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Nuclear Instruments and Methods in Physics Research A 552 (2005) 259–262
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Letter to the Editor

MHSP operation in pure xenon

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Received 13 June 2005; received in revised form 1 July 2005; accepted 5 July 2005
Available online 25 July 2005

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.

PACS: 29.40.−n; 29.40.Cs; 85.60.Gz

Keywords: Gas electron multiplier; MHSP; Xenon

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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0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.07.004

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.

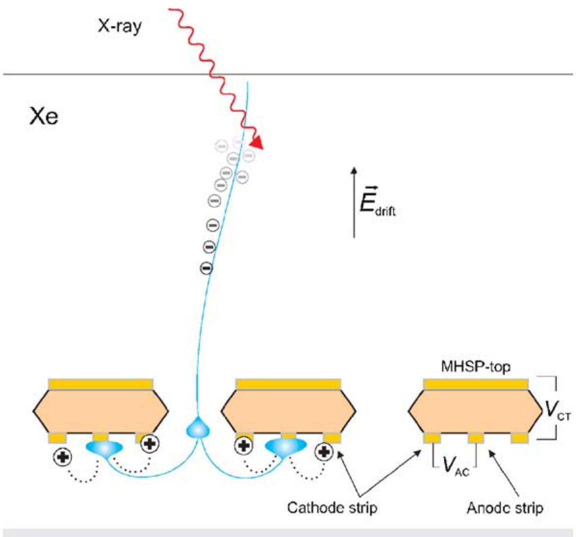

Fig. 1. Schematic of the MHSP-based detector.

The currently tested MHSP multiplier has an active area of $2.8 \times 2.8\,\mathrm{cm}^2$ 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,