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Abstract

We present an original design for large area gaseous detectors based on the MICROMEAS technology. This technology incorporates an insulating grid, sandwiched between the micro-mesh and the anode-pad plane, which provides an uniform 200 μm amplification gap. The uniformity of the amplification gap thickness has been verified. The gain performances of the detector are presented and compared to the values obtained with detectors using cylindrical micro spacers. The new design presents several technical and financial advantages.

Particle detectors based on the MICROMEAS technology [1–8] consist of a parallel-plate gas-chamber split into two asymmetric stages by an intermediate electrode made out of a micro-mesh. By applying appropriate voltages between the three electrodes, a very high electric field (~ 30 kV/cm) in the thinnest stage (the “amplification gap”) and a low electric field (3 kV/cm) in the thicker stage (the “drift” or “conversion gap”) can be simultaneously established. When a charged particle traverses the conversion gap, it generates primary electrons which are subsequently multiplied in the amplification gap. The amplified electron cloud is collected on the anode generating a fast electric signal. The associated ion cloud is quickly collected on the micro-mesh, whereas only a small fraction of the ion cloud enters into the conversion region. Based on this technology, we had earlier developed [8] large area particle detectors. In the current detector, the main modifications with respect our previous developments [8] are:

- The total area of the anode plane has been enlarged to 400×400 mm², providing an active area of 387×387 mm². The anode electrode consists of a 1.0 mm thick printed circuit board. Its inner surface is segmented in rectangular 12×12 mm² gilded copper pads. The inter-pad width is 100 μm and the total number of pads is 1024.
- The electro-formed micro-mesh¹ consists of a 7 μm thick grid of 508×508 mm² made of pure Ni. The 106 μm squared holes grid are outlined by a 20 μm thick border of Ni in steps of 126 μm , i.e. 200 LPI (lines per inch). The optical transparency reaches 70%. The micro-mesh is stretched on the Plexiglas frame whose height defines the 6 mm thick (compared to the 3 mm thick in the earlier design) conversion gap between the micro-mesh and the cathode plane. The amplification gap between the micro-mesh and the anode plane has been doubled to 200 μm .

In this letter, two different designs to keep an uniform amplification gap of 200 μm have been compared:

- **Old design.** The amplification gap is defined by cylindrical micro-spacers of 200 μm high and 250 μm in diameter, glued on to the anode-pads with a pitch of 2 mm in both directions.
- **New design.** The micro-spacers are replaced by an insulating grid sandwiched between the micro-mesh and the anode plane (see Fig.1).

The new design presents several decisive technical but also financial advantages when compared to the cylindrical micro-spacer design. Indeed, since the grid is independent of the printed-circuit board, boards and grids can be interchanged in case of malfunction of one of the two elements. Moreover, the printed-circuit board without cylindrical micro-spacers is more robust. This particular feature facilitates the production process, in particular the polishing of

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¹BMC Industries, 278 East 7th Street, St. Paul, MN 55101, USA.

the anode-pad surface. In addition, the connectors can be soldered more easily to the back of the board by standard industrial techniques, thus reducing the cost of the detectors. The choice of the grid material is dictated by the insulation properties of the material and by its mechanical properties: It must be resistant to heat and rigid enough to be manipulated. A 200 μm thick FR4 grid of the same size as the printed board ($394\times 394\text{ mm}^2$) was chosen. The grid consists of 1024 squared cells of 11.8 mm width and 300 μm pitch (see Fig.2). On the edge of the grid, 28 2.4 mm diameter holes provides wide opening for the gas to flow inside the detector.

The critical parameter in the new design is the uniformity of the amplification-gap across the grid cells. We have therefore measured the amplification-gap thickness at different positions across the grid cell and for various voltages applied to the micro-mesh. For that purpose, we used a magnifying camera whose position in the three spatial directions can be accurately measured. With this technique the thickness can be determined with a 5 μm accuracy. For non-zero voltages the mesh flattens against the grid near its edge of the grid. For usual operating voltages from -440 V to -600 V (establishing electric fields from 22 kV/cm to 30 kV/cm), the average amplification gap thickness is $(203 \pm 5)\mu\text{m}$ and the difference in the gap thickness between the edge and the center of a grid hole is less than 10 μm at -440 V and less than 7 μm at -600V (see Fig.3). Such differences do not strongly affect the gain uniformity along the grid cell. In the worse case a gain variation of no more than 40% might occur. This would induce a minor impact on the detection of minimum ionizing particles. At voltages above -700 V (electric field larger than 35 kV/cm) the mesh is deformed by the electric force and the amplification gap thickness reaches a minimum value of $(190\pm 5)\mu\text{m}$ at the center of the cell.

The gain of this newly designed detector has been measured for different gas mixtures and micro-mesh voltages. A relative determination of the gain has been obtained by measuring the electric current induced in the micro-mesh when the detector is irradiated by a ^{90}Sr radioactive source. The source was placed on a 50 μm mylar foil replacing the anode of the detector. We have compared the two designs, cylindrical micro-spacers² and insulating grid. To eliminate most of systematic differences, the measurements have been performed simultaneously, the two detectors being supplied with gas from the same source. To estimate the absolute gain in the amplification gap, we have assumed that the number of electrons collected by the cathode is equal to the number of ions collected by the micro-mesh. The resulting electric current gives a relative measure of the detector gain and the following expression gives an estimation of the gain in the amplification gap:

$$G = \frac{I}{e \langle N \rangle A} \quad (1)$$

where I is the measured electrical current, e the electron charge, A the activity of the source expressed in Bq (5.6×10^5 Bq in the present measurement) and $\langle N \rangle$ the average number of primary electrons created in the 6 mm conversion gap. This later number obviously depends on the gas mixture, being $\langle N \rangle = 27$ for Ne+CO₂(5%), $\langle N \rangle = 29$ for Ne+CO₂(10%) and $\langle N \rangle = 56$ for Ar+CO₂(10%). The sensibility of the apparatus to the micro-mesh current was InA. The results (see Fig.4) indicate that the two designs behave similarly, although for a given voltage systematically higher gains are reached. with the micro-spacer design: about 10 V more are needed for the grid design to reach the same gain as with the micro-spacers. This could be related with a systematic difference of the amplification gap thickness between both detector designs. As a matter of fact, a variation on the micro-mesh voltage of 10 V represents a gain variation of around 40%. This gain difference between both designs would correspond to a gap-thickness systematic difference of only 10 μm . In addition, the electron source was placed on a mylar foil 50 μm thick for the new design and on a Ni micro-mesh 8 μm thick for the old design.

In summary, we have presented a new design for a gas chamber based on Micromegas technology, where the 200 μm uniform amplification gap is provided by an insulating grid sandwiched by the micro-mesh and the cathode-pad board. The micro-mesh is not strongly deformed for usual operating electric fields. The measured gain in the amplification gap for different gas mixtures and micro-mesh voltages shows results similar to those obtained with cylindrical micro-spacers. The grid design presents several decisive technical as well as financial advantages when compared to the cylindrical micro-spacers design, thus allowing for the industrial production of inexpensive particle detectors.

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²In this design, the ^{90}Sr radioactive source was placed on a 8 μm thick micro-mesh Ni foil.

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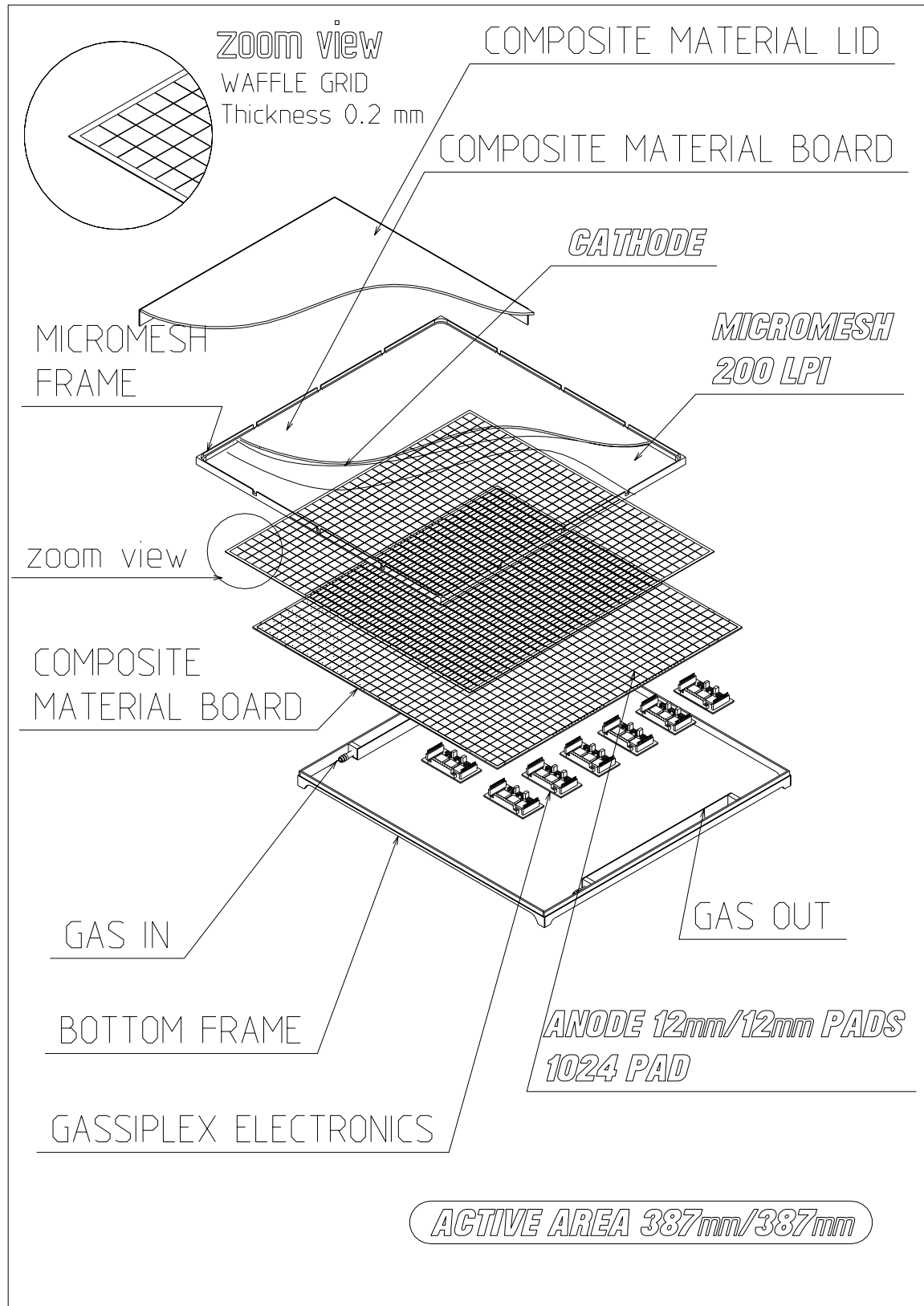


FIG. 1. Sketch of the new design for a large area particle detector with an insulating grid providing the amplification gap.

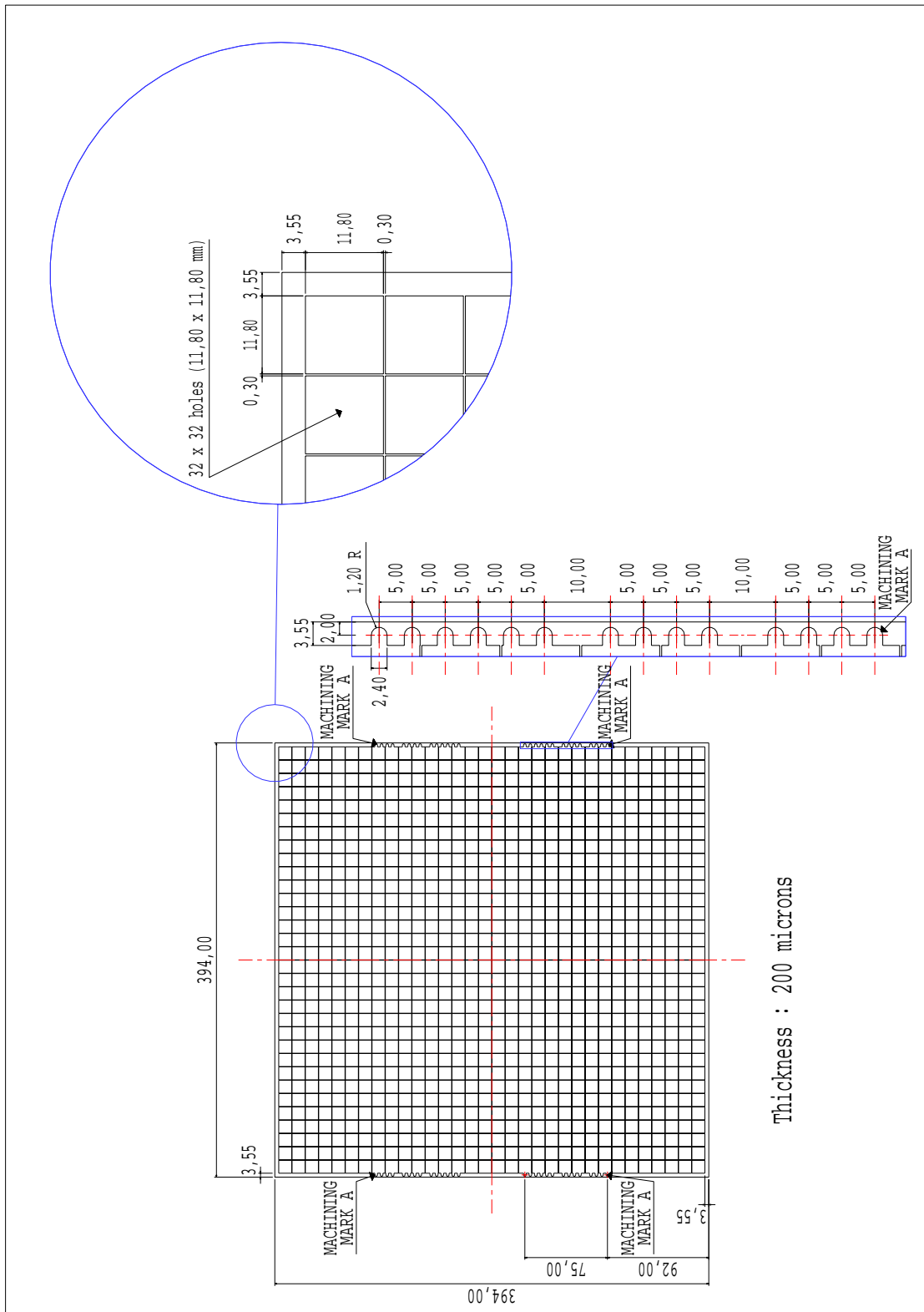


FIG. 2. Technical drawing illustrating the machining applied on a 200 μm insulating plate to obtain the grid. The circular zoom details the rectangular holes which delimit active areas. The rectangular zoom shows the holes which permit the gas to flow freely inside the detector.

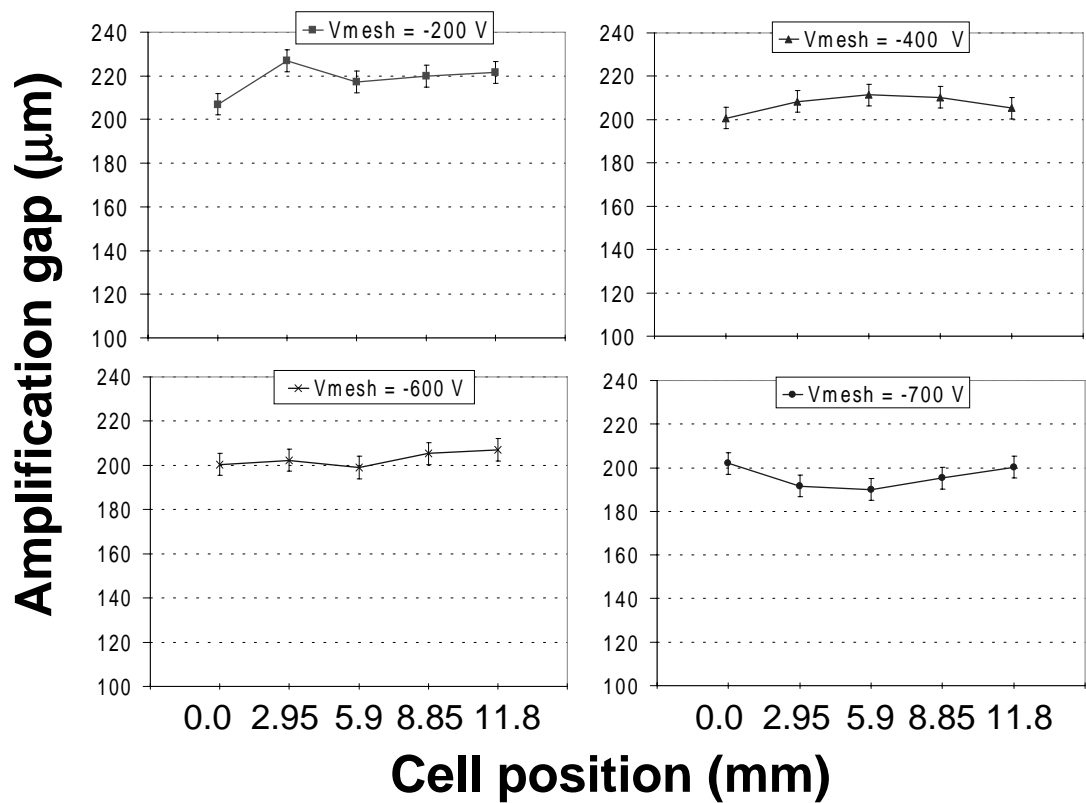


FIG. 3. Amplification gap thickness on several points of the mesh across one hole of the grid as a function of voltage applied in the micro-mesh: -200 V, -400 V, -600 V and -700 V

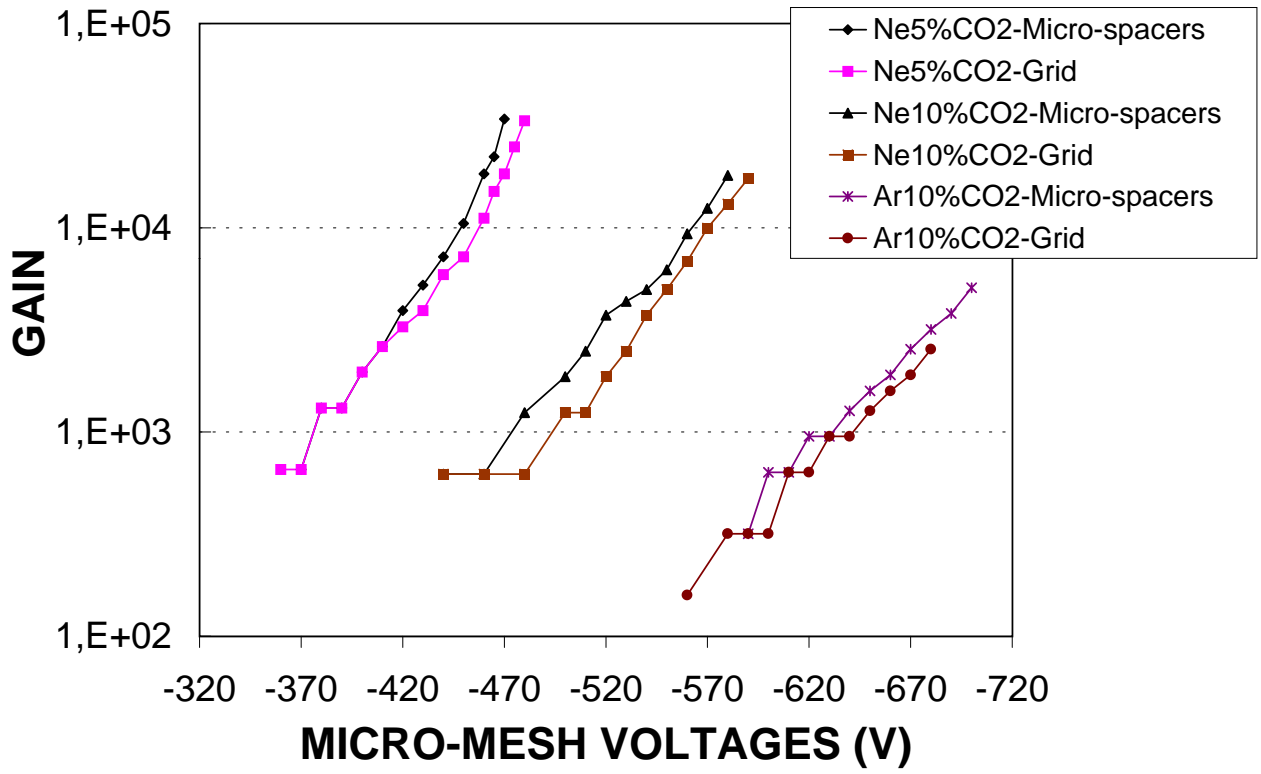


FIG. 4. Measured gain as a function of the voltage applied to the micro-mesh for two detector designs: one based on the micro-spacers design and the insulating-grid design. Various gas mixtures have been studied.