Influence of vacuum degassing on microchannel plate performance

A. Stanković, I. Zlatković, R. Nikolov, B. Brindić and D. Pantić

***Abstract*— This article discusses the influence of vacuum degassing on the microchannel plate (MCP) performance. Vacuum baking is a process of degassing by heating components to make them release molecules attached to their surfaces (mainly H_2O). Experiments were done with the MCPs with a channel diameter of 6µm, that were backed for 12h at the temperature of 430ºC under a high vacuum. The results showed a change in electrical parameters of MCP- the resistance and the gain changed up to 30% and 50%, respectively.**

***Index Terms*—vacuum degassing, vacuum baking, image intensifier tube, microchannel plate, gain, resistance.**

I. Introduction

Microchannel plate as an amplifier is commonly used in various detectors and night vision devices because of its excellent performance in electron multiplication with high gain, high resolution, low noise, and other characteristics [1-4]. Here will be considered the use of MCP in image intensifier tubes (IIT) for night vision devices. IIT is a device that amplifies low light level images to a level that can be seen with the human eye. The key component of IIT is MCP along with photocathode and phosphor screen (Fig.1).

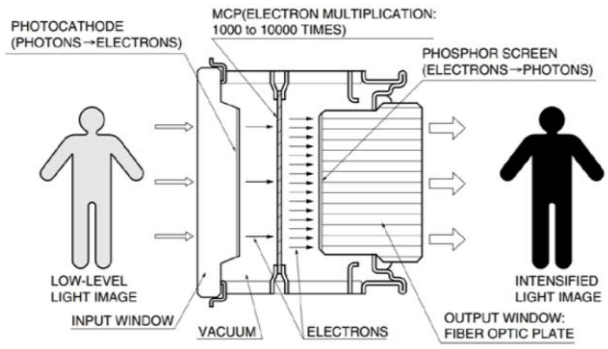

Fig. 1. Image intensifier tube operating principle [3].

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A photocathode as an input window of the image intensifier tube converts incident light (photons) into electrons. Multialkali photocathode is usually used for 2nd generation of image intensifier tubs, or GaAs for 3rd generation image intensifier tubes. Once released by the photocathode these electrons are accelerated and strike the inner wall of MCP channels, where they are amplified. For each electron that enters MCP, approximately one thousand electrons are generated and accelerated from the output of MCP to the phosphor screen, which converts the electrons back into photons.

A. MCP Operating Background

Microchannel plate consists of several million microchannels that are fused and each one serves as an independent electron multiplier. The operating principle of the MCP is based on secondary electron emission (Fig. 1): When an electron enters a channel from the input side it hits the channel's inner wall. In each collision, the electron from the channel wall excites the new 3-8 electrons, which further move accelerated by the influence of a strong electric field developed by a voltage applied across both ends of the MCP, striking the channel wall and exciting new electrons, eventually causing the avalanche of secondary electrons at the output side. This phenomenon of multiplication of an electron under the action of an electric field is called the secondary electron emission. In this way the input signal is increased about 10^3-10^4 times, depending on the operating mode of the MCP and applied voltage.

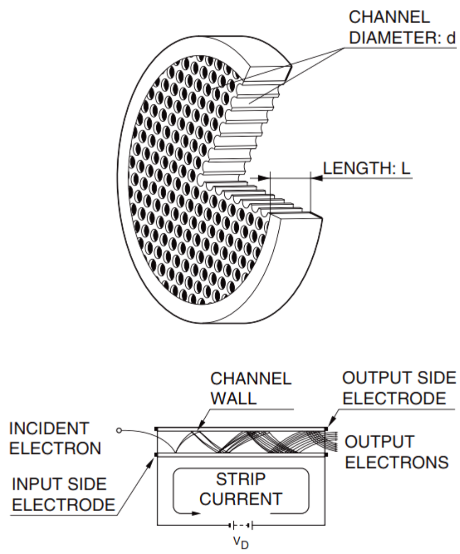

Fig. 2. The structure and operating principle of the MCP [4].

II. VACUUM DEGASSING

The microchannel plate is produced from lead-silicate glass riched in alkalies that can improve the electrical property of the glass. MCP starts as a glass tube (also called cladding) fitted with rode or a core (a soluble glass) and drawn into single-fiber, then a number of these single-fibers are stacked in a hexagonal array called a multi. The entire assembly is drawn again to form multi-fibers. The multi-fibers are then stacked to form a boule which is fused at high temperature. Then sliced on a wafer at a certain angle, polished and then each wafer is chemically processed to remove the core, leaving a honeycomb structure of million microchannels. The next process is hydrogen reduction where the wafer gets its conducting and secondary emissive properties. It is well known that when silica glass with a high amount of lead oxide is treated in hydrogen reduction at elevated temperatures, a semiconductor surface layer is formed. The surface layer of the glass appears black due to formed dispersion lead particles during the chemical reduction of PbO in hydrogen. [5]

After reduction two layers are formed (Fig.3):

- Emission layer 20 nm thick, rich in silica and alkali metals. This layer contains electrons that participate in the secondary emission and determines the gain of the microchannel plate.
- Conductive (resistant) layer 50-100nm thick. This layer is placed deeper in the channel and it is rich in lead. The conductive layer determines another electrical characteristic of MCP and that is its resistance. At the beginning of the reduction process, small lead grains are formed, then at the temperature of 450-500ºC, grains begin grouping into clusters and the principle of conducting the current is the principle of skipping the electron from the clusters to the next clusters of lead. The function of the conductive layer is to donate the electrons to the emission layer for the secondary emission by the support of the strip current. When the electron leaves the lattice of potassium silicate, a hollow left in the lattice is occupied with an electron from a conductive, lead layer and that makes the MCP current (“strip current”).

$$R = Umcp / Istrip \quad (1)$$

After hydrogen reduction, some alkaline impurities appear on the surface of the channels due to the diffusion of alkali cations in the surface through the walls. In contact with water vapor, hydrogen, and silicates on the channel walls they form various compounds that can cause excess gas, Ion feedback, etc.

So, from the MCPs fabricate process comes the residual gas molecules that are mainly hydrogen, water, carbon monoxide, and carbon dioxide. These gases make problems later when MCP is sealed in the image intensifier tube. There are two ways to eliminate these gases: electron scrubbing and high-temperature bake with a high vacuum degassing process.

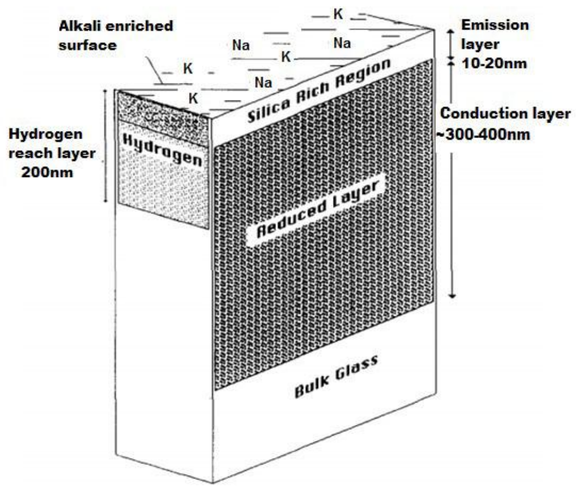

Fig. 3. MCP wall structure [5].

III. RESULTS OF VACUUM DEGASSING

For these experiments, ten MCPs with a channel diameter of 6μm were chosen to see the influence of vacuum degassing on its performances. Before vacuum degassing, all MCPs were tested in a special device for measuring the electrical characteristics of the MCPs, called “Tester”. The tester simulates the work of MCP in the image intensifier tube. We can simulate the operation of the MCP in IIT in all modes, from 10^{-5}lux corresponding to total darkness to 10^{2}lux correspondings to daylight. It consists of an ion gun (with tungsten filament), a focusing column, a chamber with an MCP holder, and a phosphorus screen. So resistance and gain at 800V on MCP were measured. After that, the experiment was done under the following conditions: vacuum 10^{-6} mbar, the temperature of 430ºC, and the time of 12h, then tested again. Table 1 shows the changes in MCP gain and the bulk resistance before and after high-temperature vacuum baking.

TABLE I
RESULTS OF THE EXPERIMENT

MCP	Parameters of VD		Results before and after VD					
	T (ºC)	t(h)	R_before [MΩ]	R_after [MΩ]	ΔR (%)	G_before (800V)	G_after (800V)	ΔG(%)
MCP 1	430	12	122.168	159.402	**30.48%**	2378	1164	**-51.05%**
MCP 2	430	12	81.135	103.09	**27.06%**	2036	1099	**-46.02%**
MCP 3	430	12	112.863	145.494	**28.91%**	2378	1164	**-51.05%**
MCP 4	430	12	118.124	151.534	**28.28%**	2533	1333	**-47.37%**
MCP 5	430	12	148.037	193.85	**30.95%**	2699	1345	**-50.17%**
MCP 6	430	12	126.91	164.312	**29.47%**	2093	1013	**-51.60%**
MCP 7	430	12	119.644	155.157	**29.68%**	2654	1454	**-45.21%**
MCP 8	430	12	116.866	152.167	**30.21%**	2246	1083	**-51.78%**
MCP 9	430	12	123.945	160.06	**29.14%**	2516	1032	**-58.98%**
MCP 10	430	12	137.655	182.831	**32.82%**	2982	1567	**-47.45%**

IV. CONCLUSION

From the results, we can conclude that with vacuum degassing we can increase the MCP resistance by 30%, and also decrease the gain by 50%. The main reason for this can be found in the fact that Pb atoms are distributed homogeneously and after high-temperature vacuum baking it changes. The size of the Pb atoms increases which leads to a decrease in emission layer efficiency of MCP, thus it increases the bulk resistance and decreases the electron gain of MCP. [6.7]

In this way, we can improve channel purity, reduce gas content, stabilize the performance of MCP, and prolong the operating life of the image intensifier tube.

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