In spite of other several choices, photovoltaic solar cells have found thin film technology as a suitable and apposite vehicle for the global transfer from fossil-based energy sources. Additionally compared to traditional crystal silicon (Si) based solar cell, thin film solar cell is cheaper, less complexity, with faster deposition process. Among all the thin film solar cell CdTe is still holding the topmost position for large scale PV industrial production as well as at the lower cost of USD 0.75 [First Solar Inc., 2010]. CdTe is a good absorber layer because of its near-optimal direct bandgap of 1.5eV and large optical absorption (> 10^4 cm^{-1}). Moreover, under proton and electron irradiation CdTe has the highest stability, which makes CdTe cells very attractive for space applications [A. Romeo et al. 2005]. The predicted efficiency of CdTe solar cell is 29%, although by epitaxial growth of CdS on p-type single-crystal CdTe exhibited a conversion efficiency of 11.7% in the late 1970s [Zubía et al. 2007]. Several researches had been done using CdTe as an absorber layer, however the highest reported efficiency for CdTe solar cell is < 17% and has not improved much in over 17 years because of some inescapable reasons [Zubía et al. 2007, A. Romeo et al. 2005]. One of the reasons is the non-ohmic contact formed between the CdTe and the metallic back contact, which leads to higher series resistance and thus lowers cell efficiency. In addition, it is believed that depositing CdTe films on smother substrate has positive effect on the growth and microstructure of the films, which eventually affect the overall cell performance. In superstrate configuration, it is possible to deposit CdTe on top of glass, having flat and smooth surface. However, in the case of substrate configuration, normally CdTe deposit on metallic or polymer foils having curved and lower surface smoothness. Alternatively, a buffer layer is used between the substrate and CdTe, in order to obtain good ohmic contact. Hence, the roughness of the buffer surface may cause negative effects due to surface variation [Aliyu et al. 2012]. One of the foremost issues associated with the fabrication of CdTe solar cells is the formation of a low resistance back contact of higher stability. However most metals do not have a sufficiency high work function to overcome the large (5.7 eV) potential barrier created by the CdTe, therefore forming of a Schottky barrier at the Back Contact is a common phenomena. The most promising approach used to date is based on the use of a heavily p-doped interlayer between CdTe and metal contact, which is known as a pseudo-contact [Hodges et al. 2009]. As a result, barrier width decreases as well as making tunneling through the barrier to form a quasi-Ohmic contact. Several materials have been investigated for the pseudo-contact layer such as Cu/Au [Hodges et al. 2009], Cu-doped ZnTe [Hodges et al. 2009], Cu/Mo [Romeo et al. 1998], ZnTe [Gessert et al. 1995] , Sb_2Te_3 [Romeo et al. 1998, Romeo et al. 1999] . The band alignment of ZnTe is favorable for the hole transfer, therefore contacting with metal is easier [Romeo et al. 1999].

In this work, we have investigated the effect and significance of different interlayer on different substrate on the film quality as well as possible effects on the performance of CdTe solar cell.

Hence Sb_2Te_3 and ZnTe are used as inter layers and Mo along with PI used as substrates. Afterward, $CdCl_2$ treatment was carried out and result of $CdCl_2$ treatment was investigated.

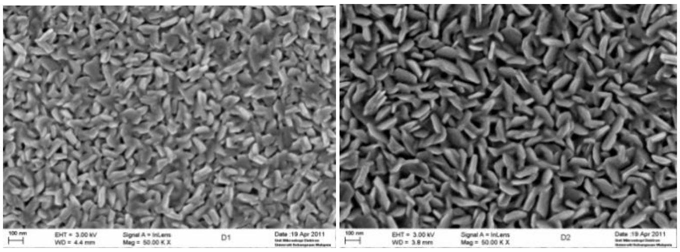
EXPERIMENTAL PROCEDURE

At first thin sheets of Molybdenum (Mo) and Polymide (PI) were cleaned by ultrasonic bath for 10 minutes each using the four stages ethanol, acetone, ethanol and DI water as well as followed by drying using nitrogen gas. After that, the sputtering chamber was evacuated up to a base pressure of $1x10^{-4}$ Torr. Hence, the sputtering condition for Mo and PI were RF power of 100W, substrate temperature of 200˚C and argon pressure of 16 mTorr. Subsequently Mo target of 99.99% purity was sputtered on top of the substrates , while the thickness were about 1.54µm. Afterword Sb_2Te_3 and ZnTe were sputtered on top of Mo ,where the sputtering conditions for both Sb_2Te_3 and ZnTe were RF power of 40W, substrate temperature of 200˚C and argon pressure of 17 mTorr. However, the deposition time for Sb_2Te_3 was 28 minute to a thickness of 60.8 nm and in the case of ZnTe the sputtered time was 23 minute to a thickness of 78nm. After that, CDTe of 1.327µm thickness was deposited using substrate configuration on both Sb2Te3 and ZnTe. The sputtering conditions were RF power of 25W, Substrate temperature of 250˚C, argon pressure of 18 mTorr, while the base pressure at which the chamber was evacuated was $6.5x10^{-5}$ Torr. After that, CdS layer of 160 nm was deposited on top of CdTe and the sputtering conditions were RF power of 30W, Substrate temperature of 250˚C and argon pressure of 18 mTorr. The base pressure at that time was $1.3x10^{-4}$ Torr. Afterword all the samples were given the $CdCl_2$ Treatment at by dipping in 0.3 M CdCl2 solution and thermal annealing for 15 minutes at 390ºC. Using SEM all the films were characterized as well as their possible effects on solar cells was investigated.

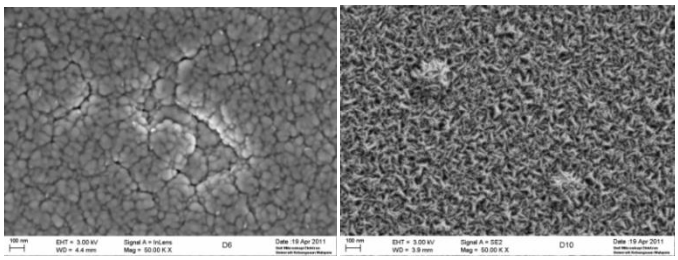
RESULTS AND DISCUSSION

Figure 1 shows the SEM image of (a) antimony telluride (Sb_2Te_3) deposited on different substrate using Mo as an interlayer under the same magnification. It is readily observed that the grain size of Sb_2Te_3 on PI substrate is larger and with better distribution. It is well known that large grain size films are important in the fabrication of high efficiency solar cells because such grains lead to reduced carrier scattering as well as improve carrier concentration by means of reducing carrier recombination [Ohring 1992]. On the other hand, Sb_2Te_3 on top of Mo substrate is compact and smaller grain size. Moreover, the crystal structure of Sb_2Te_3 on PI is sharper than that on Mo. Despite the identical sputtering conditions of both materials, Sb_2Te_3 shows better crystallinity on polymide compared to that on Mo. This may be attributed to the higher surface roughness of Mo substrate compared to that of PI [Aliyu et al. 2012].

Figure-1. (a) SEM images of Mo/Mo/Sb_2Te_3 (left) and PI/Mo/Sb_2Te_3 stacks (right), (b) SEM images of Mo/Mo/ZnTe (left) and PI/Mo/ZnTe (right) stacks



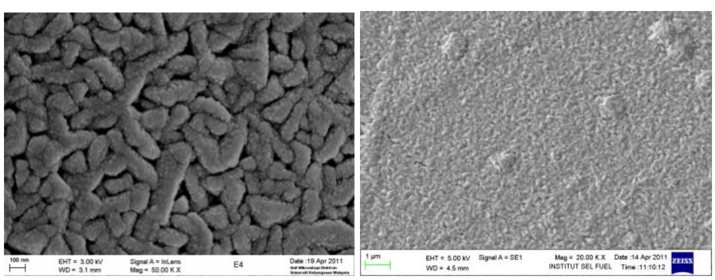
(a)



(b)

Figure 1 shows the SEM images of (b) ZnTe deposited on different substrate using Mo as a contact layer. It is apparent that while the ZnTe on the Mo substrate has large grains the same ZnTe on PI substrate show smaller grains. However, the film in figure shows signs of cracks, which was not observed in the PI sample. This we believe may be due to issues of thermal expansion coefficient and adhesion between films and substrates.

Figure-2. SEM images of Mo/Mo/Sb_2Te_3/CdTe/CdS and PI/Mo/Sb_2Te_3/CdTe/CdS stacks



.Figure 2 exhibits the SEM images of CdTe/CdS stack on Mo and PI substrates while the buffer layer in both cases is Sb_2Te_3. Hence the deposition conditions for CdTe/CdS on both substrates are same. From the images it can be concluded that CdS on top of Mo shows better grain size compared to that on PI. While in the case of PI substrate some blisters are apparent even though CdS of 160nm was deposited on CdTe of 1.33µm thicknesses, which are not observed in the Mo substrates. Similar effects are also observed in figure 3, with similar stacks except that ZnTe is the interlayer. We attribute these to be due to the poor thermal conductivity of PI compared to Mo. Thus, lower substrate temperature may cause smaller grain sizes of the PI films. On the other hand, the poor adhesion of PI may be the cause of the blisters observed.

Figure-3. SEM images of PI/Mo/ZnTe/CdTe/CdS and Mo/Mo/ZnTe/CdTe/CdS stacks.

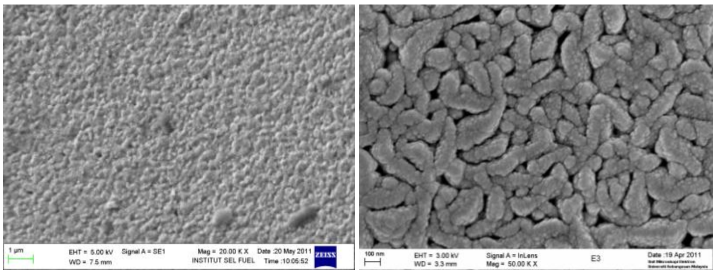
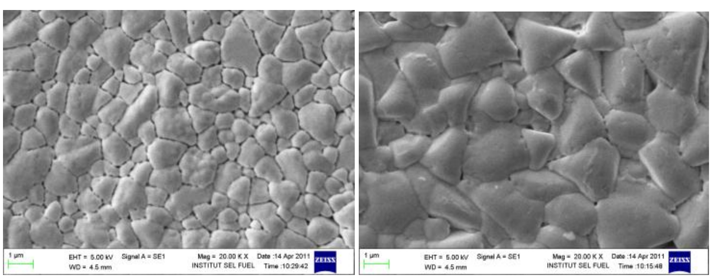


Figure 4 shows the SEM images after $CdCl_2$ treatment. From the figure, it is clear that the grain sizes are greatly improved. It is well known that $CdCl_2$ treatment facilitate to reduce the grain boundaries and increase short circuit current, as well as the open circuit voltage [Romeo et al. 2002, Romeo et al. 2006, Candless et al. 1994]. Hence, it can be concluded that grain size of CdS is better in case of using ZnTe rather than Sb_2Te_3. Additionally the grain boundaries are also more apparent in the case of ZnTe interlayer, although the substrates are same in both cases.

Figure-4. SEM images of Mo/Mo/ Sb2Te_3/CdTe/CdS and Mo/Mo/ZnTe/CdTe/CdS after $CdCl_2$ treatment.



CONCLUSION

The influence of substrate, as well as interlayer or buffer layer on the quality of subsequent layers deposited in substrate structure of thin film CdTe solar cells has been investigated. By using two different types of substrate and two different types of interlayers, the structural and morphological form of deposited films show that uniform as well as compact films are possible to produce. However, Sb_2Te_3 exhibits better performance than ZnTe on PI and Mo. Although after $CdCl_2$ treatment, the CdS on ZnTe interlayer exhibits larger grain size. Further studies on the effect of the inter layer are being carried out.

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