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Letter to the Editor

MHSP operation in pure xenon

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Abstract

We present latest results of a micro-hole and strip plate (MHSP) electron multiplier operating in pure xenon at atmospheric pressure. We report on avalanche gain of $\sim 2 \times 10^4$, stable within ~3% after an accumulated charge of $4\,\mu C/mm^2$, when irradiated with $0.5\,kHz/mm^2$ 5.9 keV photons. No photon-induced secondary effects or discharges have been observed at this gain. An energy resolution of 14% was obtained with 5.9 keV X-rays.

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The possibility to use pure noble gases as a detection medium with high charge multiplication has significantly advanced with the introduction of the gas electron multiplier (GEM [1]). The avalanche confinement within the GEM holes effectively hinders photon-mediated secondary processes, allowing high gains to be achieved in highly scintillating gases [2,3]. An intense research on the operation of such multipliers in noble gas atmospheres, often combined with solid photocathodes, has been carried out [2–6].

Pure noble gases have the advantage of being easily and efficiently purified with small non-evaporable getters [7]; they also do not age under avalanche conditions. This permits the construction of sealed detectors with stable, long-term operation under very intense radiation environments. In addition, sensitive solid photocathodes (e.g. bialkali, multialkali) can be safely incorporated in the chemically inert gases without being damaged by avalanche-induced radicals produced in standard gas mixtures [8].

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Applications of gas avalanche multipliers operating in pure noble gases include sealed gas photomultipliers, neutron detectors, X-ray imaging detectors and dual-phase noble-liquid detectors [e.g. 6,8–10]. Recent publications report on avalanche multipliers operated in pure xenon [6]; its high density and higher scintillation and ionization yields present advantages in X-ray imaging and particle detection applications.

In the present letter we report on the performance of a single micro-hole and strip plate (MHSP) electron multiplier Ref. [11,12] operating in pure xenon at atmospheric pressure. This two-stage multiplier (Fig. 1) operates in a similar way to GEM, with the first multiplication occurring within the holes and the second one occurring at the anode strips on the bottom of the plate. As in GEM, the detector structure effectively suppresses photon-induced secondary effects and can be operated in highly scintillating gases. The detector gain, energy resolution, minimum detectable X-ray energy and short-term stability are presented. The prospects of having 2D localization by further structuring the MHSP upper side are discussed.

A similar MHSP has been operated in the past with Ar-5% Xe mixture, as reported in [11,12]. This Penning gas mixture provides high gain at relatively low voltages [4]; this was of an advantage with the first production-batch of MHSPs, which suffered some manufacturing defects and were consequently limited in operation voltage. With the currently improved manufacturing quality, stable high-gain operation could be achieved even in a pure xenon atmosphere.

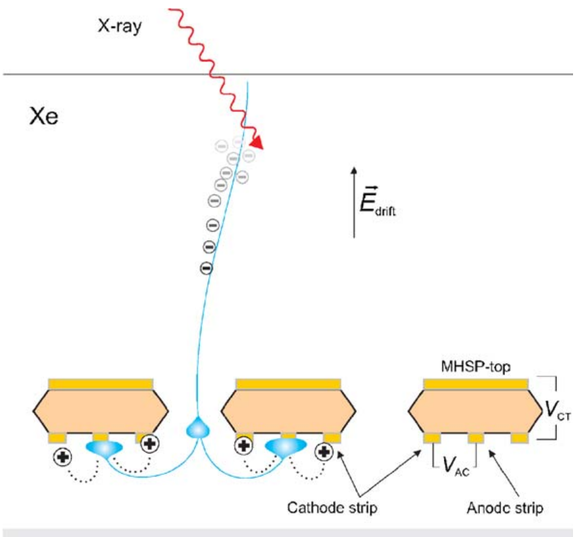

Fig. 1. Schematic of the MHSP-based detector.

The currently tested MHSP multiplier has an active area of $2.8 \times 2.8\,cm^2$ and is made of 50 μm thick Kapton foil with a 5 μm copper clad coating on both sides. The microstrip pattern, on the bottom surface of the foil, has a 200 μm pitch with anode and cathode widths of 30 and 100 μm, respectively. The bi-conical holes have about 40 and 70 μm in diameter in the Kapton and in the copper layer, respectively, and are arranged in an asymmetric hexagonal lattice of 140 and 200 μm pitch in the directions parallel and perpendicular to the strips, respectively (an illustration may be found in Ref. [11]).

The MHSP was placed between two planar electrodes (Fig. 1), defining the drift and induction gaps, of about 5 and 3 mm, respectively. All the electrodes were independently polarized. The detector was filled with atmospheric pressure xenon, continuously purified through getters (SAES St707/washer) at 150 °C, and maintained in circulation by convection. The detector was irradiated with Mn–K_α 5.9 keV X-rays from a ^{55}Fe source, filtered by a chromium film to remove the 6.4 keV Mn K_β X-rays. Most of the X-rays interact in the drift region and the resulting primary-electron ionization cloud is focused into the holes; the electrons then undergo two successive charge multiplication steps, in the holes and at the anode strips.

The signals from the anode strips were fed through a Canberra 2006 preamplifier (sensitivity 1.5 V/pC) and a Tennelec TC243 linear-amplifier (4 μs shaping time) to a Tennelec PCA2 1024-multichannel analyser. For peak amplitude and energy resolution determination, pulse-height distributions were fitted to a Gaussian superimposed on a linear background.

In Fig. 2 we present the detector's absolute gain and energy resolution, for 5.9 keV X-rays, as a function of potential difference, V_{AC}, between anode and cathode strips (Fig. 2a), and as a function of potential difference through the holes,

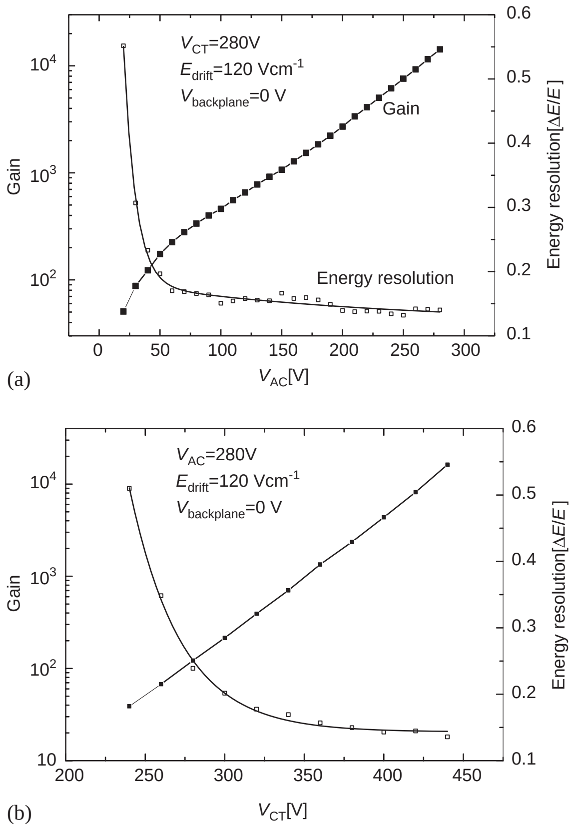

Fig. 2. MHSP gain and energy resolution for 5.9-keV X-rays as a function of: (a) V_{AC}, for $V_{CT} = 440\,V$; (b) V_{CT}, for $V_{AC} = 280\,V$. Operation in pure xenon at 1 atm.

V_{CT}, between the top-electrode and cathode strips (Fig. 2b). The backplane electrode, defining the induction field, was grounded. To avoid possible damage of the MHSP, the maximum voltages used for this study were kept below the onset of discharge. As shown, gains as high as 2×10^4 and energy resolutions of about 14% (FWHM) were obtained. In principle, higher gains should be attainable with thinner anode strips. At low V_{AC} values, Fig. 2a, the pulse amplitudes drop faster than an exponential, due to inefficient electron transport to the anode trips.

The effect of the electric field strength in the drift region on the pulse amplitude and energy resolution was investigated. Best performance was achieved with drift electric fields around 0.12–0.14 kV/cm. The effect of the induction field was also investigated, varying the backplane voltage in the -200 to $+400\,V$ range. While the pulse amplitude decreases about 10%, the effect on the energy resolution and on the noise tail, in the low-energy limit, is not noticeable.

Typical pulse-height distributions are depicted in Fig. 3, for 5.9 and 22.1 keV (of ^{109}Cd) X-rays. Respective energy resolutions of 13.5% and 7.8% (FWHM) were obtained. Fig. 3a exhibits a very low background level and a noise tail, in the low-energy limit, below 70 eV; the latter indicates upon very good prospects for the application of the MHSP to the detection of ultra-soft X-rays.

The stability of this detector, operated at a gain of $\sim 2\times10^4$ and irradiated with 5.9 keV photons at

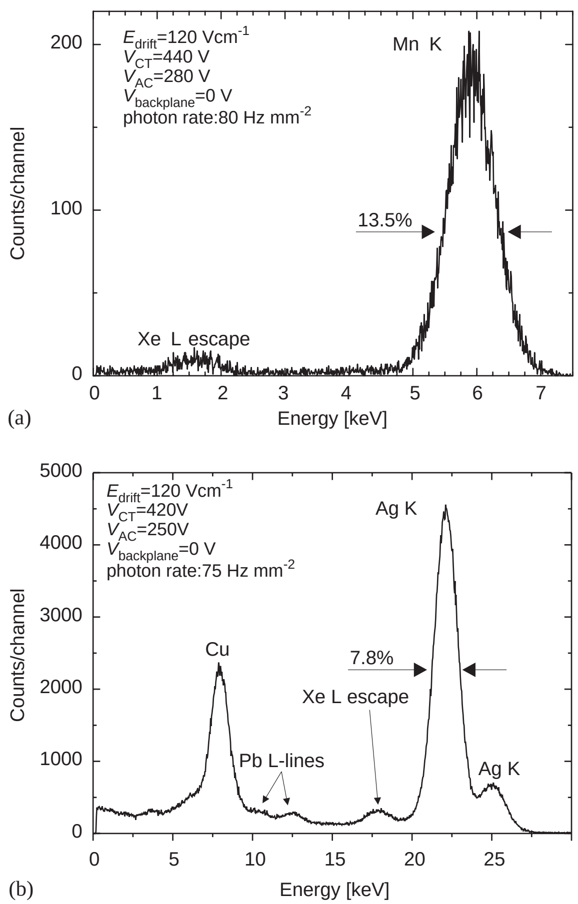

Fig. 3. Typical pulse-height distributions for 5.9 keV (a) and ^{109}Cd X-rays (b) obtained with the MHSP-based detector, operating in pure xenon at 1 atm at gains of about 10^4.

a rate of 0.5 kHz/mm^2, was monitored during 3 h, corresponding to a total integrated charge of about 4 μC/mm^2, at the anode strips. Following an initial decrease of ~4% in the first 3 min, the detector exhibited only an additional small decrease in pulse amplitude, of less than 3% over the total time period.

Having in mind the possibility of structuring the MHSP top electrode with strips perpendicular to the anode strips, for 2-D imaging, the pulse amplitudes at both top and anode electrodes were investigated. A ratio of about 0.35 was recorded between the top and anode electrodes over a broad range of operating voltages; it would be adequate for position recording.

In conclusion, the experimental results confirm a stable operation of the MHSP in a pure xenon atmosphere. Charge gains above 10^4 were reached, free of micro-discharges. This gain can be, in principle, further enhanced with thinner anode strips or in cascaded multipliers having GEMs followed by a MHSP [13]. Pulse-height spectra of 5.9 keV X-rays exhibit an energy resolution around 14% (FWHM), low background level and an electronic noise tail below 70 eV.

The fact that the MHSP operates in a stable way in pure xenon is of prime importance. It opens ways for using the primary scintillation in xenon to provide the instant of interaction, offering a possible way to eliminate the intrinsic parallax error of thick gaseous detectors [6]. Furthermore, we are presently studying GPSCs [7] for X-ray spectroscopy and imaging, where the secondary scintillation is detected within the same gas volume with a CsI-based MHSP photosensor, in which the photocathode is deposited on the top surface of the MHSP. Results will be reported elsewhere.

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