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The surface Resistive Plate Counter (sRPC): an RPC based on MPGD technology

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Abstract: The Surface Resistive Plate Counter (sRPC) is a novel RPC based on surface resistivity electrodes, a completely different concept with respect to traditional RPCs that use electrodes characterised by volume resistivity. The electrodes of the sRPC exploit the well-established industrial Diamond-Like-Carbon (DLC) sputtering technology on thin (50 µm) polyimide foils, already introduced in the manufacturing of the resistive MPGDs such as µ-RWELL and MicroMegas, that allows to realise large area (up to $2{\times}0.5\,\mathrm{m}^2$) electrodes with a surface resistivity spanning over several orders of magnitude ($0.01\div10\,\mathrm{G}\Omega/\square$). Two detector layout has been developed: the baseline layout with the DLC connected to the HV by a single dot connection outside the active area and the high rate layout with a screen printing a conductive grid onto the DLC film, which exploit the concept of the high density current evacuation scheme first introduced for the µ-RWELL. Besides the use in HEP experiments as timing detector this new technology could be exploited as thermal neutron device for homeland security applications (e.g. Radioactive Portal Monitors for ports and airports), replacing one or both DLC electrodes of the sRPC with plates coated with ∼3 µm thick $^{10}B_4C$ layer, thus obtaining neutron converters inside the active volume of the detector. Results obtained by irradiating the detectors at the calibrated ^{241}Am-B ENEA-Frascati HOTNES facility will be discussed.

Keywords: Gaseous detectors; Micropattern gaseous detectors (MSGC, GEM, THGEM, RETHGEM, MHSP, MICROPIC, MICROMEGAS, InGrid, etc); Resistive-plate chambers; Timing detectors

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1 Introduction

Resistive Plate Counters (RPCs) are based on the use of bulk resistivity electrode, typically made of bakelite [1], semiconductive [2] or float [3] glass, with a volume resistivity in the order of $\rho \sim 10^{10-12}$ Ω·cm. The avalanches produced by the passage of a particle are quenched by the voltage drop on the resistive electrode but the presence of the resistive stage affects the rate capability of the detector: the voltage recovery time around the dead zone is proportional to the volume resistivity and the electrodes thickness. Lowering the resistivity ρ and the thickness d of the electrodes is the standard recipe to achieve a sizeable increase of the detector rate capability, allowing an RPC rate capability up to 7 kHz/cm^2 [4]. The novel approach[1] reported in this paper is to realise an RPC based on easily modulated surface resistivity electrodes manufactured with industrial DLC sputtering techniques on flexible or semi-rigid supports.

2 Detector layout and performance

The sRPC electrodes consist of a 2 mm thick float glass[2] sheet on which an Apical® foil sputtered with DLC (1÷24 GΩ/□) has been glued, figure 1. The 2 mm gas gap between the electrodes is ensured by E-shaped spacers made of Delrin®, inserted without gluing at the edges of the glass supports. The electrodes sandwich is inserted in a fibreglass box that acts as gas ($C_2H_2F_4$:iC_4H_{10}:SF_6 93.5:5:1.5) volume container. The HV is applied to the DLC electrodes through DLC coated Kapton® tails reported on the external side of the glass sheets. External strip-patterned boards are used to pick-up the induced signals. The FEE is based on the six-channels VTX pre-amplifier (analog output, 10 mV/fC sensitivity). As shown in figure 2, the efficiency plateau of the first sRPC prototypes were not large (200÷300 V): instability effects correlated with a constant current drawn have been observed, with a consequent detector breakdown, around 9.5 kV. Considering that the DLC has a working function of few eV [7] and exhibits a non-negligible sensitivity to UV-photons [8], secondary electron emission due to photon-feedback and/or field emission [9] may occur at the cathode surface. The electrons, multiplied, trigger a series of avalanches leading to continuous

[1] The idea of "*Timing detectors based on surface resistivity electrodes*" was patented in 2019 [6].
[2] The glass is not put at high voltage, is used only for it's excellent smoothness and planarity.

current, inducing a constant voltage drop such that no detectable signals are produced. In order to suppress secondary electrons extraction at the cathode surface a thin barrier on the cathode electrode has been created with Licron® Crystal spray from Techspray, a static dissipative coating ($\rho \sim 10^{6\div9}\,\Omega\cdot\mathrm{cm}$), significantly improving the stability of the detector: an efficiency plateau of the order of 1 kV has been measured, figure 2, with a time resolution of about 1 ns, figure 3. Exploiting

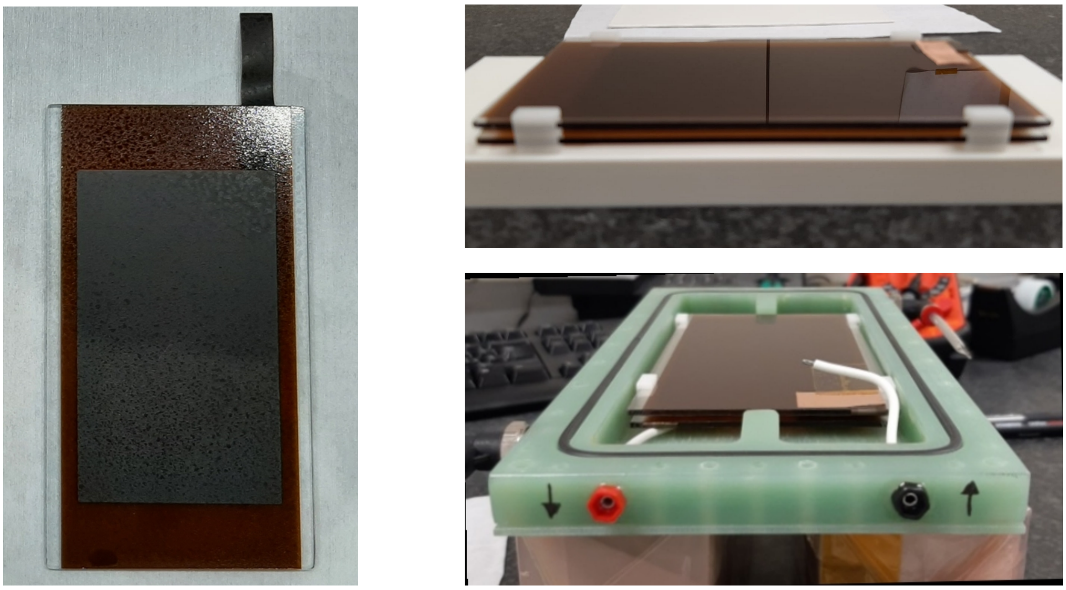

Figure 1. (Left) Glass sheets (78×140 mm^2) with the DLC coated (64×120 mm^2) Apical® foil electrode (Right) The coupling of the electrodes with the E-shaped spacer and the gas box with the HV connections.

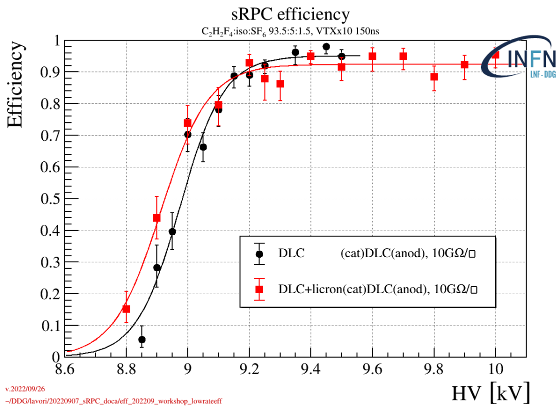

Figure 2. Efficiency curves for sRPC with different cathodes: (black) bare DLC and (red) DLC+Licron®.

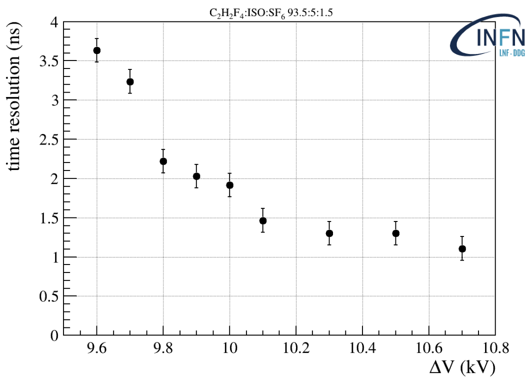

Figure 3. sRPC time resolution with cosmic rays.

the experience gained on the R&D on μ-RWELL [5], a first version of a high rate (HR) electrode layout has been developed: a conductive grid with a pitch of ∼1 cm has been screen printed onto the DLC film (∼7 GΩ/□), figure 4. The presence of the grid lead again to the onset of instabilities, reducing the efficiency plateau to ∼250 V but nevertheless a rate capability of ∼1 kHz/cm^2 has been

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measured with a 5.9 keV X-ray gun irradiating the prototype with spots with different size, always larger than the pitch of the current evacuation grid of the electrodes, figure 5.

Figure 4. DLC-HR electrodes.

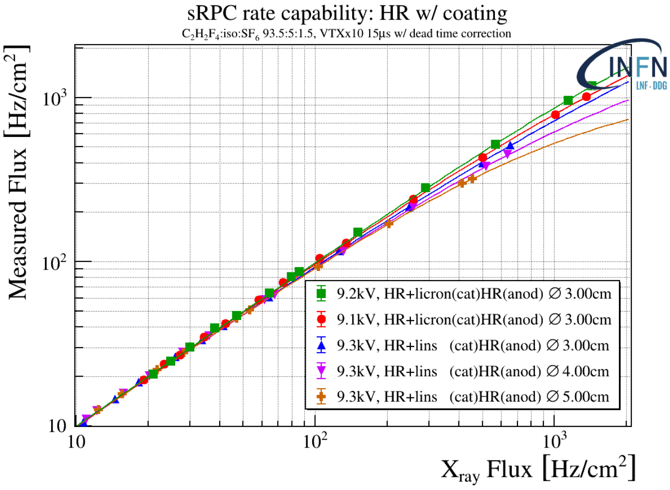

Figure 5. sRPC counts vs X-ray flux for different spot size.

3 sRPC for thermal neutron detection

Besides the use in HEP experiments the sRPC could be exploited as thermal neutron detector for homeland security applications (e.g. Radioactive Portal Monitors for ports and airports). As reported in a previous study[3] performed with the μ-RWELL [11], a 2÷3 μm thick $^{10}B_4C$ layer allows for the achievement of a global (conversion + detection) efficiency of the order of 4 %. For this purpose one or both DLC electrodes of the sRPC were replaced with plates coated with ∼3 μm thick $^{10}B_4C$ layer. This allowed the neutron conversion inside the active volume of the detector, with the production of ionising particles. Three different $^{10}B_4C$ coated electrode layouts have been tested: a) $^{10}B_4C$ cathode - DLC anode, b) DLC cathode - $^{10}B_4C$ anode, c) $^{10}B_4C$ cathode - $^{10}B_4C$ anode (figure 6). The detectors have been equipped with a custom FEE based on the CREMAT CR-110 chip and characterised at the ENEA-Frascati HOTNES facility [10], where a calibrated ^{241}Am-B source ensures an almost uniform thermal neutron fluence (758 Hz/cm^2). Taking into account the ^{7}Li/α angular emission and mean path, and the signal formation inside a parallel plate detector, the three sRPC layouts are expected to behave in different way. The results show that it is possible to obtain an efficiency for 25 meV neutron[4] of about 6 %, figure 7.

4 Conclusions

By exploiting the DLC sputtering technology developed for resistive MPGDs we realised surface resistive electrodes for a new generation high-rate RPCs. The baseline version of the detector, thanks

[3]Thanks to the uRANIA-V collaboration (INFN-Ferrara: G. Cibinetto, I. Balossino, R. Farinelli, I. Garzia, G. Mezzadri, A. Cotta Ramusino, INFN-Torino: L. Lavezzi) and to L. Lanza (University of Rome "Tor Vergata").

[4]The measurement has been done with a thermal spectrum. The only process that depends on the neutron energy is the capture cross section so it's possible to infer the detector efficiency for 25 meV neutrons with a GEANT4 simulation.

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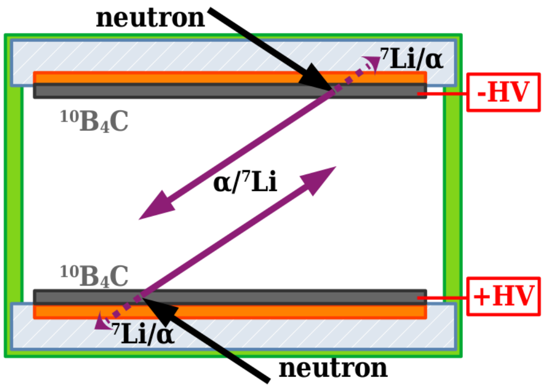

Figure 6. Sketch of the neutron conversion.

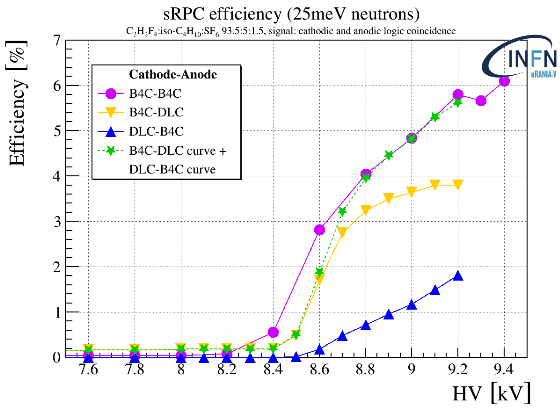

Figure 7. Efficiency for 25 meV neutrons.

to a suitable passivation of the cathode, exhibits good stability (ΔV∼1 kV) and good performance in terms of efficiency (~95 %) and time resolution (∼1 ns). The high-rate version based on a dens current evacuation schemes, despite some instability, shows a rate capability of ∼1 kHz/cm^2 with 5.9 keV X-ray. By lowering the DLC resistivity down to ∼100 MΩ/□ and optimising the current evacuation scheme a rate capability of tens of kHz/cm^2 seems to be achievable. The DLC sputtering is a scalable technology allowing to realise large area electrodes at low cost, making the sRPC suitable for applications in large HEP experiments for future high luminosity colliders. Besides HEP, very promising results with boron coated sRPC have been achieved, opening the way for a cost effective, scalable thermal neutron detector technology for homeland security application.

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