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Conference Paper · December 1996

DOI: 10.1109/NSSMIC.1996.590990 · Source: IEEE Xplore

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A New Resistive Plate Chamber with Secondary Electron Emitters and Two Dimensional MIicrostrip Readout

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Abstract

We describe a resistive plate chambers with improved rate characteristics, equipped with high efficiency secondary electron emitters and a two-dimensional microstrip readout.

I. Introduction

Resistive Plate Chambers (RPC's) are widely used in many experiments. They have also been chosen recently for the muon trigger for both LHC detectors (CMS and ATLAS).The RPC's have a lot of advantages, such as simple design, low cost, good time resolution and high gas gain. However the designs used at present have a rather low rate capability (10^4 Hz/cm^2 in avalanche mode), poor spatial resolution (several cm) and they operate with an efficiency close to 100% only in a few selective gas mixtures[1].

Our program of study is to improve the main characteristics of RPC's: rate capabilities and two -dimensional position resolution, and to enlarge the variety of gases which can be used. Towards this end, we have tested an RPC equipped with secondary electron emitters and a microstrip readout. Due to the limitation on the size of the paper only our latest results will be presented here. Previous results of this study were reported elsewhere [2,3].

II RPC design

Our set - up consists of a test chamber with a RPC inside, a gas system, and associated electronics. The design of the RPC is presented schematically in fig.1. It is essentially a parallel-plate chamber, with the anode make of Pestov glass (Schott S-8900; resistivity $2*10^{10}\Omega$ cm) and the cathode made from Al .The gap between electrodes was 5 mm. Pestov glass, 1 mm thick, was covered by Chromium strips 0.2 mm width, 0.5 mm pitch and 0.2 μm thick .Two options were tested : strips outside and inside the discharge gap. A 0.3 mm thick kapton sheet with orthogonal strips of the same pitch (0.5 mm) was attached outside the Pestov glass electrode (back plane strips).The cathode was covered by a layer of secondary electron emitter. In some cases, a disk made of secondary electron emitting materials was mechanically attached to the Al electrode. The Al cathode could also be heated up to 80^0C independently from the whole system. The gas container was made of stainless steel and could be pumped to a vacuum of 10^{-6} Torr and heated to 150^0C. Inside the gas chamber a standard Cs generator was installed. This allow us to manufacture some emitters, for example SbCs or Ga As /Cs inside the chamber (for details see for example ref. [4]). In some cases SbCs and GaAs/Cs emiitters were first manufactured in a standard evaporation system, covered by a CsI protective layer [4], and then transferred to the test chamber. We also developed a technology for manufacturing different porous substrates (TiO_2, Sb and others) which were then covered by Cs or CsI layers. To minimize the charging of

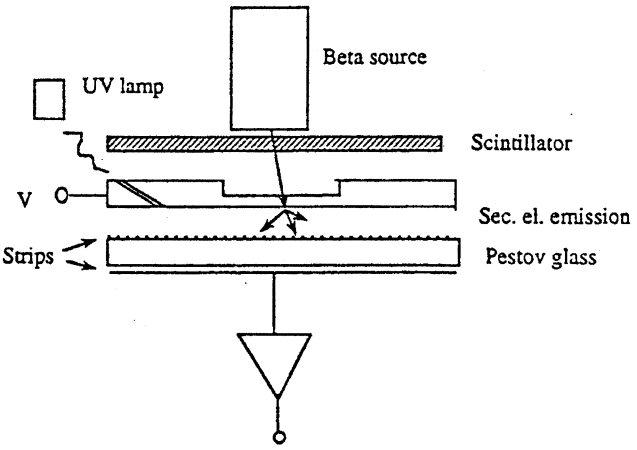

Fig.1 Design of the test chamber

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these layers during RPC operation the Secondary Electron Emitters (SEE) were always covered by a 90% transparent 200 μm pitch mesh.

We found that heating is very important for obtaining a high yield from the SEE's. All SEE's presented here were heated in vacuum to 80°C for at least r 24 hours. The rest of the test chamber was kept at room temperature during this procedure. After heating the electrode with the SEE was cooled to room temperature and the working gas was introduced.

We tested these SEE's in He- and Ar- based mixtures at a total pressure of 1 atm. The quenchers we used were CH_4 and ethane.

Sr^{90} and Ru were used as a source of primary electrons. For high rate tests and for position resolution measurements, we also used an X-ray gun, described in ref.[2].It generated an intense flux of x-ray photons with energy around 6 keV.

III .Results

As in previous works [2,3] for the estimation of the secondary electron yield in the gas, we compare pulse-height distributions for two polarities. Without secondary electron emitters the pulse-height distributions were identical[2]. However with SEE's they were completely different as shown in fig.2.

Our set -up had a small window which allowed us to irradiate the electrodes with UV light from a mercury lamp (see fig1). This was used to produce single electrons from the electrodes by a surface photoeffect. The number of electrons creating by the SEE was then estimated by comparing the mean of the given pulse-height spectrum with the mean of the single electron spectrum.

The highest secondary electron yield was obtained with porous SEE's which also had the highest yield in vacuum [3]. Table 1 shows the mean values of secondary electrons for these emitters measured in He+7% ethane mixture at a total pressure of 1 atm. Unfortunately, the most efficient SEE's were air sensitive and were stable only in a very clean gas system. In practice, porous CsI , cesiated CsI and di(ethylferrocenil) mercury (DEFM) can be used in an RPC. The DEFM was also the most robust among all tested emitters. Note that the yield obtained at 1 atm is sometimes a factor of 1.5 less than measured at low pressure (see ref.[3]). We explain this by a stronger back diffusion of secondary electrons in the He- based mixtures.

In the next series of experiments we tried to enhance the SEE yield by adding TMAE vapors to the gas mixture. Our

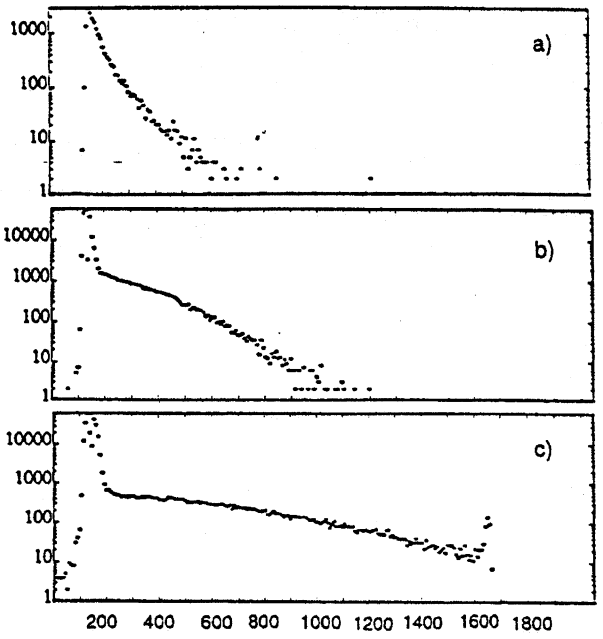

Fig 2 Pulse height distributions obtained in a He+ ethane(7%) mixture at 1 atm with a DEFM SEE at applied voltage of 6.5 kV a) A single electron spectrum, b) and c) correspond to the positive and negative applied voltages on the Al electrode

Table 1

Secondary electron yields (electrons per transiting β particle) of some emitters

SEE/ t°C	CsI	CsI/Cs	DEFM	TiO2/Cs	SbCs
20	2.3	3.2	3.5	1.7	3.8
65 (with TMAE)	2.8	3.9	4.2	2.2	4.5

previous experience with photosensitive materials show that an adsorbed layer of TMAE on the photocathode surface usually increase the quantum efficiency by a factor of 1.5 - 2 [5]. There are many similarities in the electron escape mechanisms from photocathodes and from SEE's, so one can expect an improvements in SEE yield too. Indeed all nonporous SEE's tested had 25-50% more yield when

covered by an adsorbed layer of TMAE. With porous materials, we also observed a temporal improvement of the yield of 25-30%, but then being adsorbed by porous emitters, TMAE reduces their yield almost to zero. The stable results were achieved when the emitters were continuously heated to 60°C while the rest of the chamber was kept at room temperature. Results obtained in this case are presented in Table1. One can clearly see that the yield was improved and reached, in the best cases, a value of 4.5 secondary electrons per transiting particle.

In He-ethane mixtures, with ethane concentration above 15%, the visible difference between the pulse-height spectra measured at two polarities becomes less and less, and above 20% ethane remains only in the tail of distribution. In Ar mixtures at even 10% of ethane the pulse-hight spectra were almost identical for both polarities; a small difference was observed only in the far tail of the distribution.

From a practical point of view, the most important is the contribution of SEE to the detector efficiency and its time resolution. In our experiments, an efficiency of 95% was achieved with Ar+10% ethane or methane. With an efficiency of 80% these RPC's can also operate with He- based mixtures. Since the statistics of secondary electron production is not Poisson, this relatively low efficiency does not really indicate that the number of secondary electrons is low too. The authors of [6], for example, measured an efficiency of electron detection of 70% when the mean number of secondary electrons was 5 (these measurements were done with porous CsI in a vacuum).

It was demonstrated before that in some cases the SEE improves the time resolution of the RPC by a factor of 2-3 [7]

Apart from the efficiency and time resolution the other important characteristic of the RPC is rate capability . Fig.3 shows the efficiency of the RPC (with respect to the trigger scintillator -see fig.1) vs rate. Curve 3 corresponds to the case where the strips on the Pestov glass electrode were outside the discharge gap. One can see that chamber efficiency drops at a rate > $3*10^4$ Hz/cm^2. However, in the case of strips inside the discharge gap (curve 4), we did not observe any drop in efficiency up to rate 10^5 Hz/cm^2. Unfortunately this was the maximum rate which we could obtain from our beta sources. In order to estimate the chamber characteristics at higher rates we used an X-ray gun. In this case we measured not an efficiency, but the spectrum and the amplitude of pules produce by X-ray photons inside the gas volume of the RPC. A drop of t pulse amplitudes was observed only at a rate > $3*10^5$ Hz/cm^2 (curve 5). We assume that the efficiency to minimum ionizing particles will remain unchanged up to this

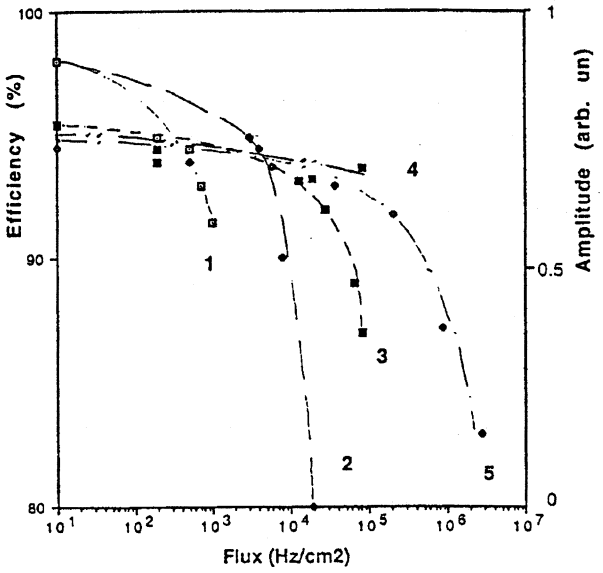

Fig. 3 Rate characteristics of RPC''s made from melamine electrodes (curve 1 and 2) and Al - Pestov glass electrodes (3-5) operating in avalanche mode.

rate This considerable improvement in the rate characteristics was possible because the charge injected to the anode can be easily collected on the metallic strips.

We should note that even if the pule amplitude does not drop, the probability to have occasional sparking at a given gain increases proportional to the rate . So for the safe operation of the RPC at high rates we reduced the gas gain (for more details see ref [8]).

The other note we should make is that there could be a difference in rate capabilities of the RPC when measured with a focused and defocused beam. In the case of the collimated beam the charge accumulated on the electrode surfaces may dissipate, not only due to their bulk resistivity, but also due to the leakage along the surface (surface resistivity). For illustration, fig.3 also presents the rate characteristics of the RPC (from ref. [9]), made from melamine sheets. Curve 1 corresponds to a defocused and curve 2 to a focused beam. One can see a considerable difference in rate capabilities. However, we believe that in the case of strips inside the discharge gap, the results for collimated and uncollimated beams will be almost the same, if the size of the beam spot is larger than the pitch. In this case the surface charge should be efficiently collected by the strips independently of the beam diameter.

Since the best rate characteristics were obtained when the

strips on Pestov glass were inside the discharge gap, the back plane with orthogonal strips cannot be placed too close to the inner part of the anode(it should be at least 1 mm apart) . This may strongly reduced the pick- up signal on the back plane strips. As we mentioned before, to avoid sparking at high rate one should reduce the gas gain. This additionally can make the readout of the second coordinate rather difficult. In order to check that such two- dimensional readout will work even at low gains , we measured not only the total amplitudes of the signals from both groups of strips, but also the profile of the current distribution. Typical results oft these measurements are presented in fig.4. One can see that the amplitudes of the

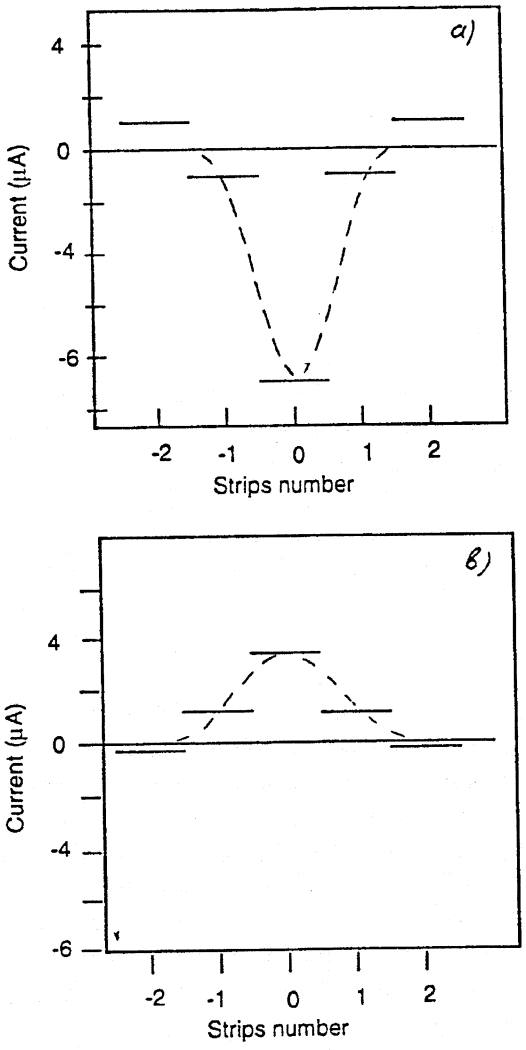

Fig. 4 Profile of induced current on inner strips (a) and back plane strips (b).

induced signals on the back plane are only 2 times weaker than on the anode strips. With our electronics, this ratio was good enough for reliable readout of both coordinate even at rate close to 10^4 Hz/cm^2. Note that the FWHM of both charge profiles is around 1 mm. Similar profile distributions were measured before with RPC's having 0.38 mm pitch. After measuring the centroids of the distribution, a space resolution better than 0.1 mm was achieved [2,3]

IV. Conclusion

We demonstrated that our new design of RPC's equipped with secondary electron emitters and microstrip readouts have excellent rate characteristics (up to 10^5 Hz/cm^2) and two-dimensional position resolutions better than 1 mm. We found that rather high secondary electron yields can be achieved with a specially prepared and treated porous SEE. Since, in a parallel-plate geometry, the gas gain depends exponentionally on the distance of the primary electrons from the anode, the electrons emitted from the SEE obtain a maximum gain. For this reason they have a large contribution to the RPC efficiency and time resolution. As a consequence one can use a wider variety of gases including light non-flammable mixtures

We believe that such an RPC can be useful for many applications, for example for detecting minimum ionizing particles

V. Acknowledgement.

Some of the tests described here were done at the LAA Lab.at CERN. We thank C. Williams and A. Zichichi for the discussions and support of this work.We thank also E. Silin for the help and assisting in preparing secondary electron emitters and B. Gobbi together with whom the first prototype of RPC was designed.

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