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Taking Into Account the Fringe Fields in Micro Channel Amplifiers Design

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Abstract

Description of mathematical model for the fringe fields in photo detectors based on microchannel plates (MCP) is given. Normally the fringe field calculation requires complex and time-consuming computations using three-dimensional commercial codes. The original semi-analytic model suggested in the paper. This model is based on the mapping procedure for pre-calculated universal fringe field patterns for channels with specific values of the diameter and applied voltages. A fast algorithm can be used for metal channels with metal deposition on the edge and without it. Comparisons of numerical and experimental data are given. The dependencies of major device parameters vs. of applied voltage, pore size, and magnetic field magnitude have been studied.

1. Introduction

Microchannel amplifiers (MCA) are widely used in astrophysics, medical diagnostics, accelerator physics, and night vision devices. They have many advantages: compactness, high gain, work stability in radiation and in strong magnetic fields. MCA includes a photo cathode, one or more MCPs, anode system and circuits for the signal processing.

Pores of micro channels have a tilt angle with respect to the axis of the device. This leads to the appearance of three-dimensional fields of a complex structure in the vicinity of the input and output holes. Previously, we computed these fields using the commercial "COMSOL" code [1, 2]. Since the pore diameter, their calibre, applied voltage and the pore angle are varied in the design of the amplifiers, the calculations result in an unjustified increase in the computational volume for each particular set of input data. Here we present an original fast algorithm which significantly reduces the computation time. Theoretical background of MCA computer design is described in the monograph [3].

2. Fringe Field Numerical Simulations in 3D

Fringe fields at the entrance of MCP channels determine the photo electron collection efficiency. Fields at the exit of pores determine the angular distribution of secondary electrons and the gain factor as the cascades of those electrons produce the exponential grows of the current along the channel axis. These fields have a complex 3D structure. The electric fields at the ends of MCP pores were simulated using the multi-physic software COMSOL to study the photoelectron collection efficiency. The simulations show that in a highly-conductive environment, the electric field in the pore is directed axially inside the pore, having a gradual turn from the value in the resistive layer near the surface.

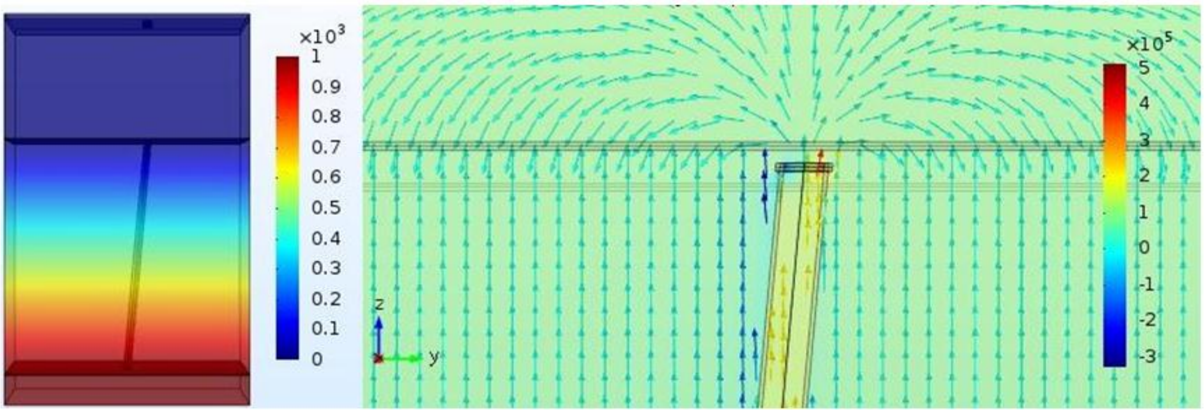

Figure-1. Field distribution in the gap photo cathode (left), and the map of electric field (right).

In our simulations we assume the relaxation time ε/σ is small enough for a thin resistive layer covered the MCP body of lead glass PbO_2. Figure 1 demonstrates the potential distribution and electric field in the gap.

Calculations show the external field penetrated in the pore on the distance of two pore diameter; hence the pore diameter is the only dimensional parameter of the problem. Thus, for a given angle of inclination, it is possible to calculate the electric field intensity profiles along the channel axis and the angle of rotation of the field to the axis for a unit radius and a single applied potential. Then these profiles can be scaled for arbitrary values of diameter and potential.

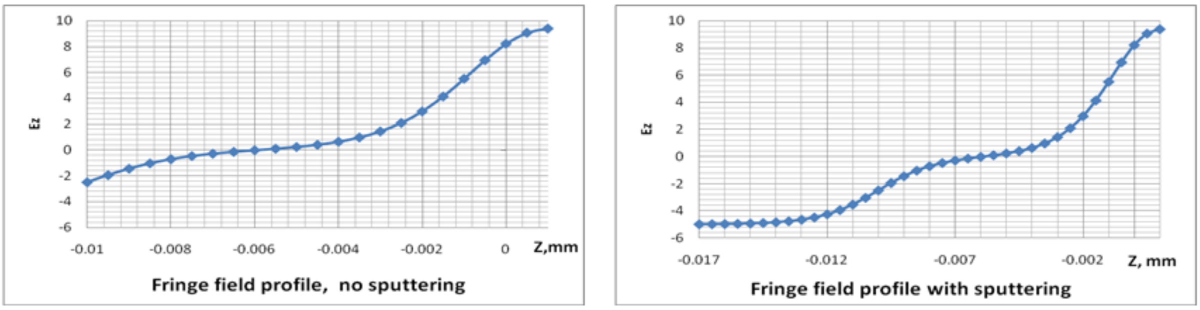

Figure-2. Fringe field Ez(z) for the channel with no sputtering (left), and with sputtering (right).

Figure 2 shows the fringe field profiles with no sputtering at the channel ends, and with sputtering zone length of one channel diameter.

3. MCP's Study with Taking into Account the Fringe Fields

We studied numerically the properties of different MCP assemblies presented in the Table 1.

Table-1. Parameters of the MCP assemblies.

Type	Name	Channel diameter,μm	Calibr L/D	Tilt angle, degree	Interplate gap, μm
Single	89664	12.5	160	5	-
Chevron	74	6	50	5	100
Chevron	88353	7	40	13	100
Chevron	82015	10	40	5	100
Z-stack	418	7.5	43	5	100

Figure 3. Shows the fringe field effect for chevron pair 82015.

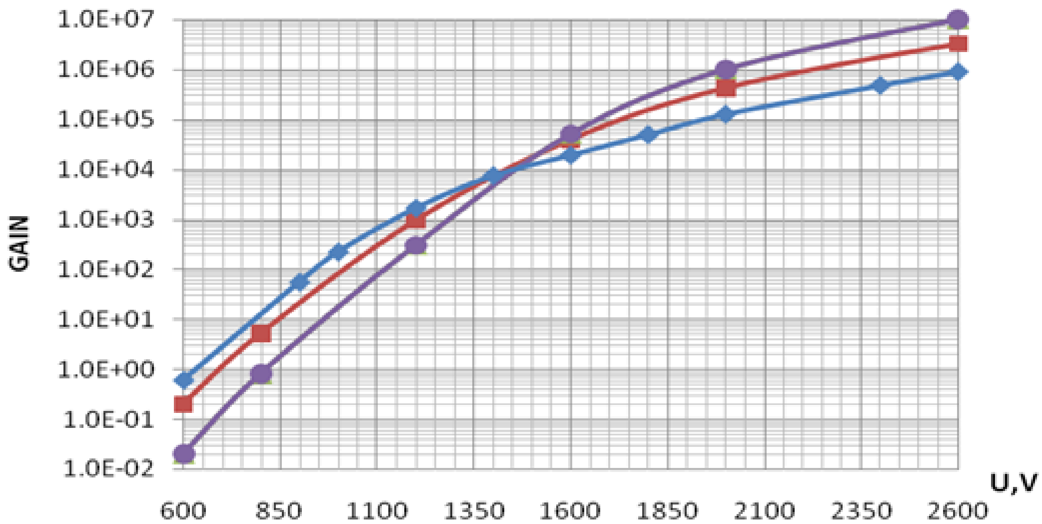

Figure-3. Gain vs. applied voltage U for chevron 82015. Circles – experiment, diamonds – numerical data with no fringe fields, squares – fringe fields + sputtering.

The results for other MCPs demonstrate a good agreement between experimental data and

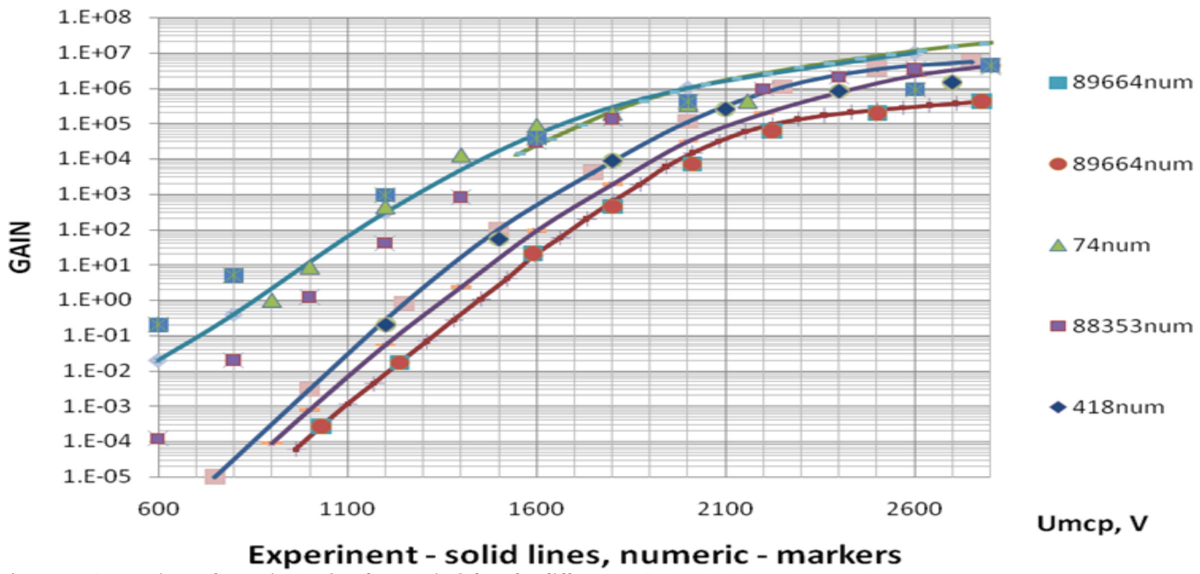

Figure-4. Comparison of experimental and numerical data for different MCPs.

numerical calculations for pores with 5 degrees of tilt angle, and some divergence for 13 degrees angle in low gain range.

4. Conclusion

Comparison of calculations and experimental data demonstrates a satisfactory agreement for the dependence gain vs. applied voltage for all studied MCPs. Modeling revealed the important role of fringe fields on the gain factor, timing resolution and on the photo electron collection efficiency. Suggested numerical model demonstrates a high computational speed in comparison with direct calculations of three-dimensional electric fields.

References

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