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COMPOSITION AND STRUCTURE OF THIN METAL FILMS DEPOSITED ON SOLID AND NONRIGID MATERIALS

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The composition and structure of Ti, Zr, Mo - based thin films formed on silicon and rubber by ion-beam-assisted deposition were investigated by utilizing the AFM and RBS technique. It was found that the films included not only metal atoms but also C, O, H, Si (from Si substrate), S, Ca and Zn (from the rubber). The coatings on the rubber have quasi-periodical topography which may be due to build in stress. The coatings on silicon are uniform with a smooth surface.

1. Introduction

Ion-beam-assisted deposition (IBAD) of metal (Me) layers on silicon has great importance for fabrication of semiconductor devices [1]. The successful deposition of the Me coatings on rubber for functional purposes is demonstrated in [2]. This work deals with the composition and topography of modified by means of IBAD surfaces of silicon and rubber.

2. Experimental

IBAD experiments were performed using a resonance vacuum arc ion source. This type of ion source with desirable metal (Me) electrodes was used to produce a mixture of neutral Me and Me^+ ion species. Substrate plates (silicon and rubber) were floated to a negative potential with respect to the source of 3 keV to accelerate the ion species. The deposition and irradiation of Ti, Zr and Mo coatings have been accomplished simultaneously on silicon (n-type, 200 Ω cm) and on rubber (GOST V-14) samples. The base pressure of the target chamber was $\sim 10^{-2}$ Pa. The relative ratio of ions/neutral atoms and deposition rates were found to be 0.2-0.4 and 0.3-0.4 nm/min in different sets of experiment.

The RBS technique was employed to analyze the target composition and for depth profiling of the components. The experimental data were compared with RUMP code computer simulation of the target content [3]. The surface roughness and topography were measured with an atomic force microscope (AFM) NT-206 in a scan area of 4×4 μm^2.

3. Results and discussion

3.1. RBS Analysis

RBS spectra of the initial rubber (1) and a sample upon which the Mo coating was deposited and also irradiated with 3 keV Mo^+ ions (2) are shown in Fig. 1. Vertical marks indicate the position of signals from identified elements entering into rubber composition and into the surface of the coating/rubber construction.

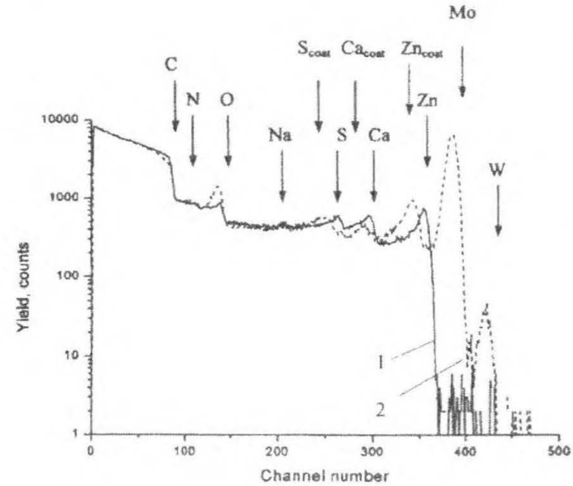
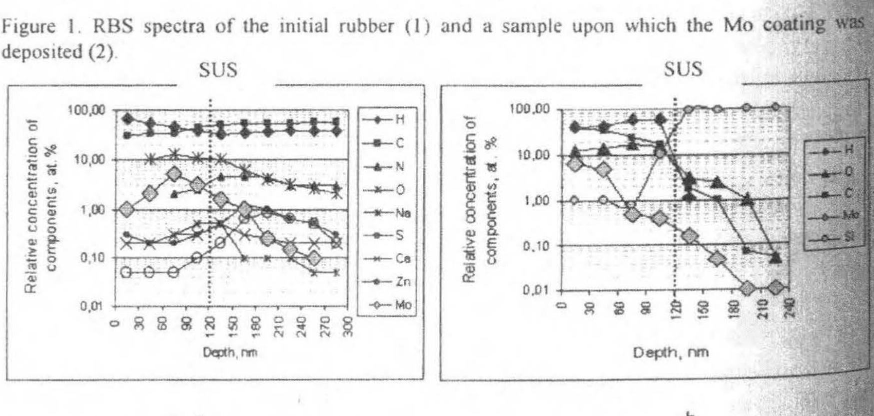


Figure 1. RBS spectra of the initial rubber (1) and a sample upon which the Mo coating was deposited (2).



a

b

Figure 2. The depth distribution of indicated components in the rubber sample (a) and in the silicon sample (b) with Mo coatings.

It is estimated that the Mo deposition using IBAD process is accompanied by the presence in the coating of oxygen, carbon and other species (S, Ca, Zr) which are diffused from the rubber.

Fig. 2 presents the depth distribution of indicated components in the rubber and in the silicon samples with Mo coating. The data indicate that the Mo concentration reaches 5 at. % and decreases near the Mo/both substrates interfaces. Position of a surface of the untreated sample (SUS) is indicated with the dashed line. A noticeable amount of Mo (~0.1 at. %) is in the depth of ~120 nm under SUS in the both constructions. The O level follows qualitatively a similar trend. The C and H levels are approximately constant in the middle of the coatings and are changed near the coatings/substrates interfaces. One can observe out diffusion of S, Ca and Zn into the coating on rubber and Si into the coating on silicon. This is known as an effect for IBAD process in a rigid materials [4], but diffusion of Ca and Zn from rubber to the coating surface was not observed before. We should emphasis that qualitatively comparable behavior of the Ti and Zr coatings on rubber and silicon was observed in experiments.

3.2. AFM Analysis

We investigated topography and roughness parameters of virgin and modified samples. Table 1 and Fig. 3 show experimental results obtained for rubber and silicon. The surface topography of the untreated rubber has uniformly distributed valleys and hillocks, Fig. 3a. The topography of the modified rubber has a shape as it is constructed from semi-ellipsoids with saw-type surfaces and sharp edges between them, Fig. 3b. An average surface roughness is about 33.64 nm. The topography of the untreated Si surface, as it was expected, is smooth. The average surface roughness is 0.18 nm. After titanium coating deposition the fairly smooth surface of modified silicon sample is observed.

Table 1. Average surface roughness (rave), the root mean square value of the surface roughness (means square) and (square area)/(projected area) (rho) of rubber and silicon surfaces modified by means of IBAD of coatings.

Parameter	Rubber		Silicon	
	Original	Mo-coating	Original	Ti-coating
Rave, nm	20.70	33.64	0.18	0.61
Mean square, nm	26.14	42.13	0.41	1.12
Rho	1.04	1.37	1.01	1.01

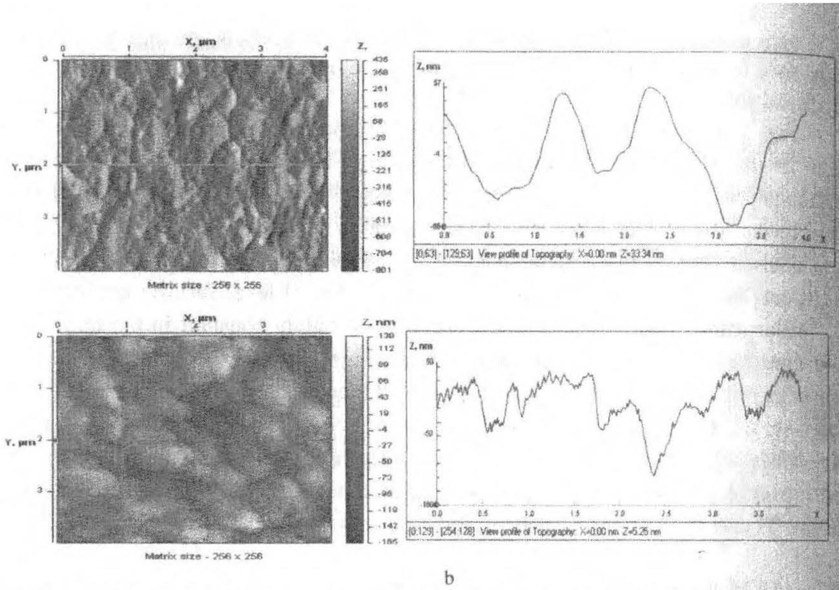


Figure 3. AFM images of the surface morphology and view profiles of topography of rubber: untreated surface (a), the surface after 3 h of Mo-based coating deposition (b).

4. Conclusions

We have shown that ion-assisted deposited on rubber and silicon thin metal films include not only metal atoms but also carbon, oxygen, hydrogen and silicon (from Si substrate), and sulphure, calcium, and zinc (from rubber). The coatings on rubber are characterized by semi-ellipsoids surface topography and increased roughness. The coatings on silicon are uniform with smooth surface.

Acknowledgments

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