INVESTIGATION OF CHROMIUM TO INDIUM TIN OXIDE (ITO) OHMIC CONTACT FOR THIN FILM SOLAR CELL APPLICATION

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1. Abstract

To obtain a suitable ohmic contact with the lowest resistivity, Chromium (Cr) thin films were deposited on transparent conductive oxide indium tin oxide (ITO) by RF sputtering method in argon atmosphere and its optical and electrical properties were optimized. The deposition of Cr thin film has been performed for the layers with thickness of 150, 300 and 600 nm in constant Ar gas flow of 30sccm. Results show that the lowest contact resistivity belongs to the layer with 600 nm thickness. Furthermore Cr/ITO has been studied for different flows of Argon gas 10, 30, 50 and 70 sccm during the deposition with constant thickness of 600 nm Cr thin films, which result gave us the lowest contact resistivity. Experimental results show that specific contact resistance decreases by reducing the flow of Argon gas. Analyze of SEM has been performed on the samples. The SEM micrographs show Cr thin films have smaller grains in 10 sccm argon gas flows, in comparison with other flows of Argon gas. The best specific contact for Cr/ITO has been obtained 4.5×10^{-6} Ωm^2 at flow of Argon gas 10 sccm with 600nm thickness.

2. Introduction

Interesting and novel applications in photovoltaic are expected from thin and flexible solar modules, especially in the fields of space, aeronautic, and mobile applications. Within the past years the development of flexible and lightweight Cu (In,Ga)Se2 (CIGS) modules has intensified. These activities were encouraged by the relatively high small-area cell efficiencies obtained on polymer as well as on metallic substrates. The most interesting substrates are metal foils, since they can be coated in a roll-to-roll process at high temperatures of up to 600 °C and in a Se atmosphere (Britt et al, 1999). Especially stainless steel foils with a potential as low-cost substrates were tested (Shirakata et al, 2007). Nevertheless, cell and module efficiencies were lower than on glass substrates. The preparation of highly efficient solar cells requires the deposition of a barrier layer to reduce the diffusion of impurities from the metal substrate into the solar cells (Hartmann, et al, 2000). If monolithically integration of the cells is desired to realize solar modules on electrically conducting substrates, the deposition of a dielectric barrier is necessary (Herz et al, 2003). Thin Cr layers (Herz et al, 2002) as well as dielectric layers like Al2O3 (Naik et al, 2001) or SiO2 deposited by sputtering or sol–gel-techniques have been used as diffusion barriers. Tin-doped indium oxide In2O3: Sn (ITO) is a highly degenerate n-type Wide gap (band-gap~3.7eV) semiconductor and belongs to the class of transparent conductive oxides (TCO) which is important for photovoltaic applications. ITO film has high transmittance, high infrared reflectance, good electrical conductivity, excellent substrate adherence and hardness (Cirpan, Karasz, 2006). Because of its unique properties, it has found extensive application in solar cells (Krebs et al , 2007), flat panel displays (Shumei et al , 2011), heat reflecting mirrors (Boyadzhiev et al, 2008), LEDs (Huang et al, 2008) and so on. In this study, the suitability of ohmic contact between Chromium layers as diffusion barriers in various terms of deposition condition with ITO was investigated. In the present investigation, we report the influence of process parameters on the comparisons of the Cr/ITO ohmic contact properties, the deposition rate, and the structure and properties of Cr coatings deposited by RF sputtering of a metal Cr target in an Ar atmosphere.

3. Experimental

3.1. Chromium deposition in different thicknesses

Cr coating were deposited by means of the RF sputtering technique from a metallic Chromium target of 99.99% purity and using argon as a sputtering gas. The deposition chamber was initially pumped to a base pressure of 1.0×10^{-6} Torr and then back filled with Ar (99.999% purity) to a process pressure of 27 mT. The ITO/glass substrates were ultrasonically cleaned in an acetone and deionized water before depositions. The gas flow rate of argon fixed at 30 sccm and RF power fixed at 300W, respectively. The thickness of Cr films varied to 150 nm, 300 nm and 600 nm.
The sputtering conditions are summarized in Table 1:

Tab.1: Sputtering condition for preparation of chromium thin films

Initial vacuum	8×10^{-6}
R.F power	300 W
Sputtering pressure	27 mtorr
Sputtering temperature	Room temp
Pre-Sputtering time	10 min
Argon gas flow	30 sccm

After every deposition the thicknesses of the Cr films were measured using an alpha-step (Decktak500). The contact resistance between deposited metal films and ITO film is measured by transfer length method (TLM). The total resistance R_T of the metal/semiconductor contacting system is, $R_T=2R_C+2R_M+R_{Sem}$, where R_M is the resistance of metal which can be neglected; R_{Sem} and R_C are the resistance of semiconductor and contact resistance between metal and semiconductor. If the distance between metal fingers are very small ($d\rightarrow0$), we can approximate $R_T\rightarrow2R_C$, now it is possible to calculate R_C. Fig. 1 shows SEM image of TLM pattern used in our measurement.

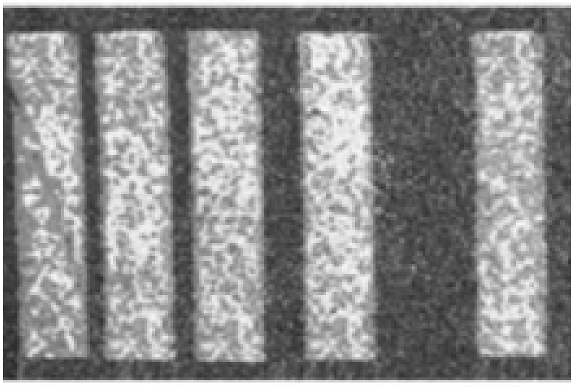

Fig.1: SEM image of TLM pattern

The I-V characteristic of the contact Chromium thin films at different thicknesses to ITO are given at Fig.2.

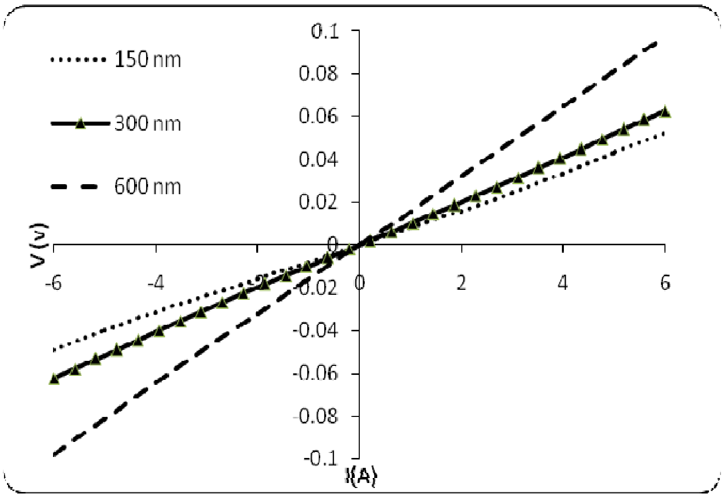

Fig.2: I-V characteristic of Cr 150, 300 and 600 nm contact to ITO

In Fig.3 ohmic contact resistance between Cr/ITO in various thicknesses are compared. By extrapolation the line equations, the value of R_T obtained. Half the value of R_T will result R_C.

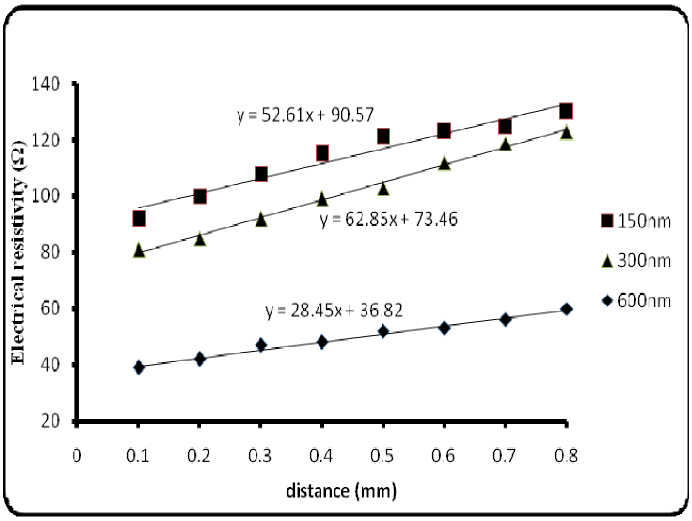

Fig.3: Cr/ITO contact resistivity in 150,300 and 600 nm thicknesses with keithley 2361 system

With specific contact relation equation:

$$\rho_c = R_c A_c$$

And by extrapolation the graph, specific contact resistances were calculated and as you can observe in Table.2 the lowest contact resistivity has been obtained in 600 nm thickness of Cr thin film.

Tab.2: specific contact resistivity of Cr/ITO in different thicknesses of Cr thin films

Thickness (nm)	150	300	600
$\rho_C \times 10^{-5} (\Omega m^2)$	1.5	1.1	5.5

Table 3 indicates the values of resistivity of Chromium thin films layer deposited with RF sputtering method.

Tab.3: resistivity of Cr thin film in 150,300 and 600 nm thicknesses

Thickness (nm)	**150**	**300**	**600**
$\rho_s \times 10^{-6}$ **(Ωm)**	8.4	4.6	1.0×10^{-1}

Surface morphology of Chromium thin films deposited by RF sputtering on ITO substrate in different thicknesses are shown in Fig.4. In this image growing trend of the crystalline grains of Chromium thin films can be observed.

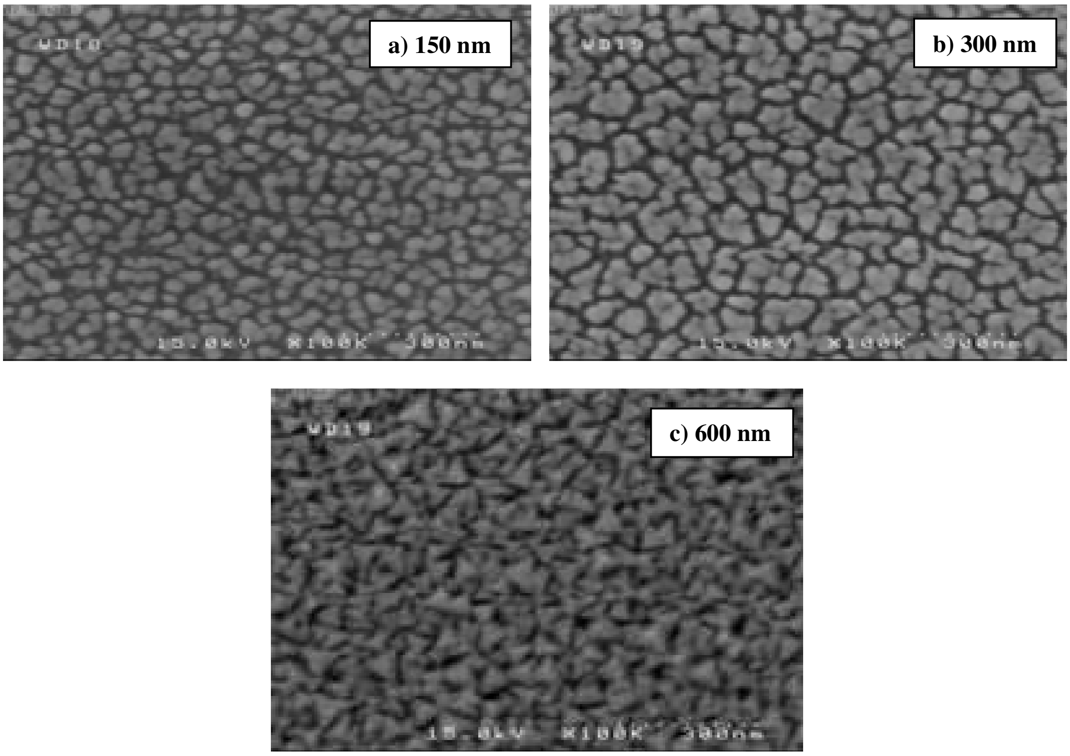

Fig.4: SEM images of Chromium thin films in different thicknesses: a) 150 nm, b) 300 nm, c) 600 nm

3.2. Chromium deposition in various flows of Argon gas

According to the results, the lowest specific contact resistance is given in 600 nm thickness of Cr thin film. Therefore at this stage of the experiments, we will examine the effect of flow of Argon gas in sputtering system with maintaining constant thickness at 600 nm. Deposition have been performed four times in different flow 10,30,50 and 70 sccm with constant thickness of Cr layer in similar condition as before.

The I-V characteristic of the contact of Chromium thin films at different flows of Argon gas 10, 30, 50 and 70 sccm to ITO are given at Fig.5.

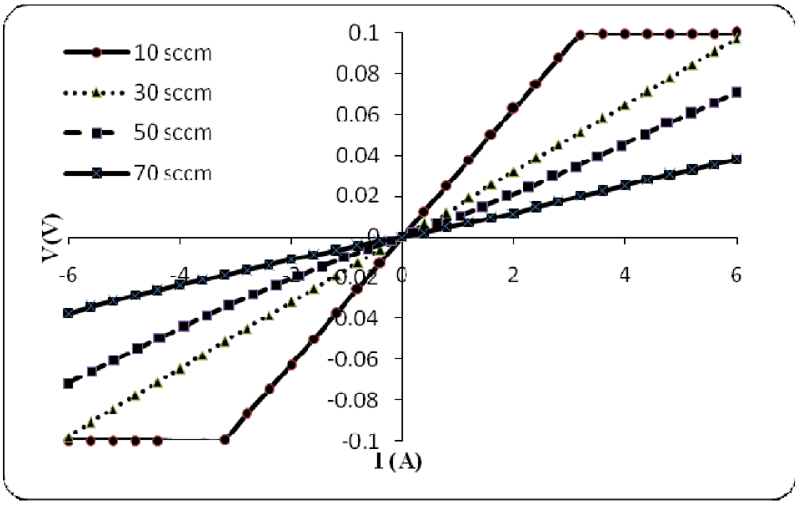

Fig.5: I-V characteristic of Cr 10, 30, 50 and 70 Sccm contact to ITO

Fig.6 depicts comparison of ohmic contact in various flows of Argon gas during deposition by sputtering system.

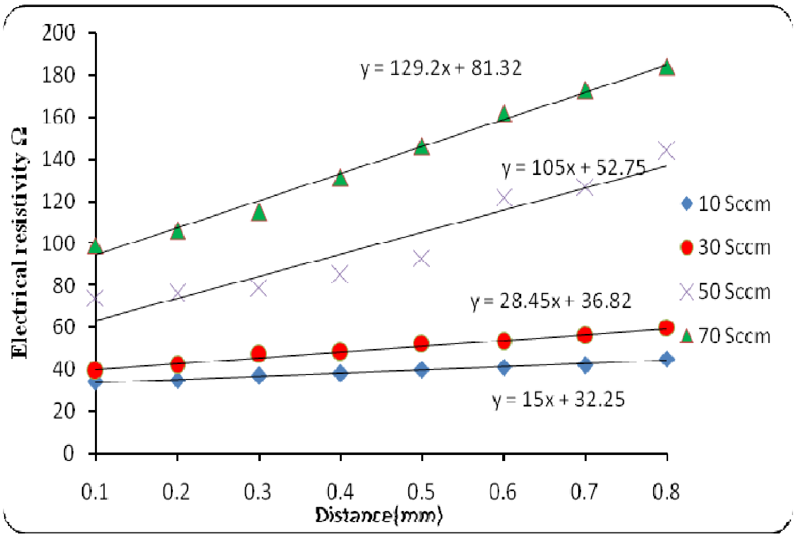

Fig.6: Cr/ITO contact resistivity in 10, 30, 50 and 70 Sccm flows of Argon gas with keithley 2361 system

And like the previous time by extrapolation the graph the specific contact resistances calculated and are shown in Table.4.

Tab.4: specific contact resistivity of Cr/ITO in different flows of Argon gas

Flow(sccm)	10	30	50	70
$\rho_c(\Omega m^2)$	4.5×10^{-6}	5.5×10^{-6}	8.5×10^{-6}	1.5×10^{-5}

Resistivity of Cr thin films in different flows of Argon gas are given in below tab.5. As we could see the Chromium thin film is deposited in flow of Argon gas 10 sccm in comparison with other layer has a lower value.

Tab.5: resistivity of Cr thin film in various flows of Argon gas

Flow(sccm)	10	30	50	70
$\rho_s \times 10^{-5}$ (Ωm)	1.5×10^{-1}	1.0	1.3	1.5

The SEM images of Fig.7 represent the structure of Chromium thin films deposited in different flow of Argon gas.

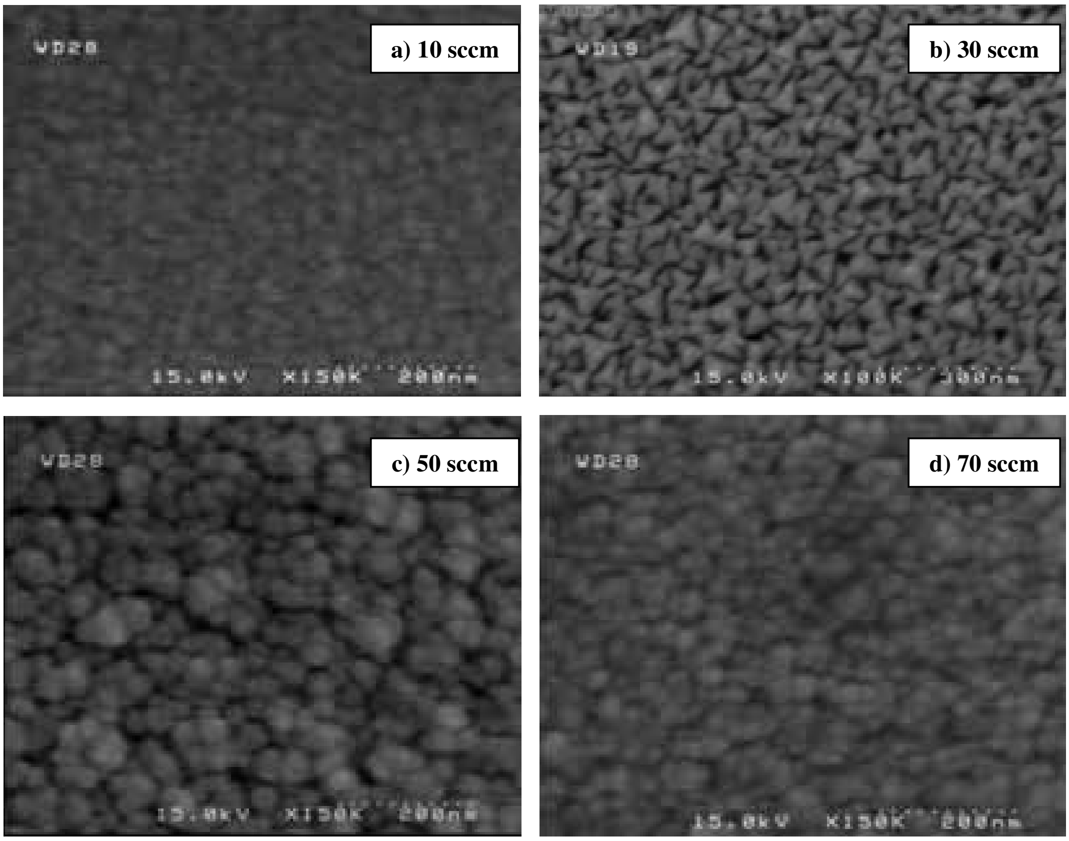

Fig.7: SEM images of Chromium thin films in various flows of Argon gas: a) 10 sccm, b) 30 sccm, c) 50 sccm, d) 70 sccm

As we could see at flow of Argon gas 10 sccm the grains of Cr thin film are smaller and smoother in comparison with other flows. The worst results are achieved at flow of 50 and 70 sccm which due to unequal grains of Cr it's predictable.

4. Conclusion

Chromium thin films of thicknesses 150,300 and 600 nm are deposited on ITO substrates using RF sputter deposition techniques. The electrical resistivities of the as-deposited films are determined by the four-point probe and keithley 2361 systems. As expected, the specific contact and resistivity decrease with increasing thicknesses in the case of as-deposited films on ITO substrates. As an experimental result, the lowest specific contact resistivity of Chromium thin films layer deposited on ITO substrate obtained about 5.5×10^{-6} Ωm^2 at 600 nm thickness in RF power of 300 W and Ar flow of 30 Sccm resistivity of $1.0\times10^{-7}\Omega m$.

The optimal deposition flow of Argon gas for Chromium thin film is 10 sccm in order to minimize the effect of ion bombardment and/or atomic peening that caused too much stress. Best result occurs as the flow rate of Ar reached 10 sccm at Cr thickness of 600 nm and RF power of 300 W, which is probably happening according to the SEM images due to the grains of Cr which have more chance to deposited on the substrate and fill the boundaries of the crystalline plate.

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