Electrical and Morphological study of Mo thin films for solar cell applications

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Abstract: *Molybdenum thin films as ohmic contact for photovoltaic solar cell were deposited on ceramic tiles by PVD technique. The supports were previously covered with different type of industrial glazes. Morphological and electrical changes have been studied as a function of parameters like: substrate temperature, glaze nature, sputtered time and cycles. Rising of the layer thickness results in significantly electrical resistance reduction and previously heated substrate provides noble contact adhesion. Different microstructures were found for the Mo films by varying in glaze nature. The obtained results allowed us to select the optimal conditions and materials for this solar cell component.*

Key words: *Photovotaic solar cell, Mo ohmic contacts, PVD*

INTRODUCTION

The photovoltaic solar cells offer a limitless and environmentally friendly source of electricity. Nowadays, these devices are used for plenty of applications as it integration in urban areas (Building Integrated Photovoltaics, BIPV) [1]. For that purpose, the layer thickness is an essential part of the cells and can varies from a few nanometers to tens of micrometers. The technology based on thin film deposition of materials on substrate has an advantage to reduce significantly production costs keeping adequate solar conversion efficiencies [2- 4]. The thin film solar cells combine very thin layers of photovoltaicly active material placed on variety of substrates like glass, metal or flexible polymers which opens a new dimension for novel applications [5]. However, an exhaustive search of previous art has not revealed any published or patented data that resemble the ceramic tile incorporation as a support for directly integrated photovoltaic solar cells.

In this sense, we have developed ceramic photovoltaic tile that have objectives of reducing production costs and adding of mark- up to the final products. An introduction of this substrate give also an advantage of high temperature uses keeping the material thermal stability. The cell components are thin films (ohmic contact, p-type “absorber” and n-type “window”, antireflection layers), whose morphological characteristics determine the reliability and efficiency of the final device.

In the present work, we performed morphological and electrical study of ohmic coatings that covers the entire back surface of the solar cell and acts as a conductor. This back contact is made out of a metal and it fabrication is a much-studied part of materials engineering filed. It fabrication relies on several requirements that cause difficulties in reproducibility and reliability of the contacts. The metals are usually deposited via sputter deposition, evaporation or chemical vapour deposition (CVD) [6- 8]. Sputtering is a faster and more convenient method of metal deposition and we used it in our experiments.

Several metals like Au, Pt, Ag, Cu, Ni, Al, etc. have been investigated as electrical contacts for $CuInSe_2$ (CIS) and $CuIn_xGa_{(1-x)}Se_2$ (CIGS) - based solar cell [9]. Nevertheless, Mo layer is preferable among the others metals, because withstands corrosion against Se and S. It is chemically stable to CIGS absorber and has thermal expansion co-efficient ($5 \times 10^{-6}K^{-1}$) close to CIS ($9.5 \times 10^{-6}K^{-1}$). However, different deposition parameters as Ar pressure, substrate temperature, coating time, etc. have been investigated in order to obtain appropriate contact layer. These parameters strongly affect to the mechanical, structural and adhesion properties of the back contact material and have to be strictly controlled during the coating process.

Here, we describe Mo thin films deposition on ceramic tiles covered previously by different types of industrial ceramic glazes. The glaze, an intermediate layer between Mo and the substrate, provides chemical stability and roughness reduction, simulating glass surface with no porosity. Physical Vapour Deposition (PVD) was used to perform the coating. Morphological changes and electrical resistance were studied as a function of process parameters like: substrate morphology and temperature, glaze nature, sputtered time and cycles. The obtained results allowed us to consider what the optimal conditions for this solar cell component are necessary.

EXPERIMENTAL PART

Molybdenum thin films as back conductive contacts for solar cell applications were deposited on ceramic tile substrates using DC magnetron sputtering system model EKMA VU-1100 “D”-03 with conventional planar electrode configuration. The ceramic supports were protected earlier by industrial glaze with sodium-calcium vitreous nature. The Mo cathode was 99.9% pure. During the sputtering process, the target material, ceramic tiles, and electrodes are in a vacuum chamber that was evacuated by pump to base pressure 10^{-3} mbar. The Ar-pressure, directed into the chamber, was manually controlled by throttling a high vacuum gate valve. The target was previously ultrasonic cleaned and further heated at 170ºC before it entrance into the chamber. There was no additional heating during the deposition.

The Mo microstructure was studied by Scanning Electron Microscopy model JEOL 700F. The films electrical resistance was measured using a digital multimeter (Volt-Ohm meter). Adhesion between Mo and support was measured using laboratory test method by applying and removing tape and scratching of the surface. These test methods are used to establish whether the adhesion of a coating to a substrate is at a generally adequate level.

RESULTS AND DISCUSSIONS

The Mo film was PVD- sputtered on ceramic substrates (porcelain stoneware bodies) previously covered with four industrial ceramic glazes. The samples are referred as S1, S2, S3 and S4. Several tests with sample S1 (randomly chosen) were performed in order to reveal the most suitable process conditions (Table 1). Sputtered time, cycles and substrate temperature were main variable during the deposition. The influence of these factors on the layer thickness, adhesion and electrical resistance were studied.

Table 1. Sample S1 tested under different sputtering conditions (time, cycle) and it corresponding results (layer thickness and electrical resistance).

Tests	Time (min)	Layer thickness (nm)	Resistance (Ω)
1	7	200	64
1a	7	200	64
2	14	318	41
3	28	390	55,7
4	14 (2)	420	12
5	14 (3)	800	6,9

The Mo deposited on a cool substrate (Fig. 1-1) shows detached 200nm layer with high electrical resistance (64Ω, Table 1- test 1). The result was unsatisfying as a strong adhesion of Mo on the glaze layer is essential since the substrate has to withstand stresses induced during photovoltaic stack manufacturing and its integration into modules without cracking or delaminating. Further on, the support have been heated at 170ºC and next sputtered. The morphology (Fig. 1-1a) reveals well-formed union between the glaze and the metal. However, the coating depth and resistance maintain constant. In order to increase the layer thickness, a time during treatment was also raised. This strategy resulted in gain in the layer depth (from 200nm to 318nm) and resistance reduction (from 64Ω to 41Ω) (Table 1- test 1 to test 2). An interesting remark was observed when an additional increment did not cause the same effect (Table 1- test 3). Thus, the procedure was repeated depressurizing the PVD chamber. The responses corresponds to Test 4 and Test 5 (Fig. 1- 4, 5), where evidence of increased layer thickness (up to 800 nm) and decreased resistance (6.9Ω) is observed. In conclusion, the electrical respond of the Mo ohmic contact is related with film thickness and it deposition conditions.

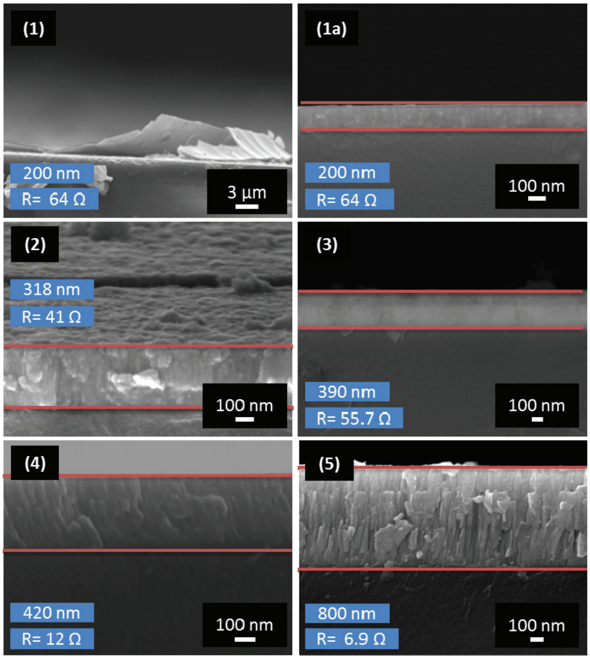

Figure 1. SEM cross-section micrographs of sample S1: (1) Test 1, (1a) Test 1 (heated support), (2) Test 2 and (3) Test 3, (4) Test 5, (4) Test 5.

Subsequently, the support compatibility has been studied. For this purpose, four ceramic tile laminates with reduced thickness (5 mm) and very low porosity (99%) referenced as S1, S2, S3 and S4 were covered with different glazes coming from a ceramic industry. The Mo films were deposited by PVD sputtering applying the optimized conditions detailed above.

Four different microstructures for the Mo films were found (Fig. 2). Surface micrographs shown in Figure 2 displays different crystal growth according to the glaze employed. Sample S1 (Fig. 2a) presents grains (≤ 20nm) that are crystallized in different directions. Sample S2 (Fig. 2b) differs by having shape, size and particle distribution more uniform than S1, but it morphology reveals certain sintering process. Samples S3 and S4 presents similarity in crystal forms, but S4 highlights with better crystallinity and homogeneous grain orientation. From these observations it is hard to say which the most accurate support is.

Thus, cross-sectional views of the substrates were also done. The most uniform layer corresponds to sample S2 (Fig. 3b) in agreement with its crystalline growth discussed before. In other micrographs similar microstructures are observed (Fig. 3a, c and d). As a consequence, S2 support was selected as more appropriate for solar cell application.

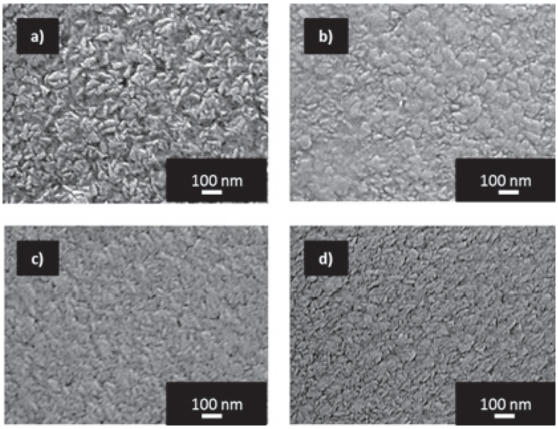

Figure 2. Surface morphology of Mo thin film deposited by PVD on ceramic substrate: (a) S1, (b) S2, (c) S3 and (d) S4.

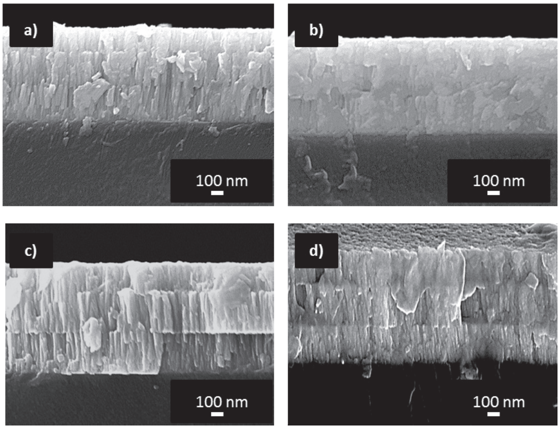

Figure 3. SEM cross-section micrographs of: (a) S1, (b) S2, (c) S3 and (d) S4.

CONCLUSIONS

Molybdenum thin films as conductive back contact component for photovoltaic solar cell were studied. The metal layer was deposited on ceramic tiles by PVD technique. Morphological and electrical changes occurs varying substrate temperature, glaze nature, sputtered time and cycles. Rising of the layer thickness results in significantly electrical resistance reduction and previously heated substrate provides noble contact adhesion. The glaze nature affects to the Mo morphology. Different crystal growth directions and grain dimensions are observed varying the glaze type. The obtained results were used to determine the more suitable deposition conditions and materials for this solar cell component.

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