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High rate performance of Small-pad Resistive Micromegas. Comparison of different resistive protection concepts

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Motivated mainly by future detector upgrades at HL-LHC and at future colliders, most of the HEP R&D collaborations have been focusing on the design of new prototypes of particle detectors for operation under very high particle flow. In the field of Micro-Pattern-Gaseous-Detectors, the Small-pad resistive MICROMEGAS prototypes were designed to overcome the actual limitations of more standard strip resistive MICROMEGAS. In these new prototypes, small pads with a few mm^2 area replace the readout strips to reduce the occupancy, and the spark protection resistive layer has been redesigned and optimized with different techniques to permit a safe behaviour of the detector, without efficiency loss, at rates of the order of MHz/cm^2 over large surfaces. The firstly-developed design exploits a pad-patterned (PAD-P) embedded resistor layout by screen-printing while the most recent technique involves uniform sputtered DLC (Diamond Like Carbon structure) layers, where the current evacuates through vias to ground. Comparative studies have been conducted on the performances of the prototypes with different resistive layouts or different values of DLC resistivity and vias pitch. The preliminary results of the tests done with high-rate X-rays and with high energy charged particle beams will be presented.

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1. Introduction

In MICROMEGAS detectors, the introduction of additional resistive strips (other than the readout strips) has already proved to be a good quencher for possible discharges [1]. In fact, a spark causes a voltage drop on the resistive elements that can locally decrease the effective amplification electric field as much as extinguishing the spark itself without significant gain variation up to O(100 kHz/cm^2) rates. New resistive protection concepts are required to be compatible with the small pad segmentation of the readout plane.

2. Detector layouts

A pad-patterned (PAD-P) and two Diamond Like Carbon (DLC) small-pad Micromegas prototypes have been built sharing common features in terms of the depths of drift and amplification gaps, mesh, pillars and readout electrodes. Their 48x48 mm^2 active areas are covered by matrices of 48x16 copper anode pads with a 1 mm pitch in the precision coordinate and a 3 mm pitch in the other one. As shown in the upper part of Fig. 1-left, two layers of screen-printed resistive pads cover the readout anode pads in the PAD-P prototype. Each independent column of pads is interconnected through vias to evacuate the current towards the ground. The vias are shifted, in the two planes, such as the current path is almost the same, regardless the impinged point where charges of the avalanche hit the pad (more details in Ref. [2]). In the second scheme, two continuous sputtered DLC foils substitute the resistive pads. This layout, with continuous resistive layer, has the advantage to eliminate any exposure of dielectric to the amplification region, with the exception of pillar, thus mitigating effects of charging-up. In the DLC prototypes, a different pattern of vias was implemented with respect to PAD-P. The vias pitch is 6 mm in one side and 12 mm in the other of each DLC prototype (see Fig. 1-right). The first DLC prototype (DLC50) uses ∼50 MΩ/sq [3] resistivity foils, while the second (DLC20) uses ∼20 MΩ/sq foils.

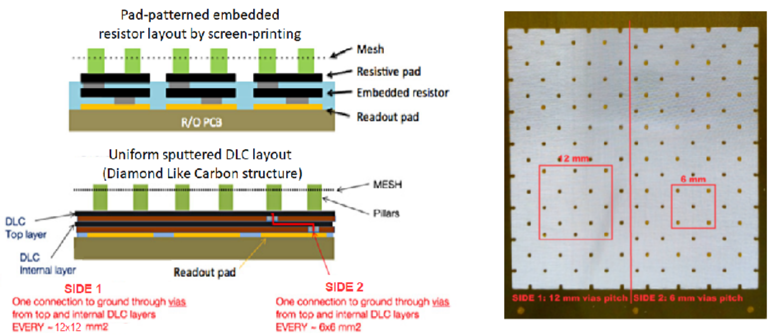

Figure 1: (left) Sketches of the two spark protection resistive schemes: PAD-P (up) and DLC prototypes (down) and top view of an un-assembled DLC prototype (right).

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3. Results of X-rays and beam tests

The active areas of detectors were exposed to X-rays coming from a 8 keV photopeak Cu target gun to study the current response (rate capability) at high rate. Measurements were performed varying the portion of exposed area, the distance from the source and the intensity of the X-rays current. The spatial resolution and tracking efficiency were measured exposing the prototypes to CERN SPS-H4 muon and pion beam at different amplification fields. During all tests, the gas mixture and the intensity of drift field were fixed at: 93:7=Ar:CO_2 and 0.600 kV/cm, respectively. As reported in Fig. 2-left, the trends of current per unit area as a function of the rate show that the PAD-P and DLC20 with 6 mm vias pitch have a comparable behaviour up to $\sim$ 90 MHz/cm^2 if they are irradiated in a 1 cm diameter circle. From test beam data, cluster properties, efficiency and spatial resolution measurements resulted comparable for the two sides of a DLC prototype with different vias pitches. The DLC prototypes show a better spatial resolution than the PAD-P layout, as shown in Fig. 2-right. The trends in Fig. 3 suggest that a shorter vias pitch and lower resistivity move a significant voltage drop toward higher rates. On the other hand, the DLC detectors result more sensitive to the discharges. At fixed rate/cm^2, the amplification voltage drop is more severe when the exposure area is larger in both DLC prototypes (Ref. [3] and [4]). This behaviour is not observed in the PAD-P prototype for the investigated exposure areas.

4. Conclusions

Both resistive protection concepts are suitable to operate at rate of order of the MHz/cm^2. One layout is preferable to the another according to the specific application. The DLC prototypes show better resolutions when compared to PAD-P, while, at rate higher than 10 MHz/cm^2, PAD-P has a more linear current trend than DLC prototypes, in which effects of the amplification voltage drop are sizable and dependent on the exposed area. The comparisons between the current per unit area as measured in the sides with different vias pitches and different resistivities show qualitatively that a shorter vias pitch and lower resistivity move a significant voltage drop toward higher rates in DLC prototypes.

For the DLC resistive protection concept, new prototypes are ready to be tested. They were made by the PCB standard Sequential Build-Up technique (SBU), taking advantage of the now available copper-clad DLC foils to improve the precision of grounding vias and their overlap with pillars to suppress the possible discharges triggered by uncovered grounding vias.

5. Acknowledgments

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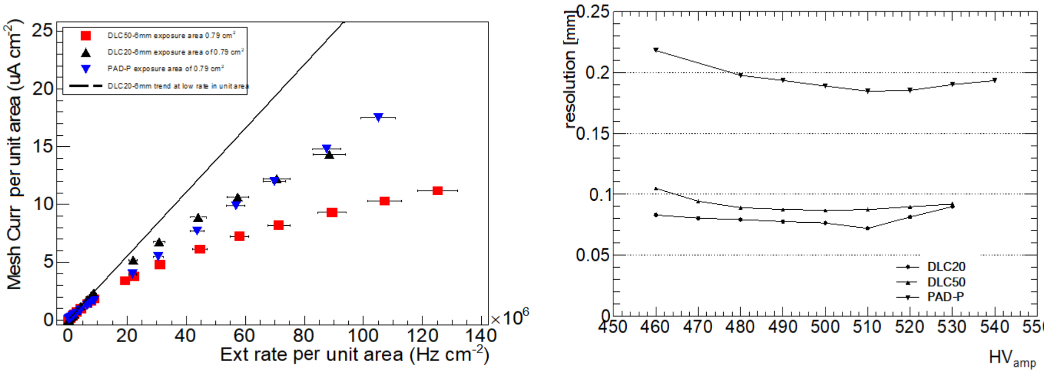

Figure 2: Mesh current per unit area as a function of the extrapolated rate per unit area of PAD-P (scheme 1) and DLC20, DLC50 (scheme 2) with 0.79 cm^2 exposure area and ∼8000 gain factor at low rate (left) and spatial resolution as a function of the amplification voltage for the three detectors (right).

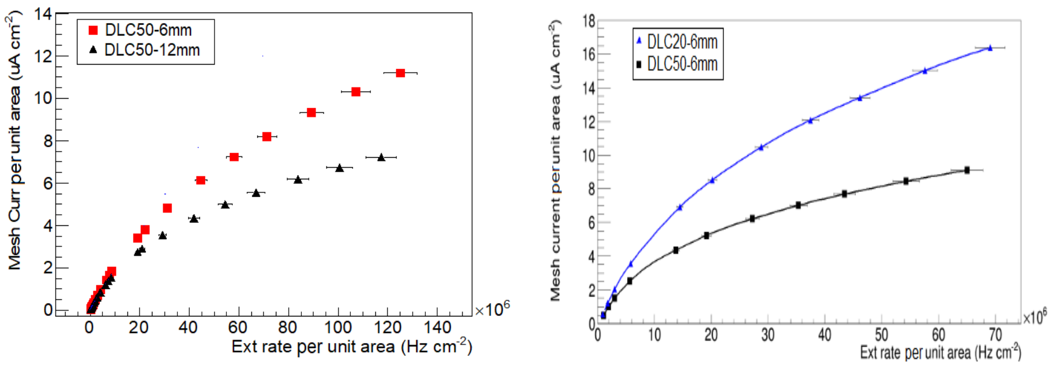

Figure 3: Mesh current per unit area as a function of the extrapolated rate per unit area of DLC50-6 mm and DLC50-12 mm vias pitch (left), DLC20-6 mm and DLC50 (right) with 0.79 cm^2 exposure area and ∼8000 gain factor at low rate.

References

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