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Analysis of composition, morphology and wettability of Mo thin layers deposited on glass

Abstract. *In this paper a composite structure, topography, wettability of a glass surfaces modified by means of ion-assisted deposition of molybdenum films in conditions of a self-irradiation are discussed.*

Streszczenie. *W niniejszej pracy przedstawiono struktury kompozytowe, topografie, zwilżalność powierzchni szkła modyfikowanego na drodze naparowywania jonowego warstwy molibdenu w warunkach napromieniowania.* ***(Analiza składu, morfologii i zwilżalności Mo cienkiej warstwy osadzonej na szkle)****.*

Słowa kluczowe: nanowymiarowe warstwy, skład, topografia, zwilżalność.
Keywords: nanodimension films, composition, topography, wettability.

Instroduction

The deposition of nanodimension metal films on glass wafers has both scientific and practical interest. Molybdenum thin films are often considered as suitable back contact at manufacture of solar cells. Several metals have been investigated for using as back contact of $CuInSe_2$ (CIS) and $CuIn_{1-x}Ga_xSe_2$-based (CIGS) solar cells [1].The choice of molybdenum as the material for back contact layer of CIS and CIGS solar cells is based on the requirements imposed by the application and the different processing steps. Mo as back contact has desired stability at the processing temperature, resistance to alloying with absorber layer elements such as Cu and In, and its low contact resistance to CIGS. For CIGS solar cells, the back contact is a thin metallic Mo layer that not only provides the back electrical connection, but also is considered as crystal seed grains for the growth of CIGS absorber [2]. Thus, we shall focus attention on deposition molybdenum layer on glass substrate in order to investigate the structural properties of Mo back contact on glass.

In general, Mo back contact layer is deposited onto glass substrate by ion plasma sputtering (dc-magnetron sputtering, for example). Among the various methods, vacuum evaporation is relatively successful in many cases when improved adhesion is important [3, 4]. The self-ion-assisted deposition (SIAD) is a materials engineering technique which provides ion-beam-mixing of the substrate atoms and atoms of a thin film without introducing an admixture of noble gases. In order to control the properties of film surfaces on the substrate it is necessary to diagnostic film/substrate systems. In this paper a composite structure, topography and wettability of a glass surface modified by means of ion-assisted deposition of Mo films in conditions of a self-irradiation are discussed.

Experimental section

The system employed for the film deposition has been described in detail elsewhere [5] and consists, essentially, of a vacuum chamber to which a resonance vacuum arc source (RVAS) with molybdenum electrodes to produce a mixture of Mo atoms and Mo^+ ions is attached. Substrate (glass wafers) was floated to a negative potential with respect to the source of 5 and 10 kV to accelerate the ion species. The SIAD system was pumped by a conventional diffusion pump and attained during film deposition a base pressure of 10^{-2} Pa.

To investigate atom mixing processes at an interface region of a film/substrate it is useful to know a position of initial surface of substrate (PISS).

The composition of the film/substrate structures were investigated using Rutherford Backscattering Spectroscopy. The energy of the He^+ ions was 1.7 MeV and the energy resolution of analysing system was 15 keV. The experimental RBS data for concentration against depth were compared with data from the RUMP code simulation [6]. Roughness parameters of virgin silicon substrate and substrate with Me films were measured using atomic force microscope NT-206, accompanied with corresponding software. The AFM cantilever of CSC21 type was used. The wetting behaviour is characterized by the value of the contact angle (CA, Θ). CA was measured automatically. A specially designed program “Angle” filters the image of the system “water drop-film surface-air” so that the gas phase was selected and the image of the system was projected onto a plain. CA measurements were based on the sensible drop method described in [7]. The wetting agent was doubly distilled water. The droplet volume was 9.3 μl. The total error of our measurements is $\Delta\Theta$=0.5.

Results and discussion

Fig.1 shows the Rutherford backscattering spectrum of the structure Mo film/glass, produced by SIAD.

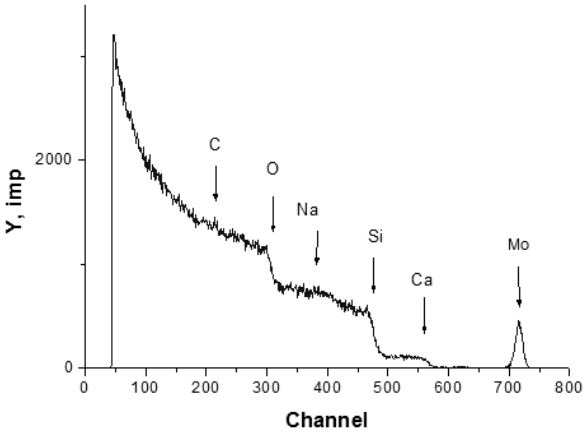

Fig.1. Rutherford backscattering spectrum of He^+ ions of the structure Mo film/glass, produced by SIAD

It is evident that the spectrum of the investigated construction contains signals of carbon, oxygen, silicon, calcium and molybdenum. Atoms of O, Na, Si, Ca appear in Mo thin film we suppose, because of diffusion from glass substrate during ion-assisted deposition of Mo thin film.

Fig.2 shows the profiles of the depth distribution of components in the film/substrate structure obtained during the deposition of molybdenum film on glass.

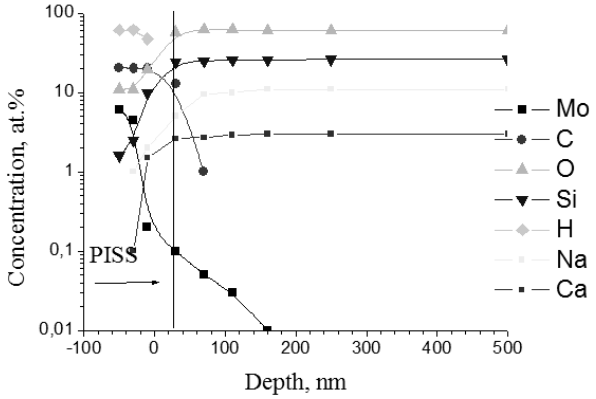

Fig.2. Relative content of species in SIAD *Mo* film on glass. Acceleration voltage is 10 kV, time of deposition – 5 hours.

It is confirmed that the film on silicon is characterized by complicated composition. Films comprise metal atoms, hydrogen, carbon, oxygen, sodium, calcium and silicon. The appearance in the studied films O, C, H we associate with the deposition on the surface of the film during its growth together with Mo atoms accompanied, hydrocarbon fraction and O from the residual vacuum in the target chamber, steam-pumped by the diffusion oil pump. Analysing of the results, Fig.2, it is showed that the composition of films approximately similar for different substrate [8].

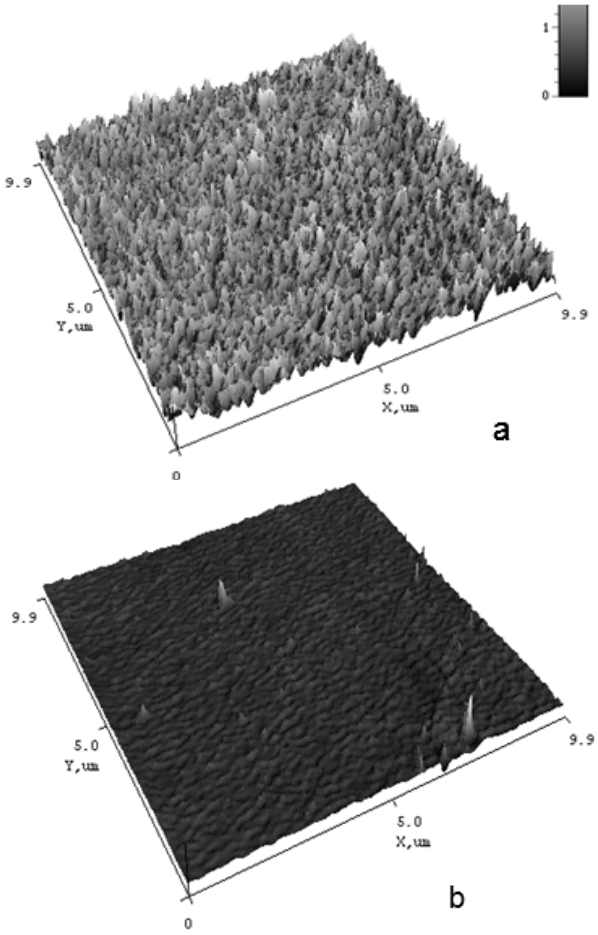

Fig.3. Three-dimensional AFM surface morphology of virgin glass (*a*) and glass with deposited Mo film (Z=50 nm) (*b*).

In the study of topography of systems film/substrate and the pure glass site 10×10 μm^2 were chosen. According to 3D - images of the surface topography of molybdenum film in the Fig.3 one can conclude that the high quality surface of films on glass is generated. The roughness (R_a) of the glass surface is 2.537 nm and the Mo thin film (50 nm thickness) is 0.216 nm.

Fig.4 shows photographs of water droplets on the surface of glass and on the surface of the Mo film.

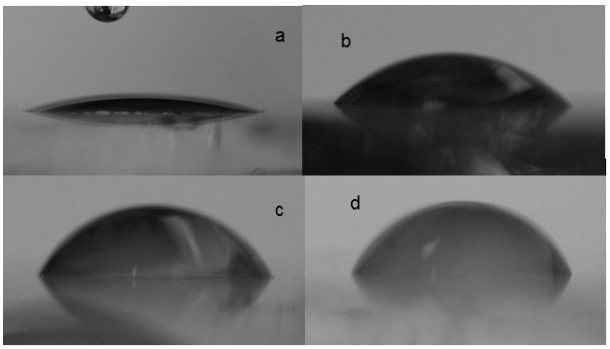

Fig.4. Pictures of water droplets on the surface of the virgin glass (*a*) and glass with Mo films of different thickness: *Z* = 20 nm (*b*), *Z* = 30 nm (*c*), *Z* = 50 nm (*d*).

The CA of the droplet on glass substrate is ~22.0º. That means that the surface of glass passives of hydrophilic properties. Molybdenum thin layer (50 nm thickness) surface is characterized with CA, which is equal 65º. Therefore we can conclude that wettability of Mo/glass surface depends very strong on thickness of thin Mo layer in glass.

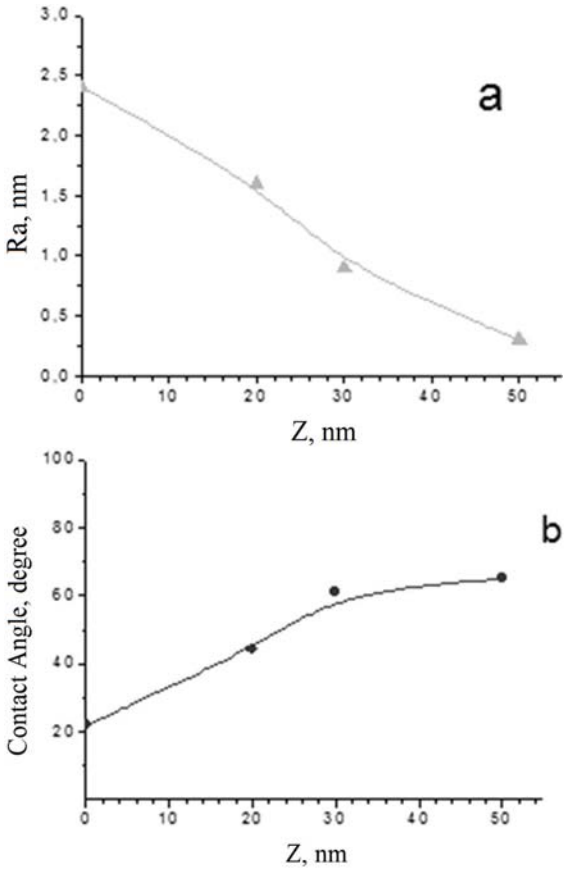

Fig.5. The dependence on a thickness of Mo films of average roughness (*a*) and of value CA (*b*).

The dependence of the value CA and average roughness on a thickness of the molybdenum films have been observed. Corresponding cures are presented in Fig.5. The R_a decreases with the increase of the thickness of films. The surface becomes smoother which reduces the roughness to 0.216 nm. This results indicate the possibility of managing the roughness of the film surface by changing the thickness of deposited Mo films.

The wettability measurments confirm the fundamental difference between the Θ of glass substrate (~21.8º) and Θ of Mo/glass surfaces (61.8 – 65.1), observed first time in [7]. Two factors affect the surface wettability: element composition of the surface (Fig.2) and surface morphology (roughness). Therefore we can conclude these results indicate the possibility of managined of Mo thin film on glass changing the thickness of the films.

Conclusion

The Mo thin films/glass substrate constructions have been investigated. It is determined that the Mo films on glass have composed composition. It is found out that films include metal atoms, hydrogen, carbon, oxygen, sodium, silicon and calcium.

Investigations of influence of Mo thin film thickness deposited on glass substrates by SIAD on its surface topography and wettability ware carried out. In the paper we observe some steps in the process of film growth. The result can be useful for obtaining a surface of back contacts with desirable wettability in application related to solar energy.

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