AES CHARACTERIZATION AND ANALYTICAL DESCRIPTION OF POTASSIUM MIGRATION IN MICROCHANNEL PLATES MULTILAYERS

Prepared from poster presentation on the 4th European Vacuum Conference (EVC-4) and 1st Swedish Vacuum Meeting (SVM) in Sweden, Uppsala, 13-17 june 1994

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Keywords: optoelectronics, MCP, microchannel plates, AES depth profiling, Auger electron microscopy, electrodiffusion migration, electrodiffusion, Goldhorn software packages, potassium chemical elements, multilayer structures, analytical descriptions

Abstract: The nature of potassium migration through the active multilayers structure of microchannel plates (MCP) was determined. Comparing the variation of Auger signal for K (252 eV) through a fresh and aged sample showed that a few surface monolayers of the aged sample are relatively rich in potassium what is indicative of K migration from the underlying layers to the surface. Data on the potassium migration onto active intrachannel surface and migration of K through the underlying layers were obtained with the AES method and analyzed using the Goldhorn software package. The analyses with the Goldhorn software package gave us the analytical description of AES measurements.

AES karakterizacija in analitičen opis gibanja kalija skozi plasti mikrokanalnih ploščic

Pripravljeno po posterski predstavitvi na 4. Evropski vakuumski konferenci (EVC-4) in 1. švedskem vakuumskem srečanju (SVM) na Švedskem, Uppsala, 13-17 junij 1994

Ključne besede: optoelektronika, MCP ploščice mikrokanalske, AES Auger spektroskopija elektronska - profiliranje globinsko, selitev elektrodifuzijska, elektrodifuzija, Goldhorn paketi opreme programske, K kalij elementi kemični, strukture večplastne, opisi analitični

Povzetek: Določana je bila narava gibanja kalija skozi večplastno strukturo mikrokanalnih ploščic (MKP). Primerjava spreminjanja intenzitete Augerjevega vrha K (252 eV) v plasteh svežega in staranega vzorca pokaže, da se v nekaj monoplasti površine staranega vzorca nahaja povečana vsebnost K. Primerjava nazorno nakaže, da gibanje K poteka iz spodaj ležečih plasti proti površini. Podatke o gibanju K iz globine proti površini notranjih sten kanalov smo dobili z AES profilno analizo. Obdelava tako dobljenih podatkov s pomočjo Goldhorn programske opreme je podala analitičen opis AES meritev.

1. INTRODUCTION

The active intrachannel surfaces in MCP s' or the surfaces lining the walls of the channel are composed of a few surface monolayers, the superficial about 20 nm thick silica-rich emitting layer, about 10 nm thick buffer layer and the underlying about 100-1000 nm thick semiconducting layer. The MCP layers composition is presented in Figure 1. All these layers are formed during the final stages of the manufacturing. Normally characterized by a decrease in channel gain, the ageing process is necessary to ensure a stable operation and minimum outgassing. The ionic migration on the active glassy surface and silica-rich emitting layer changed the elemental distribution of these layers during the ageing process (electron scrubbing). To characterize the essential differences in the elemental distribution of the glassy layers of the fresh and aged MCP s', AES sputter depth profiling through the 60 nm thick channel wall was applied. Comparing the variation of Auger signal for K (252 eV) through a fresh and aged sample shows that a few surface monolayers of the aged sample are relatively rich in potassium what is indicative of potassium migration from the underlying layers to the surface. Data on the potassium migration onto the active intrachannel surface in MCP s' and migration of K through the underlying layers were obtained with the AES method and analyzed using the Goldhorn software package. The analysis gave us the analytical description of the measurements.

2. EXPERIMENTAL

Two microchannel plates were investigated. The first was examined before and the second after ageing (electron scrubbing). Both samples were analyzed with a Scanning Auger Microprobe (Physical Electronics Industries SAM 545 A). A static primary electron beam of 5 keV energy, 0.3 μA beam current and a 10 μm diameter was used. The electron beam incidence angle with respect to the normal to the average surface plane was 30°. The both samples were ion sputtered with two symmetrically inclined beams of 1 keV Ar^+ ions, rastered over a surface area larger than 5 mm x 5 mm at

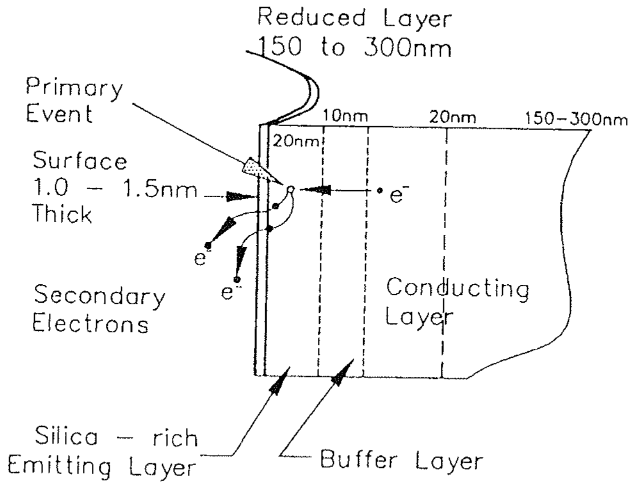

Fig. 1: Microchannel wall cross-section

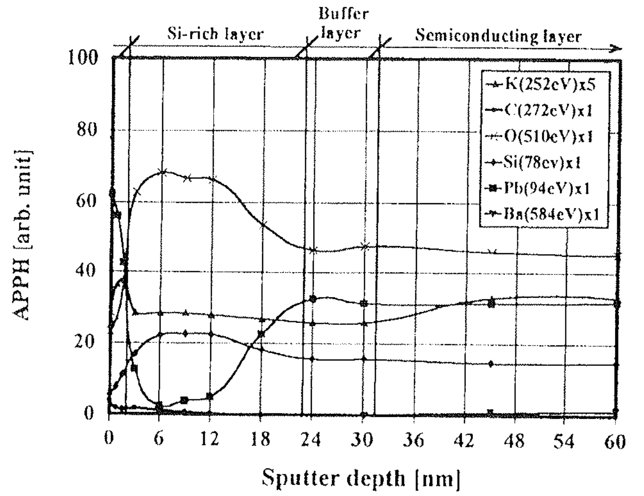

Fig. 2: AES sputter depth profiles of the important elements in the active surface of the channel before ageing of the MCP. The measured peak-to-peak intensity is normalized to the corresponding pure elemental target value which is set at 100.

an incidence angle of 47°. The sputter rate of about 3 nm/min for the MCP glass is assumed to be equal to that for SiO_2 and was determined on a standard multilayer Ni/Cr/SiO_2/Ni/Cr/<Si>. During simultaneous AES analysis and ion sputtering the Auger peak-to-peak intensities of Si(78 eV), Pb(94 eV), K(252 eV), C(272 eV), O(510 eV) and Ba(584 eV) were recorded against the sputtering time. In the depth profiles the peak-to-peak intensities of the corresponding Auger transition are normalized to the pure elemental sample value which was equated to 100 units.

3. RESULTS AND DISCUSSION

3.1. AES sputter depth profiles of intrachannel glassy layers

Fresh and aged microchannel plates were investigated by AES sputter depth profiling. Depth profiles of the elemental composition of both investigated active intrachannel glassy layers are similar and reveal the presence of the glass constituent elements: Si, O, K, Pb, Ba and C. The depth distribution of six main constituents of the unexposed sample is shown in Figure 2. The surface is composed of Pb, O, Si, K and C namely. The concentration of Pb is very high on the surface, while in a layer about 10 nm under surface the Pb concentration is considerably reduced. Deliberately and consequently this layer is enriched with Si and O. On the surface and in the underlying conducting layer the K concentration is almost the same, except for 1.5 nm beneath the surface, where a sudden increase of K concentration was observed. The quantity of C on the surface presents a relatively low contamination and its concentration decreases quickly to negligible amounts. The presence of Ba was observed in a depth of about 35 nm beneath the surface, and its content increases slowly in the bulk material. The distribution of the present element versus sputter depth of the exposed sample (Figure 3) shows that on the surface K concentration is rather increased, while the Pb concentration is significantly reduced, and C contamination seems to be higher in comparison to the unexposed sample. The thin silica-rich layer beneath the surface of the aged sample is enriched with Pb, and in the same layer the decrease concentration of K, Si, and O was observed. We found out that particles migration through the active glassy layers changed the elemental distribution, especially for K and Pb of these layers during the ageing process. The comparison of AES depth profiles shows a great increase in content of K, significantly reduced content of Pb and a minor reduction in that of Si and O on the intrachannel surface of the aged MCP. In the silica-rich emitting layer the empty places left by K, Si, and O, are replenished with Pb.

3.2. The variation in potassium Auger signal with ageing process

After the ageing process the concentration of potassium on the surface increased substantially, while the concentration in underlying about 20 nm thick silica rich layer decreased to about half of the original value compared to the unexposed sample. The concentration of potassium in the semiconducting layer of the intrachannel wall remained practically unchanged. We were interested in the major process occuring on during the ageing. To that end, the AES data were analyzed by the use of the Goldhorn software package, which has been developed recently /3/. One of the unique package features is not only to fit a curve through points, but also to finds a differential equations governing the process under investigation. The AES data shown in Figure 4, together with those of lead (Pb), were therefore processed with a computer. After an extensive computation

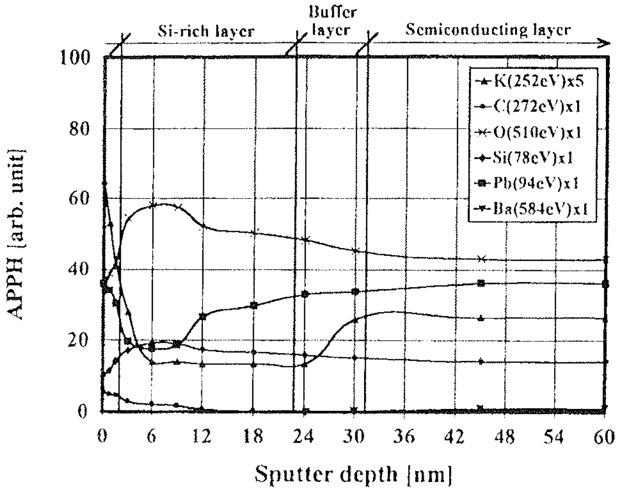

Fig. 3: *As figure 2, but now after ageing of the MCP*

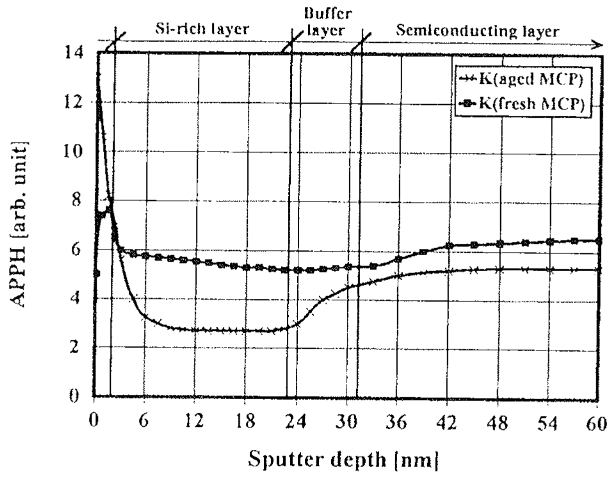

Fig.4: *The variation in Auger peak-to-peak intensity for potassium without and with ageing process*

it was found that the final distribution of potassium an lead follows differential equation

$$\nabla^2 C_K \left(a \frac{dC_K}{dx} + bC_K + cC_{Pb} + d \right) = e$$

Here, C_K and C_{Pb} are concentration of potassium and lead, respectively, ∇ is the nabla operator, $\frac{dC_K}{dx}$ is the gradient of the potassium concentration, a,b,c,d and e are constants, which were also computed by the Goldhorn package, and have the values -0.51, +1.38, -1.00, +15.31, and +0.48, respectively. The degree at which the equation fits the observed distribution of potassium is excellent, since the R factor is less than 0.01.

4. CONCLUSION

The differential equation computed by the Goldhorn software package has the same form as the theoretical equation for the distribution of particles suffering of electrodiffusion migration. Therefore, it can be concluded that the only process going on during the ageing procedure is pure electrodiffusion, since if any other machanisms of migration of potassium were presented the diffferential equation computed by the Goldhorn software package would have consisted of additional terms of a higher order.

5. REFERENCES

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Prispelo (Arrived): 19.03.1996 *Sprejeto (Accepted): 24.03.1996*