Study of the secondary ion emission by electrons from micro-channel plates (MCP)

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Abstract. The purpose of the present work is to study the composition of the emitted ions and to characterize the surface composition of MCP as function of temperature using ESD, AES and SEM techniques. It is found, that sodium and potassium have significant contribution to the desorbed ions. Intensity of these elements increased with increasing surface temperature. The presence of water and hydroxyl ions was negligible. Heating of the surface simultaneously with electron bombardment resulted in changes of the chemistry of the surface, which consisted mainly in a decrease of C and in an increase of Na and K on the surface.

1. Introduction
Photoelectronic devices (PED) are extensively used in modern science and technology for detection of ultra fast processes in physics, in astronomy, night vision, etc. The ultimate generation PED contains very sensitive GaAs photocathode as well as micro-channel plates (MCP). The micro-channel plate is a perforated glass disk with several hundreds of thousands of orifices of 5 µm to 10 µm diameter. The photoelectrons emitted from the cathode are accelerated by the high electric potential applied to the entrance of the MCP and initial intensity is amplified by multiple impacts along the inside wall of the micro-channel. To increase the efficiency of the electron multiplication the micro-channels are inclined several degrees to the surface normal. In addition to the avalanche of secondary electron emission the incident electrons also produce secondary ion emission from the micro-channel surfaces. These secondary ions are accelerated by the applied electric field towards the cathode. As a result, the lifetime of the cathode is considerably reduced.

One of the ways to avoid the undesirable ion bombardment of the cathode is to use an ion barrier film at the entrance surface of the MCP. This ion barrier (IB) is a thin (10 nm) Al film, which is transparent for high energy electrons, but detains secondary ions. By using IB the lifetime of the device can be significantly increased, however, the signal-to-noise ratio becomes much lower, than without IB, since not all emitted electrons can penetrate the IB.

Another way to reduce the ion bombardment of the cathode is by using a pulsed power supply [1]. In this case the device is operating during short time intervals therefore the overall lifetime can be increased. However, this method does not avoid completely the secondary ion bombardment, so the problem remains. To achieve significant progress in lifetime and quality of PED the secondary ion emission from MCP should be investigated. In the present, a study of the secondary ion emission from MCP using Electron Stimulated Desorption technique at various temperatures is performed. Chemical composition of MCP surface is characterized by using AES.
2. Experimental

Schematic of the Electron Stimulated Desorption (ESD) technique already described [2] is shown in Figure 2. The MCP was bombarded by the primary electrons from the electron gun situated at approximately 45° to the surface. The secondary ions are detected and analysed using a quadrupole mass-spectrometer. The mass-spectrometer operated in an ion count mode with an ionization chamber switched off. Residual gas pressure during experiments was $10^{-9}$ mbar. No potential was applied to the MCP during ESD experiments. Before introducing the samples into the vacuum system they were baked in an oven at 250 °C for 1 hour for water desorption.

![Figure 2. Schematic of the experimental setup for secondary ion emission measurement](image)

Two types of the samples were studied: normal MCP and the section of the MCP along the axis of the micro-channels (Figure 3). Chemical composition was characterized using AES in the same chamber.

![Figure 3. SEM images of the normal MCP surface (left) and the section (right)](image)
3. Results and discussion

Figure 4 shows the ESD spectra from the normal MCP as function of the sample temperature.

![ESD spectra](image)

**Figure 4.** ESD spectra at indicated temperatures from normal MCP (a) and from the section of MCP (b)

The detected desorbed ions include hydrogen, fluorine, sodium and potassium. Surprisingly, hydroxyl and water ions were not detected. Although for a long time these ions were supposed to have a large contribution to the secondary ion emission yield since wet chemical processes are used at the manufacturing stage of MCP. Fluorine is a typical contaminant in a vacuum system, while the origin of fluorine is not clearly understood [2,3]. Even at very low surface concentration fluorine can be easily detected in the ESD spectrum due to its very large cross-section. Sodium is one of the main components of the MCP glass and also has large cross-section for ESD. However, the behaviour of the sodium desorption rate with temperature is different of that of fluorine. As temperature increases the desorption rate of fluorine first increases and then decreases. This indicates that fluorine is present at the surface as a contaminant from residual vacuum. In contrast, desorption intensity of sodium increases with the increase of the temperature. At temperature of 200 °C and above a small peak of potassium is also observed. Its intensity also increases with the temperature increase. Potassium can be deposited on the surface of the micro-channels during manufacturing process.

On the section along the axis of micro-channels the intensity of the surface ions is much lower than on the normal surface, however, the spectra have generally the same profile. The observed decrease of the surface ions may be due to roughness of the fractured surface that led to larger angular scattering of the desorbed ions.

Surface composition of the samples before and after heating at various temperatures was studied using AES (Figure 5). Since some of the incident electrons could pass through the holes of the MCP and reach the Ta sample holder, AES spectrum was obtained also for the sample holder alone for comparison purposes. The AES spectrum of the sample holder was completely different from the spectra of the MCP. So, it was concluded that despite of the large number of the holes in the MCP there is no contribution of the sample holder on the MCP spectra.
Figure 5. AES spectra from normal MCP as function of heat treatment at indicated temperatures

For MCP before heating the surface is largely contaminated with carbon. The detected signals of chromium and oxygen are due to the fact that the MCP normal surface has a thin chromium film for electric current conductance. After heating at 275 °C carbon peak decreases and potassium peak appears. There is also a very small peak of sodium. After heating at 500 °C the carbon peak further slightly decreased, while the potassium peak increased.

The different behaviours of sodium and potassium in ESD and AES spectra can be explained by different cross-section for Auger electron emission and for ESD of these elements.

The decrease of the carbon content on the surface can explain the increase of the sodium and potassium desorption rate at higher temperatures, because this C layer shield other elements.

4. Conclusions
The detected ions obtained by ESD from MCP includes hydrogen, fluorine, sodium and potassium ions. Intensity of the sodium and potassium desorption increases with the increase of temperature, while desorption of fluorine first increase and then decreases that indicates that fluorine is a contamination form the residual vacuum. Increase of the sodium and potassium desorption at higher temperature can be related with carbon clean-up from the surface by heating.

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6. References
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