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AES studies of active intrachannel surface in microchannel plates

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The chemical composition of internal active glassy layers of the channels is responsible for the performance of the microchannel plates (MCP). A detailed account will be given of the performed work, using Auger electron spectroscopy (AES). To know the essential differences in the elemental distribution of the glassy layers inside the channels of the fresh and aged MCP, depth profiling through the about 60 nm thick channel wall was applied. This method gives the possibility to establish various glass constituents and to follow their ionic transport phenomena as a result of the ageing process.

1. Introduction

The microchannel plates (MCP) are the principal amplification elements in image intensifier tubes. These compact, low-noise devices consist of parallel arrays of millions of independent single-channel electron multipliers, made of a special type of glass. The ability of the MCP to detect and amplify high input signal levels is limited by saturation effects. Saturation effects are normally observed as a reduction in gain and in photon counting devices as a broadening of the pulse-height distribution.

Fig. 1 illustrates a typical channel wall cross section. In operation primary events striking the channel wall at the input side produce secondary emission. Influenced by the electric field within the channel, a cascade of electron multiplication occurs. Replenishment electrons are derived from the conductive layer. At high input signal levels severe charge depletion occurs at the channel output side rendering the channel useless until the charge is replenished. Microscopically, as a sizable cascade develops toward the output end of an activated microchannel, secondary electrons lost from the superficial (~ 10 nm) silica-rich emitting layer on the microchannel wall leave behind a positive charge (holes), which must be neutralized before another cascade can be generated. This recombination process uses electrons from the bias current flowing along the underlying semiconducting layer (~ 100–1000 nm thick), requiring tens of milliseconds or more to replenish pulse-counting charge levels of 10^5–10^6 e^- in single standard-resistance MCPs. Normally characterized by a decrease in channel gain, the ageing process is necessary to ensure stable operation and minimum outgassing. The reduction in gain following the electron bombardment degassing process known as scrubbing is believed to result from a decrease in the secondary electron yield of the material [1,2]. In this paper, the results of AES depth profiling through active glassy layers of the channel made on fresh and aged MCP are reported. This method gives the possibility to define key constituents of the channel walls and an attempt was made to correlate the elemental distribution of the active glassy layers and ionic transport phenomena during the ageing process.

2. Experimental

Two Varian microchannel plates were investigated. The first was examined before and the second after ageing (electron scrubbing) in the image tube. The samples of MCP were broken

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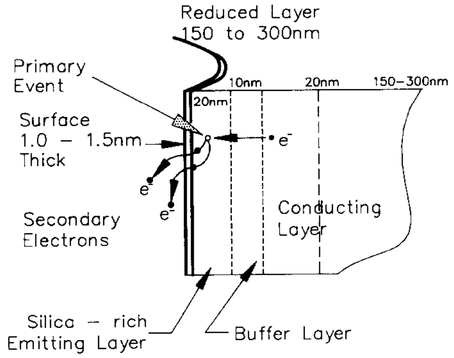

Fig. 1. Microchannel wall cross-section.

along microchannels and separately implanted into pure indium substrate. The samples were analyzed in the channels by scanning Auger microprobe (Physical Electronics Industries, SAM 545 A). A static primary electron beam of 5 keV energy, 0.5 μA beam current and about 10 μm diameter was used. The electron beam incidence angle with respect to the normal to the average surface plane was 30°. The samples were ion-sputtered with two symmetrically inclined beams of 1 keV Ar^+ ions, rastered over a surface area larger than 5×5 mm at an incidence angle of 47°. The sputter rate of about 3.0 nm/min was determined on a standard multilayer Cr/Ni thin-film structure [3]. In the depth profiles the peak-to-peak intensities of the corresponding Auger transitions are normalized to the pure elemental sample value which was equated to 100 units.

3. Results and discussion

Depth profiles of the elemental composition of both investigated active layers are similar and reveal the presence of the glass constituent elements: Si, O, K, Pb, Ba and C. The active glassy layers of the channels were examined to a depth of about 60 nm. The depth distribution of constituents of the unaged active surface inside the channel is shown in fig. 2. The surface is composed of Si, O, K and Pb. The quantity of C on the surface presents a relatively low contamination, and its concentration decreases quickly to

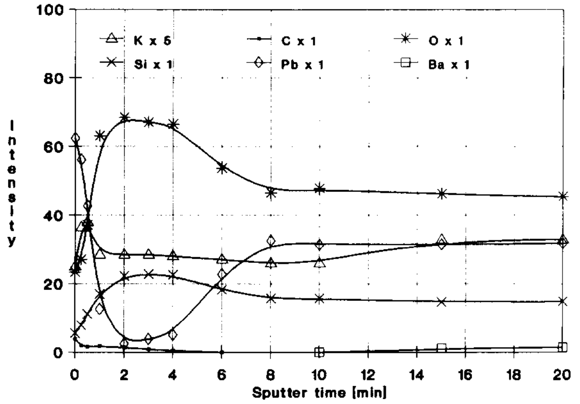

Fig. 2. AES sputter depth profiles of the important elements in the active surface of the channel before ageing of the MCP. The measured peak-to-peak intensity is normalized to the corresponding pure elemental target value which is set at 100.

negligible amounts. The Pb concentration is very high on the surface, while in a layer about 10 nm under the surface the Pb concentration is considerably reduced. In the same depth the increase of Si and O was observed. The significantly reduced Pb amount in the mentioned region is caused during the final stages of chemical processing in the manufacturing technology. Pb is leached off from a thin layer under the surface. Deliberately and consequently this layer is enriched with Si and O. In the near-surface region a sudden increase of K concentration was observed. On the surface and beneath the mentioned region the K concentration is almost the same as in the bulk material. The presence of Ba was observed in a

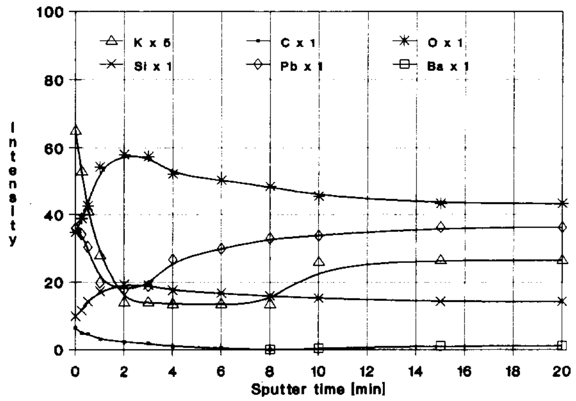

Fig. 3. As fig. 2, but now after ageing of the MCP.

depth of about 35 nm beneath the surface, and its concentration increases slowly in the bulk material. The distribution of the present elements versus sputter depth of the exposed sample (fig. 3) shows that on the surface the 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 layer beneath the surface of the aged sample is enriched with Pb. The discovered increase is probably due to an ionic diffusion process of Pb.

4. Conclusion

Fresh and aged microchannel plates (MCP) were investigated by AES. We found out that probably ionic transport on the active glassy surface and silica-rich emitting layer changed the elemental distribution of these layers during the ageing process. The comparison of AES depth profiles shows a great increase in content of K and a minor in that of Si and O on the channel surface of the aged MCP. Pb ions replenished empty places left by K, Si and O in the silica-rich emitting layer. After the ageing process a small increase in carbon contamination of the channel surface was observed.

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