Electron transmittance characteristics of MCP ion barrier film

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ABSTRACT

The MCP ion barrier film in low-light-level imaging tube and its process techniques were introduced in this paper. The electron transmittance of this film was studied. The results of half field-of-view testing comparisons and the concept of dead voltage were presented. The dead voltage curve and the relation between dead voltage and thickness of film were tested. The composition of film was analyzed by XPS.

Keywords: microchannel plates, without pollution film forming process, electron transmission characteristics, dead voltage, UV photoelectric method

1. INTRODUCTION

Microchannel Plates (MCP) is a two-dimension array-type channel electron intensifier that is lumped by millions of single channel electronic multipliers (CEM). It has a cellular structure. Fig.1 shows its basic structure and principle of single channel electronic multiplier. It has already widely applied to the extremely faint optical signal detector, low-light-level image device, electron, ion, UV ray, X ray and γ ray detectors because of its advantages such as high gain, low noise, high resolution, wide band, low power consumption, long life and self-saturation effect, etc. In the third generation low-light-level image intensifier (Fig. 2), high density electron cloud is formed in MCP output end. Residual gas molecules are ionized to positive ions with the action of back proximity field intensity and they are feedbacked to photocathode, which destroyed the structure of Cs-0 activate layer on surface of negative electron affinity III-V subgroup GaAs photocathode, reduced sensitivity of photocathode, shortened life of the device, formed an ion spot on output screen and made the background deteriorative. So we deposit a dielectric film of 3-4nm on MCP input surface, call that ion barrier film (or electron transmission film). Most electrons can transmit it and it can prevent positive ions feedback to the front proximity area effectively in order to avoid positive ions bombarding the photocathode, lengthen device life and improve image background.1, 2

2. LAYER PREPARATION TECHNOLOGY

In middle of the 1990s, ion barrier film was made on input surface of MCP by adopting traditional process (direct current or magnetron sputtering) method and it was used in developing the third generation image intensifier.3

Figure 1: Microchannel plate and single channel electron multiplier.
Figure 2: The third generation low-light-level image intensifier.
1. photocathode 2. front proximity area 3. MCP with film 4. back proximity area 5. screen 6. fiber-optic image inverter
Technological process: deposit an organic film carrier on the input surface of MCP → sputter aluminium film on film carrier → forced oxidize → deprive the organic film carrier. The organic film carrier is kept intimate contact with MCP all the time of whole course. It is extremely serious in polluting MCP especially C pollution while decomposing and depriving the film. For this reason new process without pollution film forming was developed in recent years. Technological process: sputter aluminium film on self-sustained organic film carrier (MCP nonintervention process) → adhere aluminium film to the input surface of MCP (the organic film carrier is not contact with MCP directly). It is oxidized and the organic film carrier is deprived at the same time. The probability polluted by the organic matter in the ion barrier film and MCP channel is lowest at the whole process.

3. ELECTRON TRANSMITTANCE CHARACTERISTICS OF FILM

3.1 Experiment of half field-of-view comparison

On MCP input surface, half of it coat Al₂O₃ film, the remaining half have no film. We adopt UV photoelectric method to test the characteristic of MCP. We observe and contrast through the experiment and so we can judge thickness of film layers (d), dead voltage (Vₑ), uniformity of film layers, having flaw and needle hole or not, etc. Fig.3 and Fig.4 show the principle of UV photoelectric method device and the relation between luminance distribution of screen and the input electronic energy in the experiment of half field-of-view comparison. Fig.4 shows that when input voltage Vᵢn<150V, the output screen that was corresponded with film area is almost not illuminated. When Vᵢn>150V, the luminance of output screen increased linearly with the increase of electronic input energy. When Vᵢn>700V, the luminance of output screen with film and without film were basically corresponded. Fig.5 shows the relation among output current and input energy at film area or without film area. It presents the same regular as the compared result of the luminance of output screen.

Figure 3: Pattern for principle of UV photoelectronic method.

Figure 4: Relations between screen output brightness distribution and input electron energy of half film MCP.

3.2 Electron transmission characteristics of the whole film MCP

Relation between output electric current and input electronic energy of the whole film MCP was measured through experiments, as is shown in Fig.6. Here we introduce the concept of dead voltage that is used to describe the ability that
ion barrier film prevents electron from transmitting it. We provided here is the intersecting point of the reverse extension line of the straight part of the curve and the voltage axle, which is exactly the value of the dead voltage of the film which thickness is given definitely. If electronic energy is greater than the dead voltage, the probability of transmitting film increase rapidly. So dead voltage can be regarded as a probable measurement of film thickness. Fig.7 presents the relation of film thickness and dead voltage. It is nonlinear that mainly because outer electrons of the film atoms and free electrons scatter with input electrons. High-energy electrons directly transmitting and inside secondary electrons that scattered to transmit form the input electron-stream of MCP. The higher incident electronic energy, thinner film or lower density of materials of film is, the greater probability of directly transmitting film and smaller scattering is. So there are a group of curves shown in Fig.6.

3.3 Electrical characteristic of MCP with film
In the two processes of MCP film making, we have adopted UV photoelectric method to measure electron gains, volume resistance and dark current change of MCP with film by contrast to those without film. The dates are given in table 1. The gains reduction results from the film blocking electron and C polluting the surface. The increase of volume resistance is caused by structural changes of surface and conducting layers. The reason why dark current is decreased is that the increasing of potential barrier which is caused by structural changes of the surface.

Table 1: Change of electron gains, volume resistance and dark current when MCP with film or not.

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<th>Decrease of gain (%) (V&lt;sub&gt;MCP&lt;/sub&gt;=900V)</th>
<th>Increase of volume resistance (%) (V&lt;sub&gt;MCP&lt;/sub&gt;=500V)</th>
<th>Decrease of dark current (%) (V&lt;sub&gt;MCP&lt;/sub&gt;=1000V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional process</td>
<td>15~20</td>
<td>15~20</td>
<td>&lt;10</td>
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<tr>
<td>New process</td>
<td>5~10</td>
<td>&lt;10</td>
<td>&lt;5</td>
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4. COMPOSITION ANALYSIS ON FILM

The analysis results in X-ray Photoelectronic Spectrum (XPS) show that films prepared by traditional process and new one all have O, Al, C, N, etc. We found that film interior composition of O and Al is the same basically as the surface after analyzing by Ar ion deep etching. It is indicated by binding energy (peak position of characteristic) and atom concentration of elements that Al exists as oxide of Al<sup>3+</sup> in film, namely Al<sub>2</sub>O<sub>3</sub>. At the meantime we found that there were less carbon content in new process than traditional process. The ratio of their atom concentrations is 10.71: 6.51. Fig.8 shows the XPS analysis chart.

![Figure 8: The XPS analysis of the film surface on filmed MCP.](image)

(a) Sample from conventional process. (b) Sample from new process

5. CONCLUSION

(1) Al exists as oxide of Al<sup>3+</sup> in ion barrier film. According to structure and atom concentrations, we conclude that the
film is $\text{Al}_2\text{O}_3$.

(2) Dead voltage is an important parameter to evaluate the electron transmittance characteristics of ion barrier film. Its value is a kind of indirect method to predicate film thickness too.

(3) Half field-of-view comparison is a direct-vision and feasible method to judge film exists or not, thickness and homogeneity of layer, etc. There are practical meanings.

(4) Ion barrier film without pollution forming process is scientific and feasible. It has wide application prospects for not only pollution is light but also the film has a little effect on MCP characteristic.

(5) In order to attribute ion being blocked ability by MCP ion barrier film quantitatively, it is imperative to measure ion transmittance.

REFERENCES