Nuclear Instruments and Methods in Physics Research A 639 (2011) 134–136

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

THCOBRA: Ion back flow reduction in patterned THGEM cascades

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

[a] I3N, Physics Department, University of Aveiro, Portugal
[b] Physics Department, University of Coimbra, Portugal
[c] Department of Particle Physics, Weizmann Institute of Science, Israel

ARTICLE INFO

Available online 9 November 2010

Keywords:
Micropattern gaseous detectors
Thick-GEM
Gas avalanche multiplication
Gaseous photosensors
RICH

ABSTRACT

A new concept for avalanche ion back-flow (IBF) reduction in cascaded gaseous detectors is presented. The Thick-COBRA is a Thick-GEM (THGEM) with a patterned electrode, aiming at reducing secondary effects by trapping avalanche ions. The patterned electrode faces the electron drift region, trapping ions flowing back from the cascaded multiplier and those produced within the Thick-COBRA. Total IBF values of about 5% were obtained, about six times below that reached with a THGEM in a triple-THGEM configuration, keeping full single-electron detection efficiency. Experimental and simulation studies of IBF and electron collection/transmission efficiencies are presented; the suitability for application of Thick-COBRA in photon detectors for RICH is discussed.

1. Introduction

Ion Back Flow (IBF) poses severe performance limitations in gaseous detectors, critical to many applications such as TPCs, RICH gaseous photosensors, etc. Secondary effects promoted by the back-flowing ions induce electric field distortions, feedback pulses and photocathode ageing due to ion bombardment.

Following the success of the MicroHole and Strip Plate (MHSP) [1], operating in reverse or flipped reverse mode, reaching IBF values of about 0.01% [2–4], a similar concept was developed in a "thick-hole" configuration – the THick-COBRA (THCOBRA) [5]. Similar to the thick gas electron multiplier (THGEM) structure [6,7] it is produced by a printed-circuit board technique, but includes additional electrode patterned on one side – to trap ions flowing from the multiplication stages. The THCOBRA ion-trapping could occur in different ways (Fig. 1): (a) with an additional electrode facing the electron multiplication region allowing the back-flowing ions to be trapped (THCOBRA in reverse mode) and (b) with this electrode facing the opposite of the electron multiplication region (flipped configuration with reverse polarization); in the latter, not only ions flowing back from the multiplication regions can be trapped by the extra electrode, but also those produced in its own multiplication holes. In both modes the operation voltages of all electrodes should be carefully tuned in order to effectively trap ions without sacrificing the full electron detection efficiency.

In this work, simulations and experimental studies of the IBF and of the total electron collection efficiency are presented for the THCOBRA with flipped configuration with reverse polarization.

2. Detector configuration and motivation

The main goal of this study is to significantly reduce the IBF in a photosensor for RICH, based on a triple THGEM cascade with a solid photocathode (CsI) deposited on the top of the first THGEM [8–11], keeping full single-photoelectron detection efficiency. Such CsI-THGEMs could play an important role in future generations of RICH detectors, e.g. presently investigated for CERN COMPASS and ALICE upgrades [12–14]. The CsI-THGEM would have an order of magnitude higher gain compared to present CsI-MWPC photon detectors; it would be operated in more stable way at high particle flux environments—as discussed in Refs. [10,11], resulting in a significant total number of produced ions. A reduced IBF operation is thus highly desired. The THCOBRA, substituting the second THGEM in the cascade, could further reduce ion-induced secondary effects and lower photocathode aging, Fig. 2.

As we will show, this configuration reduces the IBF significantly. Also, placing it as the second element of the cascade, allows keeping the collection efficiency in the first element (THGEM) at maximum level, with a gain above 100 in this element, as recommended in Ref. [9]. In principle, this way an eventual decrease in the electron transmission efficiency of the THCOBRA electrode does not compromise the total detection efficiency of the photosensor.

UV photons interact with the CsI photocathode: emitted photoelectrons are focused into the holes of the first THGEM by

* Corresponding author.
E-mail address: joao.veloso@ua.pt (J.F.C.A. Veloso).

0168-9002/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2010.10.083

the dipole electric field in the holes of the structure. The photoelectrons are preamplified in the first element and avalanche electrons are transmitted along the cascade, undergoing a sequence of multiplications in the successive stages—leading to high gains, ranging from 10^5 to 10^6 [7–13], depending on the voltages applied in each multiplier. The electron avalanches results in an equal number of ions, of which about 30% flow back towards the first THGEM and reach the photocathode. This rather high gain and high level of CsI ion bombardment would lead to CsI ageing with degradation of its quantum efficiency. IBF reduction will lead to a proportional increase in the CsI lifetime.

3. Simulation

To evaluate the capability of the THCOBRA for ion trapping, simulations were carried out for the flipped THCOBRA configuration using Garfield [15] (Fig. 3a corresponds to the THCOBRA unit cell built in Ansys, used for the simulation). 50,000 ions were generated below the structure (Fig. 3b) and the number of those that were transmitted through the structure was counted. In Fig. 3b the drift lines for ions generated below the THCOBRA structure are plotted for three values of the voltage applied between the ion trapping electrode (C) and its neighbour (A), $V_{AC}=0$ V (THGEM mode), 120 and 180 V. For $V_{AC}=0$ V about 50% of the ions were transmitted. However with higher absolute value of the voltage applied to the ion-trapping electrode, a reduction of the IBF was apparent, due to the effective collection of ions at the ion trapping electrode on the top of the structure reaching ten times lower values of IBF below for $V_{AC}=180$ V as compared to the initial value ($V_{AC}=0$ V).

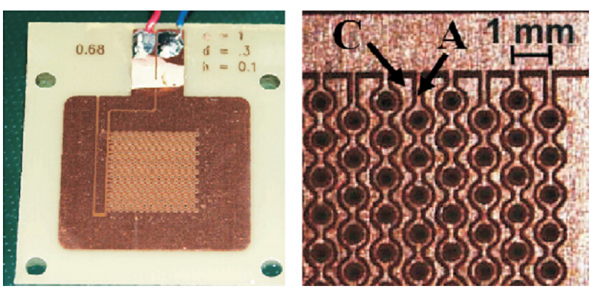

Fig. 1. Global view of a THCOBRA (on the left); close-up view, with indication of cathodes and anodes, for a reverse operating THCOBRA (on the right).

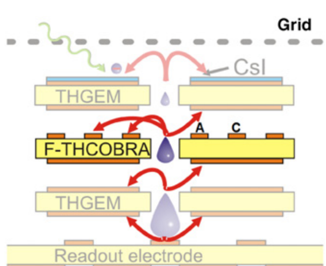

Fig. 2. Detector configuration using a flipped THCOBRA as the second stage.

4. Experimental setup

For the experimental study of the effect of the THCOBRA on the IBF and photoelectron collection efficiency, the proposed configuration (CsI-THGEM/THCOBRA/THGEM) was implemented (Fig. 2). A 500-nm thick CsI photocathode was deposited by vacuum evaporation on the top of the first THGEM. Distances between the THGEM elements and between the grid and the first element were set to 3 mm. The photodetector was operated in pure neon. A VUV lamp was used for the measurements.

The THGEMs had an active area of 28×28 mm^2, a thickness of 0.4 mm, a 0.7-mm hole diameter, a rim of 0.1 mm around holes and a pitch of 1.3 mm. The THCOBRA had an effective area of 15×15 mm^2, a 0.4-mm thickness, a 0.3-mm hole diameter and a rim of 0.1 mm. The ion trapping electrode (C in Fig. 1) had a pitch of 1 mm.

5. Results and discussion

5.1. Ion back flow

For the IBF measurements the currents from various electrodes were recorded. During measurements the Grid and the top of the first THGEM were interconnected ($\Delta V=0$ V) and their currents (I_G+I_{t1}) were measured together. The avalanche charge current, I_a, was measured on the Pad interconnected with the bottom of the third THGEM element. The IBF was calculated from $(I_G+I_{t1})/I_a$. The transfer fields were set to $E=0.3$ kV/cm and the amplification voltages in the various amplification elements were chosen specifically to reach a gain around 10^5. For this gain, the primary photocathode current was negligible and was not considered. The results of this study are shown in Fig. 4. As can be seen, the IBF decreased with the increase in V_{AC}, between the THCOBRA electrodes A and C. With $V_{AC}=340$ V the IBF is one order of magnitude lower than with a THGEM ($V_{AC}=0$ V). It is important to verify that while increasing V_{AC} the full photoelectron detection efficiency is not compromised. To validate that, a study of the collection efficiency was performed.

5.2. Detection efficiency

The detector photoelectron detection efficiency was measured in pulse mode keeping the same gain by setting, in each measurement, the same slope in the Multichannel Analyzer (MCA) pulse-height

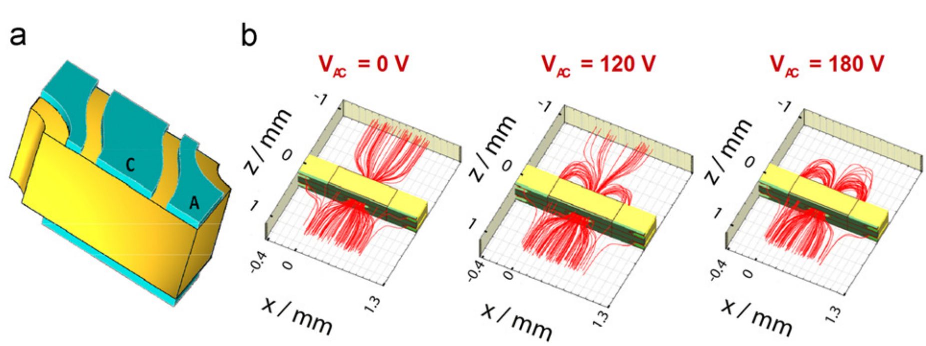

Fig. 3. (a) THCOBRA unit cell built in Ansys. (b) Ion drift lines in a THCOBRA operating in a flipped configuration with reverse polarization, for $V_{AC}=0$ V (left); $V_{AC}=120$ V (middle); and $V_{AC}=180$ V (right).

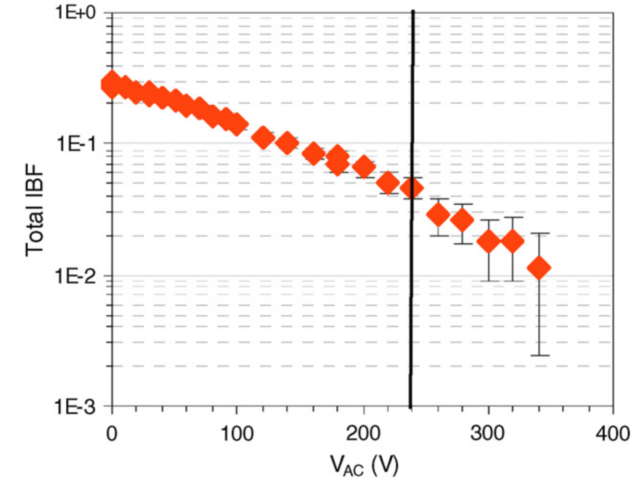

Fig. 4. Plot of Ion Back Flow (IBF) as a function of V_{AC} for the detector of Fig. 2.

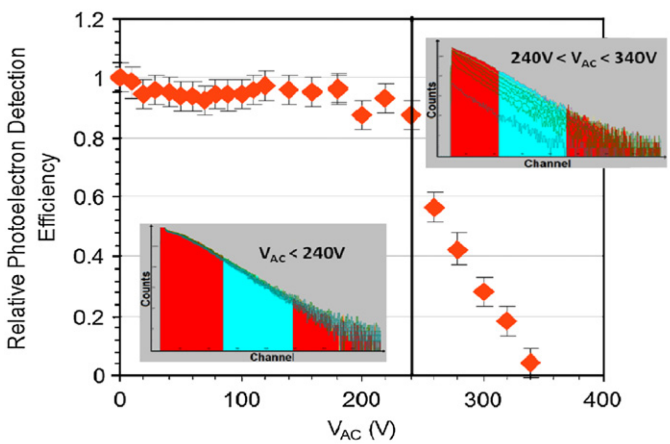

Fig. 5. Relative Photoelectron Detection Efficiency as a function of V_{AC}, in the detector of Fig. 2. Single photon spectra for $V_{AC} < 240$ V (on the bottom, left) and for $240\text{V} < V_{AC} < 340$ V (on the top, right) are also presented.

spectra (for details see Ref. [4]). We have set a region of interest (ROI) in the MCA and measured, under VUV irradiation, the number of counts in the ROI window for each measurement and using a constant acquisition time. By plotting the difference between the number of counts for $V_{AC}=0$ V (THGEM mode) and the number of counts for the different V_{AC} voltages, the detection efficiency could be derived, assuming that it is 100% for $V_{AC}=0$ V [9]. As shown in Fig. 5, for the present operation conditions, full detection efficiency could be achieved for V_{AC} voltages up to about 240 V. Beyond this value, the collection efficiency of the electrons is too strongly attenuated and the overall detection efficiency is affected. From the IBF values presented in Fig. 4, this means that the best IBF value is around 5%, which is about 6–7 times smaller compared to the THGEM (as the 2nd element in the cascade). These results can be regarded as a preliminary one, because the drift fields and voltages across the various multipliers were not varied and optimized. More systematic studies are needed to optimize these values. Of course the values of IBF and detection efficiency should be re-measured for every THGEM and THCOBRA geometry.

6. Conclusions

The present results show good potential for the application of the THCOBRA concept, operating in flipped-reverse mode, in CsI triple-THGEM photosensors. Ion back flow reduction of about 6 times, at full photoelectron detection efficiency, achieved with THCOBRA, could allow increasing the lifetime of gaseous photomultipliers in RICH detectors, operating at high radiation flux, reducing as well ion induced secondary effects.

Acknowledgments

This work was supported by projects CERN/FP/109283/2009 and CERN/FP/109324/2009 under the FEDER and FCT (Lisbon) programs. C.A. Santos and C.D.R. Azevedo were supported by FCT under Doctoral Grants SFRH/BD/60455/2009 and SFRH/BD/35979/2007, respectively. A. Breskin is the W.P. Reuther Professor of Research in The Peaceful Use of Atomic Energy.

References

[1] J.F.C.A. Veloso, et al., Rev. Sci. Instr. 71 (6) (2000) 2371–2376.
[2] J.F.C.A. Veloso, et al., Nucl. Instr. and Meth. A548 (2005) 375–382.
[3] A.V. Lyashenko, et al., Nucl. Instr. and Meth. A 598 (2009) 116–120.
[4] A.V. Lyashenko, et al., JINST 4 (2009) P07005.
[5] F.D. Amaro, et al., JINST 5 (2010) P10002.
[6] R. Chechik, et al., Nucl. Instr. and Meth. A 535 (2004) 303.
[7] A. Breskin, et al., Nucl. Instr. and Meth. A 598 (2009) 107.
[8] M. Alexeev, et al., Nucl. Instr. and Meth. A 617 (2010) 396.
[9] C.D.R. Azevedo, et al., JINST 5 (2010) P01002.
[10] V. Peskov et al.JINST, submitted for publication. arXiv:1008.0151.
[11] A. Breskin et al., Nucl. Instr. and Meth. A., this issue.
[12] M. Alexeev, et al., JINST 5 (2010) P03009.
[13] V. Peskov et al., Nucl. Instr. and Meth. A., this issue.
[14] S. Levorato et al., Nucl. Instr. and Meth. A., this issue.
[15] 〈http://garfield.web.cern.ch/garfield/〉.