

PROPERTIES OF Cr AND Mo THIN FILMS DEPOSITED BY RF SPUTTERING

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This report summarizes our recent efforts to produce a good quality Cr and Mo thin films for use in Cu(InGa)Se₂ (CIGS) based solar cells. The surface morphology and the resistivity of Cr and Mo films with various thicknesses ranging from 280 to 750 nm were investigated. The films were deposited in a Tokyda-CPF-4EF RF sputtering system, at powers ranging from 100 to 250 W in a 1 Pa argon atmosphere. The substrate temperature was about 200 °C. The deposition rate did not exceed 900 nm/h. The morphology of the films was studied by SEM, and the resistivity was measured by a Four Point Probe method. A correlation was established between the surface morphology (grain size), the resistivity, and the deposition parameters of the Cr and Mo-based layers.

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1. Introduction

Thin film photovoltaic device technology has made a lot of progress in recent times, resulting in high performance devices with moderate costs. Thin film solar cells based on evaporated copper indium di-selenide CuInSe₂ (CIS) or its gallium or sulfur alloys exhibit high efficiencies – almost 17 % on laboratory scale [1] and 15.2% in a 24cm² cell designed by Tuttle *et al.* [2]. This success was mainly determined by the efforts of different groups of scientists to understand the fundamental properties of the photovoltaic materials. A variety of metals have been investigated as a back contact layer, such as Au, Ti, Mo, Al, Ni, Ag and Cu [3-5]. Martinez and Guillen [6] studied the influence of the microstructure of RF sputtered Mo on the properties of CIS thin solar films. Other works have revealed that Au, Ti, Mo and Ni form fairly reproducible low resistance contacts to CIS layers, when annealed at high temperatures. However, only Ni and Mo have emerged as suitable ohmic contacts to these cells [5]. The structure, morphology and electrical characteristics of these layers depend on the deposition conditions. The aim of the present study was to show how the resistivity of Cr and Mo layers, and their morphologies, are influenced by the process parameters of the RF system.

2. Experimental details

The metallic layers were sputtered onto [100]-p type, 4-6 Ω. cm silicon substrates, in the Tokuda CPF-4EF reactor. Before the deposition, the silicon wafers were chemically cleaned in H₂SO₄:H₂O 1:1 for 30 min, washing in deionized water and centrifuged at 6000 r/min. The sputtering conditions are summarized in Table 1:

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Table 1. Deposition parameters.

Operational parameters	
Temperature [°C]	200
Vacuum [mbar]	$1 \cdot 10^{-2}$
Ar gas flow [sccm]	80
Power [W]	100, 150, 200, 250
Sputtering time [min]	60

Table 2. The measured thicknesses d [nm], sputtering rates V [nm/min] and resistivities ρ [$\Omega \cdot \text{cm}$] of the Cr and Mo layers.

Power [W]	Parameters					
	Cr			Mo		
	d	V	ρ	d	V	ρ
100	400	6.6	4	280	4.7	1.61
150	600	10	1.64	460	7.3	0.70
200	750	12	1.25	600	10	0.45
250	950	16	0.9	750	12.5	0.90

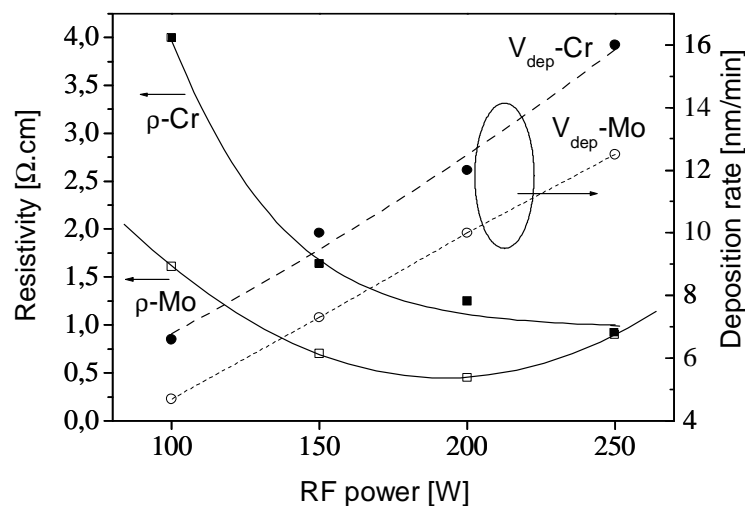


Fig. 1. Resistivity and deposition rates for Mo and Cr layers, as functions of the RF power.

The deposition rates and the sheet resistance of the Cr and Mo layers are given in Table 2, for different sputtering powers. These results are also presented in Fig. 1.

The plotted results reveal distinct dependences of both the deposition rates and the sheet resistances, as functions of the applied RF power. The lower resistivity values were achieved for supplied powers in the range 180-200 W. We can conclude that in this region the energy supplied to the growing film by the bombarding particles and the ion density current are optimal in respect of the arrival ratio of ions/metal particles. It is expected that at higher deposition temperatures, the resistivity curves should be shifted toward lower RF power values (Fig. 1), as far as the ion bombardment and the temperature are synergetic factors. These factors result in a denser packed crystalline structure. The deposition rates of the Cr layers at all four power levels were about 30 %

higher than those of the Mo layers. If we estimate the sputtering coefficients for the Mo and Cr targets, using the SRIM code, we find values of 1 and 1.22 for a 500 eV Ar energy respectively, i.e. the Cr sputtering yield is about 20% higher. An interesting result was that for Ar energy bombardment from 300 eV to 1 keV, the best fit to the deposition rates (Fig. 1) was obtained using ion energies higher than 600 eV.

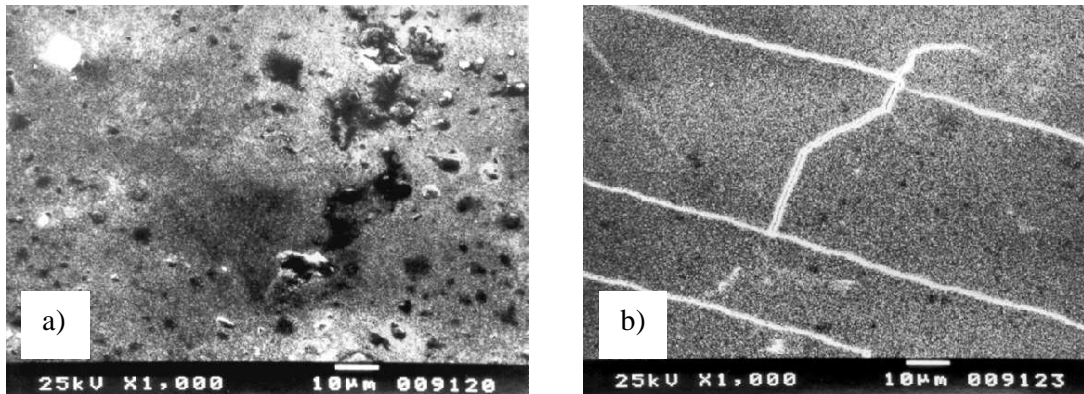


Fig. 2. SEM images of the surfaces of Mo films deposited at a) 200W and b) 250W RF power.

SEM revealed smooth and homogeneous surfaces for Cr layers deposited under all the deposition conditions. The same morphology was found concerning the Mo layers deposited at 100 and 150 W. However, the layers grown at 200 W had a rough structure, with the incorporation of conglomerates with dimensions of 2-12 nm (Fig. 2a). The layers obtained at 250W, (Fig. 2b) had smooth surfaces, but cracks of 750 nm width appeared, perhaps due to internal stress. The energy supplied by the bombarding particles in this case was sufficient to grow a highly oriented crystal structure. However, under these conditions the mismatch with the substrate results in tensile stress, leading to cracks.

3. Conclusions

This work aimed to compare the electrical and morphological qualities of Cr- and Mo- metal back contacts, when applied to CIGS-based solar cells. The films were RF sputtered at a constant gas pressure and different power ranges from 100 up to 250 W. The Cr-based metal contacts showed about a 20 % higher deposition rate, but the Mo-based layers featured significantly lower resistivities, which means better ohmic contacts when PV solar cell production is envisaged. Both types of film showed resistivity-power dependences, allowing the definition of an optimum power for yielding densely packed films. SEM images revealed a smooth topography as a rule, but cracks appeared when the deposition energy was around 250 W.

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