High-rate operation of the Micro-Hole and Strip Plate gas detector

J.F.C.A. Veloso[a],*, C.C. Caldas[a], C.A.B. Oliveira[a], C.D.R. Azevedo[a], J.M.F. dos Santos[b], A. Breskin[c], R. Chechik[c]

[a]Physics Department, University of Aveiro, 3810-193 Aveiro, Portugal
[b]Physics Department, University of Coimbra, 3004-516 Coimbra, Portugal
[c]Department of Particle Physics, The Weizmann Institute of Science, 76100 Rehovot, Israel

Available online 21 May 2007

Abstract

We report the performance of the Micro-Hole-and-Strip-Plate (MHSP) operated in xenon, under high-flux irradiation of a 30-kV X-ray Cu-tube. Stable operation in pulse-counting mode for gas gains above 10^4 was measured up to counting rates of $5 \times 10^5 \, Hz/mm^2$. A gain variation of less than 5% was observed for gains of 10^4, while the energy resolution for 8-keV X-rays degrades from ~16% to ~18%. No visible degradation was observed on the MHSP irradiated area.
© 2007 Elsevier B.V. All rights reserved.

PACS: 29.40.Cs; 29.40.−n; 85.60.Gz

Keywords: MHSP; Count rate; Xenon

1. Introduction

Micropattern electron multipliers have been developed and studied for almost two decades, with applications to many different areas of knowledge, such as particle tracking, X-ray and neutron detection and imaging or diffraction experiments [1,2]. For most of the applications there is a continuous interest in developing high-count-rate detectors to cope with the high luminosity of particle and synchrotron radiation beams.

The small spacing between anode and cathode electrodes allows for small drift distances for positive ion collection, leading to fast transit times and decreased space charge effects, thus increasing the count-rate capabilities of the new gaseous detectors. In addition, the small pitch of patterned electron multipliers provides high spatial resolution, in the sub-mm range.

However, the maximum achievable gain drops with the count rate for all micropatterned detectors [3–5]. Moreover, for a given gain its value drops with increasing rate, at high count rates. Indeed, a fraction of the charge

produced in the avalanches induces charge build-up on the surface of the insulators that support the different electrodes, with consequent rate-dependent gain [e.g. Refs. 6–8].

A new electron multiplier, the Micro-Hole and Strip Plate (MHSP), has been recently proposed [9,10]. It integrates, on a single element, two successive independent charge amplification stages: a GEM-like and a MSGC-like stage. Like the GEM [11], the MHSP is fabricated with printed circuit board technology from a 50-μm Kapton foil, metalized with 5-μm-thick copper-layers on both sides. A GEM-like pattern of holes is etched through the foil with a continuous metal electrode on the top-side, and a standard microstrip pattern etched on the bottom side, with the holes centered on the wide cathode strips, Fig. 1.

The MHSP presents gains that are more than one order of magnitude higher than the single-GEM, reaching values well above 10^4 in pure xenon [12], and fast signal response [10], ~10–30 ns. In addition, it has highly reduced ion-backflow, e.g. in a single MHSP more than 80% of the avalanche ions are trapped on the nearby cathodes [13]; this helps controlling ion-induced feedback effects.

Up to now, we had not yet investigated the performance of the MHSP operating at high count rates. While GEMs

---

*Corresponding author. Tel.: +351 239 410667; fax: +351 234 424 965.
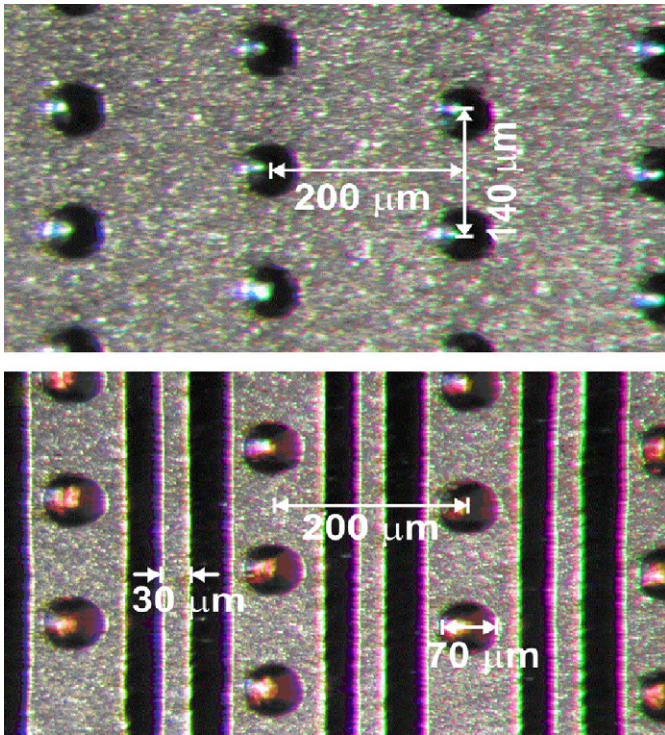E-mail address: jveloso@fis.ua.pt (J.F.C.A. Veloso).

Fig. 1. Photomicrograph of the MHSP electron multiplier, top and bottom sides.

Fig. 2. Schematic diagram of the MHSP electron multiplier and its operation principle.

do not exhibit gain variations up to 10^6 Hz/mm^2 [8], for standard MSGC the surface charge build-up effects play a significant role and a degradation in gain is already noticeable for rates as low as 10^4 Hz/mm^2 [6,7].

In this work, we investigate the MHSP capability to operate under high-flux irradiation of 8-keV X-rays. Gain and the energy resolution degradation are monitored for counting rates up to 5×10^5 Hz/mm^2.

2. Experimental set-up

The present MHSP has an active area of 2.8×2.8 cm^2. The bi-conical holes, around $\varnothing 40/70\,\mu$m are implemented in the Kapton/copper film, arranged in an asymmetric hexagonal lattice of 140- and 200-μm pitch in the directions parallel and perpendicular to the strips, respectively (Fig. 1). The anode and cathode micro-strip widths are 20 and 100 μm, respectively, with a 40-μm gap between them and a 200-μm pitch. All the MHSP electrodes are independently polarized, with the drift electrode at ground potential. The electric field in the holes is established through the voltage difference applied between the cathode strips and the top-electrode, V_{CT}, while on the bottom-side of the MHSP an MSGC-like electric field is established through a potential difference between the anode and the cathode strips, V_{AC}. The bottom mesh electrode was grounded and an electric field of 0.2 kV/cm was set in the drift region.

The MHSP operation principle is depicted in Fig. 2. Electrons produced by radiation in the gas volume above
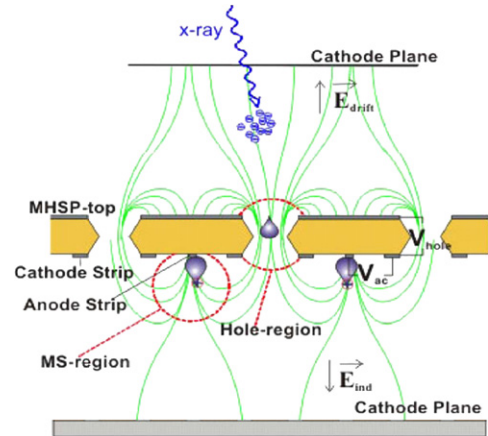
the MHSP (the drift region) are focused into the holes and undergo multiplication in the strong dipole electric field. The avalanche electrons are extracted towards the anode strip, in the MHSP bottom-side, where they are further multiplied in the strong electric field, and collected. The avalanche ions are mostly collected on the cathode plane and cathode strips. The drift and the induction regions are 5- and 3-mm thick, respectively.

The detector was irradiated with X-rays from a copper X-ray tube operated at 30 kV, placed at a distance of 30 cm from the detector. The X-ray beam was collimated to $\varnothing 0.5$ mm. The detector was filled with pure xenon at atmospheric pressure. Detector signals from the anode strips were fed through a Canberra 2006 charge preamplifier (sensitivity of 1.5 V/pC) and a Canberra linear-amplifier (0.5-μs shaping time) to a multichannel analyzer. The electronic chain sensitivity was calibrated for absolute gain measurement, using a calibrated capacitor directly connected to the preamplifier input and to a precision pulse generator.

3. Experimental results and discussion

In Fig. 3 we depict the detector relative gain and energy resolution as a function of the detector output count rate, for different MHSP absolute gains. The X-ray tube output flux was controlled varying the filament current. The values of V_{CT} and V_{AC} established for each gain are similar to those presented in Ref. [12]. No noticeable variation in the detector gain and energy resolution was observed for count rates up to 10^5 Hz/mm^2. This demonstrates that MHSPs can withstand, without gain modifications, and at an avalanche size of 3.6×10^6 electrons (i.e. for gains of 10^4), detected radiation rates of 10^5 Hz/mm^2. For count rates of about 5×10^5 Hz/mm^2, i.e. the maximum rate that we could achieve with our X-ray tube, gain variations of only 5% were obtained for gains of 10^4, and less than 2% for gains below 3×10^3. The energy resolution for high gains
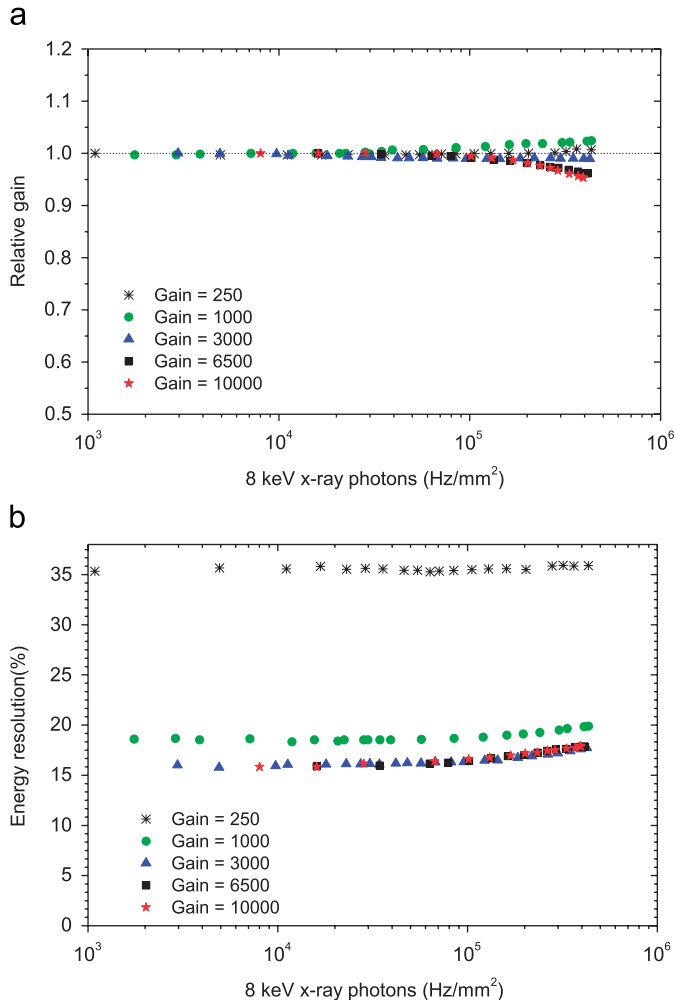
a

b

Fig. 3. Detector relative amplitude and energy resolution as a function of the detector output count rate, for different MHSP gains.
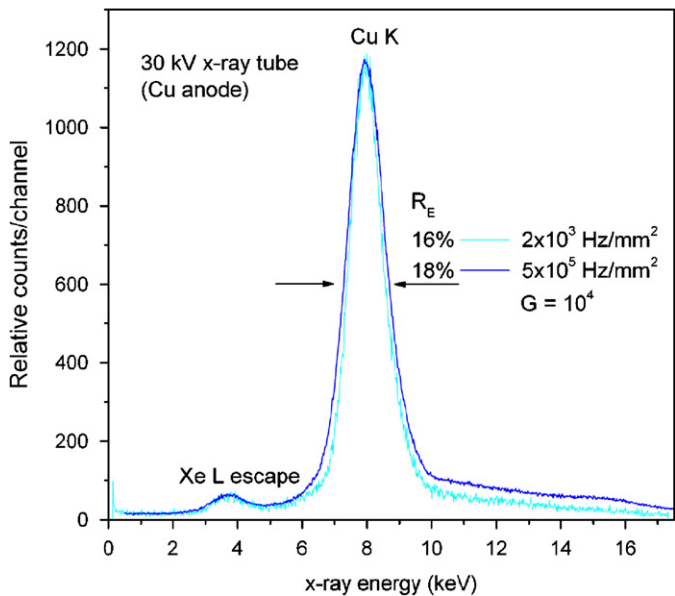

Fig. 4. Typical pulse-height distributions obtained for the X-rays emitted from the tube at low and high count rates and for a MHSP gain of 10^4.
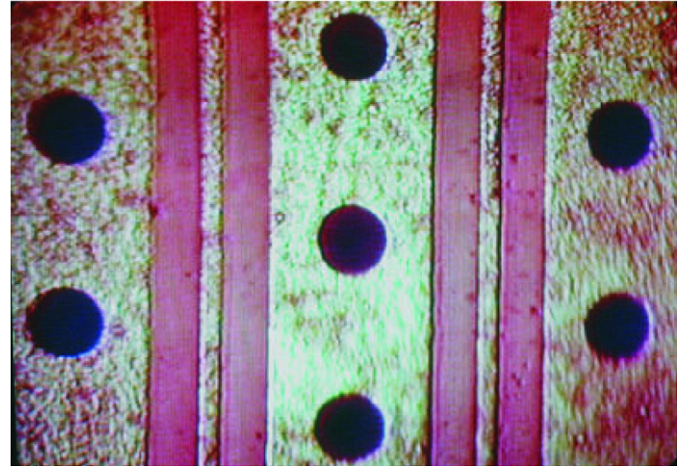

Fig. 5. Photomicrograph of a detail of the MHSP irradiated region.

degrades from 16% to 18% when the count rate increases from 10^5 to 5×10^5 Hz/mm^2.

Fig. 4 presents two typical pulse-height distributions obtained for X-rays emitted from the tube at the maximum achievable count rate and, for comparison, at a low count rate (2×10^3 Hz/mm^2), for MHSP gains of 10^4. A small amount of pile-up is observed in Fig. 4, contributing to the small degradation of the detector energy resolution.

The detector has been in continuous operation for several months, exposed to high rates for long periods, with no discernible radiation damage. The MHSP was exposed to charge rates in excess of 0.2 μC mm^{-2} s^{-1} for more than 1000 s. After a detailed inspection, no damage was observed in the irradiated region of the MHSP, Fig. 5.

4. Conclusions

We have investigated the performance of the MHSP electron multiplier operated in pulse-counting mode under high rate irradiation of 8-keV X-rays, in pure xenon at atmospheric pressure. The MHSP demonstrates stable operation for gains of 10^4 and count rates of about 5×10^5 Hz/mm^2.

No visible variation of the detector gain and energy resolution was observed for count rates up to 10^5 Hz/mm^2. For count rates of about 5×10^5 Hz/mm^2 it presented gain variations of only 5% for gains of 10^4, and less than 2% for gains below 3×10^3. The energy resolution at high gains degrades from 16% to 18% when the count rate increases from 10^5 to 5×10^5 Hz/mm^2.

No visible damage was observed in the irradiated area of the MHSP, after data taking during several months and exposure of the MHSP to charge rates in excess of 0.2 μC mm^{-2} s^{-1} for more than 1000 s.

References

[1] L. Shekhtmann, Nucl. Instr. and Meth. A 494 (2002) 128 and references therein.

[2] A. Sharma, 2000 IEEE Nuclear Science Symposium Conference Record, 2001, pp. 2–3.

[3] Yu. Ivaniouchenkov, et al., Nucl. Instr. and Meth. A 422 (1999) 300.

[4] Bressan, et al., Nucl. Instr. and Meth. A 424 (1999) 321.

[5] V. Peskov, et al., IEEE Trans. Nucl. Sci. NS-48 (2001) 1070 and references therein.

[6] J. Bohm, et al., Nucl. Instr. and Meth. A 360 (1995) 34.

[7] F.D. van den Berg, et al., Nucl. Instr. and Meth. A 401 (1997) 156.

[8] J. Benlloch, et al., IEEE Trans. Nucl. Sci. NS-45 (1998) 234.

[9] J.F.C.A. Veloso, et al., Rev. Sci. Instr. 71 (2000) 2371.

[10] J.M. Maia, et al., Nucl. Instr. and Meth. A 504 (2003) 364.

[11] F. Sauli, Nucl. Instr. and Meth. A 386 (1997) 531.

[12] H. Natal da Luz, et al., Nucl. Instr. and Meth. A 552 (2005) 259.

[13] J.M. Maia, et al., Nucl. Instr. and Meth. A 523 (2004) 334.