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The state of art of μ-RWELL technology

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ABSTRACT: The μ-RWELL is a single-amplification stage resistive Micro-Pattern Gaseous Detector (MPGD). The detector amplification element is realized with a single copper-clad polyimide foil micro-patterned with a blind hole (well) matrix and embedded in the readout PCB through a thin Diamond-Like-Carbon (DLC) sputtered resistive film. The introduction of the resistive layer, suppressing the transition from streamer to spark, allows to achieve large gains ($\geq 10^4$) with a single amplification stage, while partially reducing the capability to stand high particle fluxes. The simplest resistive layout, designed for low-rate applications, is based on a single-resistive layer with edge grounding. At high particle fluxes this layout suffers of a non-uniform response. In order to get rid of such a limitation different current evacuation geometries have been designed. In this work we report the study of the performance of several high rate resistive layouts tested at the CERN H8-SpS and PSI πM1 beam test facilities and with a high intensity 5.9 keV X-ray tube. These layouts fulfill the requirements for the detectors upgrades at the HL-LHC and for the experiments at the next generation colliders FCC-ee/hh and CepC.The possibility to realise the detector on flexible elements opens the way to use the technology for non-planar geometry such as the instrumentation of the Inner Tracker at future Charm-Tau factories. In addition, it must be stressed that the μ-RWELL device can be manufactured with full sequential-build-up technology, thus allowing a straightforward technology transfer of the manufacturing process to the industry.

KEYWORDS: Micropattern gaseous detectors (MSGC, GEM, THGEM, RETHGEM, MHSP, MICROPIC, MICROMEGAS, InGrid, etc); Gaseous detectors; Muon spectrometers; Particle tracking detectors (Gaseous detectors)

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Contents

1 Introduction

The μ-RWELL, figure 1, is a single-amplification stage resistive MPGD that combines in a unique approach the solutions and improvements achieved in the last years in the MPGD field. The R&D on μ-RWELL aims to improve the stability under heavy irradiation while simplifying the construction procedures in view of an easy technology transfer to industry: a milestone for large scale applications in fundamental research at the future colliders and even beyond the HEP. The detector layout and the performances are described in detail in [1, 2] and [3]. The sketch of the principle operation is shown in figure 2.

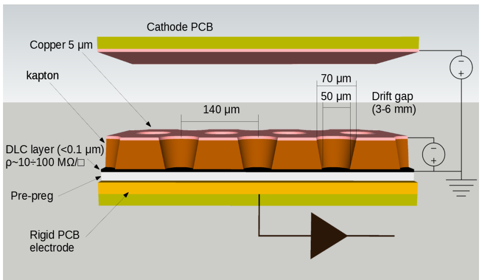

Figure 1. Layout of the μ-RWELL.

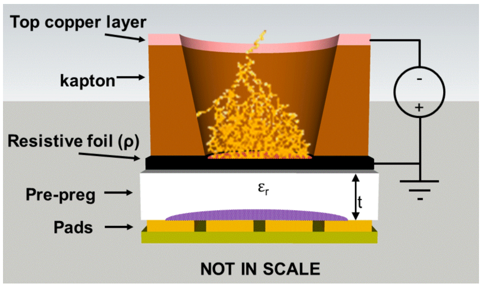

Figure 2. Principle of operation of the μ-RWELL.

A drawback correlated to the introduction of the resistive layer (Diamond-Like-Carbon DLC), is the reduced capability to stand high particle fluxes.

In this paper we discuss new resistive layouts for high rate purposes and their performance in terms of efficiency and rate capability as measured in beam tests at CERN H8-SpS and PSI πM1 and with an X-ray tube respectively and operated with $Ar/CO_2/CF_4 = 45/15/40$.

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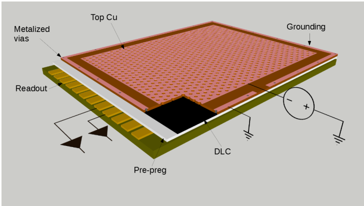

Figure 3. Sketch of the Single-Resistive layout.

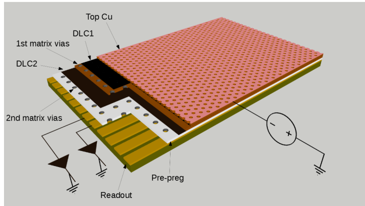

Figure 4. Sketch of the Double-Resistive layout.

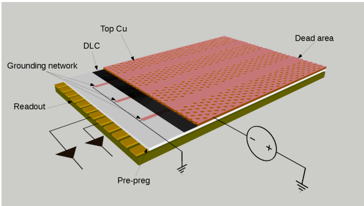

Figure 5. Sketch of the Silver-Grid layout.

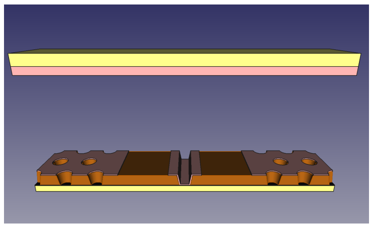

Figure 6. Sketch of the PEP layout.

2 The high rate layouts

The simplest scheme for the evacuation of the current in a μ-RWELL is based on a single resistive layer with a grounding line all around the active area, figure 3, (Single-Resisitive layout — SRL). For large area devices the path of the current to ground could therefore be large and strongly dependent on the incidence point of the particle. In order to cope with this effect the solution is to reduce as much as possible the average path towards the ground connection, introducing a high density grounding network on the resistive stage. Three different high rate (HR) layouts with dense grounding scheme have been implemented: the Double-Resistive Layer (DRL), the Silver-Grid (SG) and the Pattern-Etching-Plating (PEP).

2.1 The Double-Resistive layout

The DRL layout is sketched in figure 4. The first DLC film, sputtered on the back-plane of the amplification stage, is connected to a second DLC layer by means of a matrix of metalized vias (v1). A further matrix of vias (v2) connects the second DLC film to the underlying readout electrodes, providing the final grounding of the whole resistive stage. The vias density is typically $\leq 1\,\text{cm}^{-2}$.

2.2 The Silver-Grid layout

The Silver-Grid (SG) layout, is sketched in figure 5. The conductive grid deposited on the DLC layer acts as a high density 2-D current evacuation system. The presence of a conductive grid on the DLC can induce discharges over its surface. This effect, depending on the resistivity, requires the introduction of a small dead zone in the amplification stage above the grid lines (see figure 5).

The SG layouts exhibit a geometrical acceptance lower than DRL due to the presence of dead zone. Thanks to the DLC+Cu technology, allowing the photo-etching of very thin grid lines (≃100 μm width), for the SG2++ it has been possible to reduce the dead zone down to 5% of the active area.

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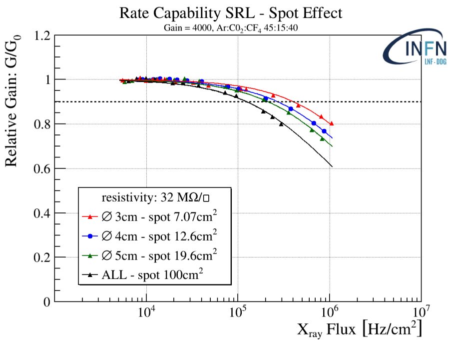

Figure 7. Normalised gain for the SRL.

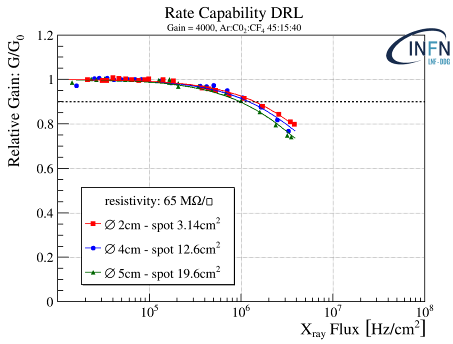

Figure 8. Normalised gain for the DRL.

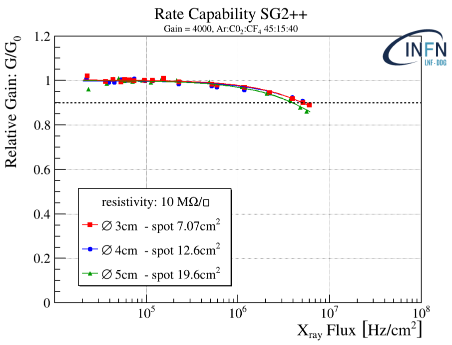

Figure 9. Normalised gain for the SG2++.

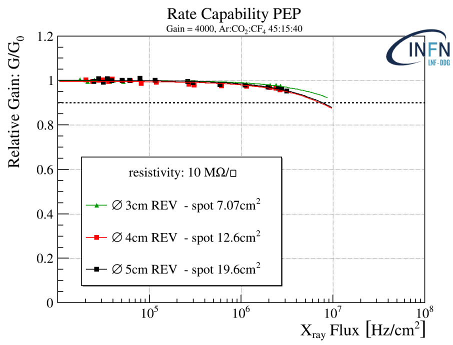

Figure 10. Normalised gain for the PEP.

2.3 The Pattern-Etching-Plating layout

The PEP layout (figure 6) is the new single DLC layer high-rate scheme recently introduced as a synthesis of the above mentioned high-rate versions of the µ-RWELL. The idea is to realise a layout similar to the SG: the ground connection is performed creating a conductive grooves by etching from the top Cu layer of the base material through the Kapton foil down to the DLC. For the first PEP version, the distance from the blind closed hole to PEP lines and the latter has been set to 750 µm resulting in a dead zone of ~ 20%. A new optimized PEP layout will be designed to reduce the dead zones at a level of less 2–3%.

3 Performance of the HR-layouts

3.1 Rate capability measurement

The gain drop effect due to the particle flux on the HR layouts has been investigated with a high intensity 5.9 keV X-ray tube at a gas gain of 4000. The normalised gas gain curves of the SRL and HR layouts as a function the X-ray flux for several spots are shown in figures 7, 8, 9 and 10 respectively. Since the irradiated area is larger than the basic current evacuation cell defined by the density grounding network (see table 1), the gain drop of the HR layouts as expected is almost independent on the spot size standing an X-ray flux larger than 1 MHz/cm^2.

Table 1. Geometrical parameters of the HR-layouts compared with the low rate baseline option (SRL).

Layout	ground-pitch (mm)	dead-zone (mm)	geometric acc. (%)
SG1	6	2	66
SG2	12	1.2	90
SG2++	12	0.6	95
DRL	6	0	100
PEP	9	1.5	83
SRL	100	0	100

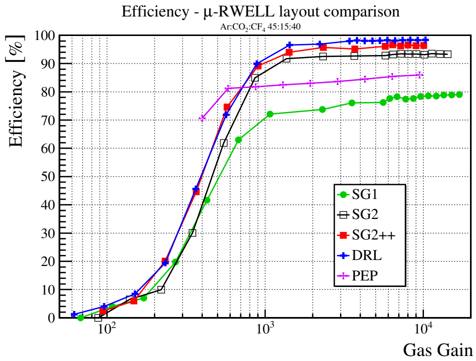

Figure 11. Efficiency as a function of the gas gain.

3.2 Efficiency measurement

In figure 11 the efficiency of the HR-layouts is reported as a function of the detectors gain, where the PEP has been irradiated with a pion beam of momentum of 150 Gev/c at SpS and the other HR layouts with a low pion momentum of 350 MeV/c at PSI (minimum ionizing particle).[1] The efficiency has been evaluated considering a fiducial area of 3×3 pads around the expected hit. At a gain of 5000 the DRL shows an efficiency of 98%, while the optimized SG layout (SG2++) tends to an almost full efficiency of about 97%. As expected, the introduction of larger dead zone in the active area for SG1, SG2 and PEP layouts is reflected in a detection efficiency of 78%, 95% 85% respectively, which is larger than their geometrical acceptance.

4 Conclusions

In this paper we have discussed different resistive layouts of μ-RWELL for high rate applications. The rate capability and the perfomance of the prototypes have been validated with a 5.9 keV X-ray gun and pion/muon beams at CERN and PSI. Among the proposed layouts different solutions have been found that satisfy the very stringent requirements for the detectors in view of the phase-2 upgrades of muon apparatus at the HL-LHC as well as in the apparatus at the future accelerators FCC-ee/hh and CepC. The use of flexible elements open the way towards non-planar geometry μ-RWELL as Inner trackers for Tau-Charm Factories of next generation. A rate capability greater than 1 MHz/cm^2 with a detection efficiency of the order of 97÷98% are achievable with the proposed layouts. In addition, it must be stressed that the PEP layout can be manufactured with full sequential-build-up technology, thus allowing a straightforward technology transfer of the manufacturing process to the industry.

[1] Lower is the primary ionization in the conversion gap, higher is the gain to reach efficiency knee.

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