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Dependence of the Characteristics of Mo Films on Sputter Conditions

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ABSTRACT

The residual stress, resistance, orientation, and microstructure of sputtered Mo films were studied as a function of varied-deposition power and pressure. CIGS films were deposited by the three-stage process on the Mo films and their efficiency were related to the Mo films. The varied-deposition parameters of the Mo films produced CIGS device efficiencies from 13% to 17%.

1. Introduction

Mo thin films are used as an ohmic back contact for CIGS devices. Scofield [1] investigated deposition parameters for good adhesion. Here we revisit in more detail the deposited Mo-film characteristics: sheet resistance, residual stress, and adhesion to soda-lime glass. These properties are expected to influence the growth of the subsequent CIGS layer and, ultimately, the device performance.

2. Experimental

Films were sputtered using a 5" x 8" x 0.125" Mo target in a DC magnetron with a substrate to cathode distance of 78 mm. The 4" x 4" substrates were rotated into the path of the cathode and held stationary for the predetermined time to deposit a 0.75-µm-thick film. The base pressure in the vacuum system prior to deposition was less than 4 x 10^{-7} Torr. The soda-lime glass used for this experiment had a water-buff treatment performed by USPG on the float side of the glass. The water-buffing procedure uses CeO_2 slurry to polish the glass surface and remove imperfections. The matrix for this study consisted of Mo deposited in the constant-current mode at 1, 3, 5 and 7 amps. For each current setting, the pressure was 0.6, 0.7, 0.8 and 0.9 and from 1 to 16 mTorr in 1mTorr steps. The sheet resistance was measured diagonally across the substrate in three-equal distance steps using a four-point probe. The substrates were cut for XRD, thickness measurements, and SEM micrographs. CIGS films were deposited on a 3" x 3" portion of the Mo substrate.

3. Results

Power density was calculated using the target area. The power density for 1, 3, 5 and 7 current settings ranged 7~9, 21~29 and 38~50 and 66~82 W/in^2 respectively. The bulk resistance was calculated from the average of the sheet-resistance measurements and is shown in Figure 1. The bulk resistance decreases as deposition current increases. Figure 2 shows residual stress calculations made by the XRD Sin$^2\psi$ technique. Again, the curves shift with increase in current.

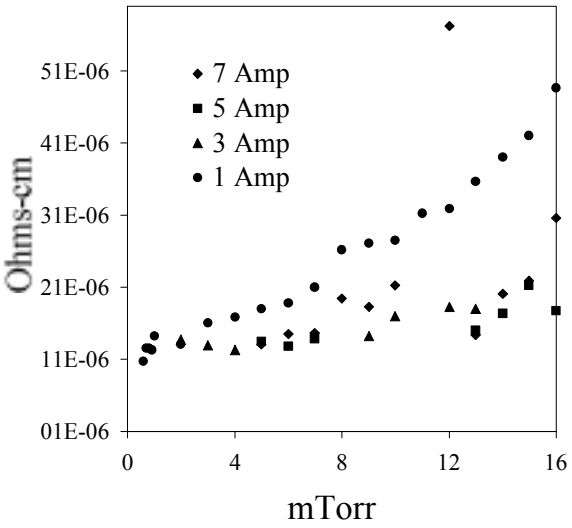

Fig. 1. Bulk resistance as a function of deposition pressure

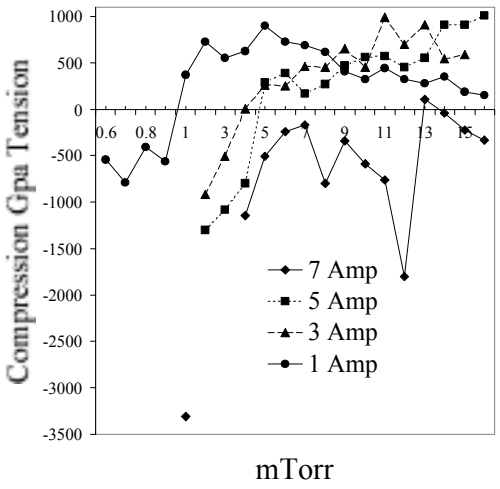

Fig. 2 Residual stress measured by the XRD Sin$^2\psi$ technique

XRD θ/2θ results of the films show a strongly-oriented 110 Mo film. The 211/110 ratio decreases as deposition pressure increases, as shown in Figure 3. The 211/110 ratio for powdered Mo is 0.31 [2]. A SEM micrograph of 0.8-mTorr-deposited film is surface shown in Figure 4. Figure 5 shows a SEM micrograph of a film deposited at 10 mTorr exhibiting increased grain size. The film sputtered at 0.8 mTorr was measured to be in compression and to have poor adhesion to the substrate while the 10-mTorr-sputtered film was under tensile stress and exhibited good adhesion using the tape test method [1].

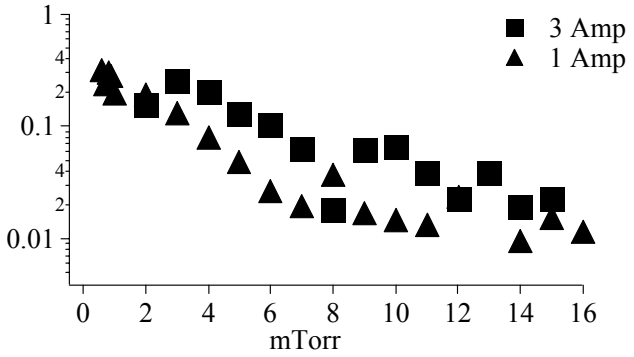

Figure 3 Normalized XRD 211/110 peaks

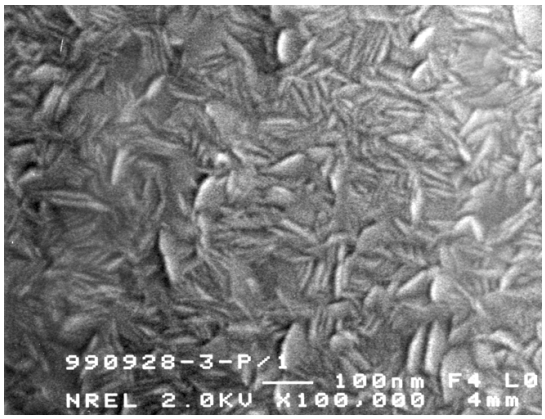

Fig. 4. SEM view of Mo surface deposited at 0.8 mTorr

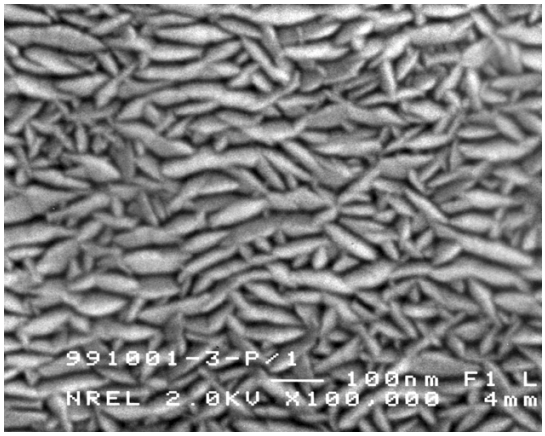

Fig. 5. SEM view of Mo surface deposited at 10 mTorr

Devices consisting of soda-lime glass/Mo/CIGS/CdS/ZnO were measured in the laboratory and results of the devices on Mo films sputtered at 1 amp are shown in Table 1.

mTorr	Voc (V)	Isc (ma)	FF (%)	EFF (%)
0.6	0.603	12.92	72.48	13.13
4.0	0.665	13.845	73.09	15.64
8.0	0.680	14.29	75.05	16.96

Table 1. Results of CIGS devices made on Mo films sputtered at power density of 7~9 W/in^2.

4. Discussion

The bulk resistance shown in Figure 1 shows a trend of lowered resistance as the deposition current increases. The shift is caused by the localized-pressure drop in front of the cathode where an increase in the current gives a larger plasma with greater heating effect. These conditions are also responsible for the shift in residual stress. The 7 amp residual stress and bulk-resistance values are skewed because the Mo target was replaced during the middle of the deposition set and the large amount of heat generated by the plasma. The break in period of the Mo target was not long enough and impurities on the target surface added to the changes.

5. Conclusion

Mo films were sputtered at different power densities and Argon pressure. The resulting films showed similar sheet resistance and intrinsic stress, taking into account the effect of localized heating around the plasma and lowering of pressure. The microstructure of the Mo film was shown to have greater ordering as the pressure was increased. The combined characteristics of the Mo films are shown to influence the CIGS films such that finished soda-lime glass/Mo/CIGS/CdS/ZnO device efficiencies ranged from 13% to 17%. The highest efficiency was obtained for devices made on Mo films deposited at 1 amp and 8 mTorr. The results will be reviewed in a future article in greater detail.

REFERENCES

[1] J. Scofield, A. Duda, D. Albin, B. L. Ballard, P. K. Perdecki : "Effects of Argon Pressure on the Properties of Sputtered Mo Films for CIS and CIGS Thin Film Solar Cell Back Contact Applications" 1st World Conf. on Photovolt. Energy Conv. Hawaii 1994

[2] JCPDS card 42-1120 Mo cubic a=3.1472