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SF_6 GAS MIXTURES FOR AVALANCHE OPERATION OF A THIN GAP RPC

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ABSTRACT

In this work we describe the study of one thin gap (300 µm) parallel plate resistive chamber irradiated by a ^{60}Co source. The applied voltage influence on the detector gain was verified by the spectra charge analyses, what made possible to establish the chamber operation limits in avalanche mode and the threshold of streamers production in different gases mixtures of argon, isobutane ($CH(CH_3)_3$) and sulphur hexafluoride (SF_6). The chamber charge gain and response stability changes due to the presence of small concentrations of SF_6 allowed us to observe the excellent quenching properties of this gas, reducing the released charge in the RPC and extending the applied voltage range in the avalanche regime.

1. INTRODUCTION

During the last years, resistive-plate chambers (RPC) have been the object of extensive studies since they are expected to be widely used in high-energy physics (HEP) experiments, as TOF systems [1-3] and trigger detectors [4-6], due to their advantages such as simple design, low cost, good time operation and high gas gain. These gaseous detectors are similar to the parallel-plate avalanche chambers with the exception that, at least one of the electrodes is made from high-resistivity ($\geq 10^{10}$ Ωcm) materials. High voltage applied to the electrodes produces a high electric field across the gas gap. Electrons liberated in the gas by through-going ionizing radiation generate avalanches, thus producing signals on the electrodes. If the electric field is even stronger, the avalanches can initiate a spark breakdown.

In this work we describe the study of one thin gap (300 µm) parallel plate resistive chamber irradiated by γ-rays. The applied voltage influence on the detector gain was verified by the spectra charge analyses, what made possible to establish the chamber operation limits in avalanche mode and the threshold of streamers production in different gases mixtures of argon, isobutane ($CH(CH_3)_3$) and sulphur hexafluoride (SF_6).

2. EXPERIMENTAL SETUP

The detector cell used in this work, a single gap chamber, is constituted by a resistive electrode (cathode) with 3 mm thickness, 9 cm^2 of area, made from a commercially available darkened glass (2.10^{12} Ω.cm resistivity) and by a metallic anode (aluminium), 2 mm thickness. The different elements were assembled in a plastic box that provides electrical insulation and mechanical rigidity (Fig. 1). This box has holes for the wires that connect each electrode, as well as for the gas circulation and for the insertion of the spacers that define the gas gap. These spacers are tiny pieces of optical glass ϕ = 300 μm, that are inserted along the four corners of the chamber. The cathode was kept at ground potential and the anode was connected (throw a 6.8 MΩ charge resistance) to a positive high voltage and feed a pre-amplifier (Canberra 2006).

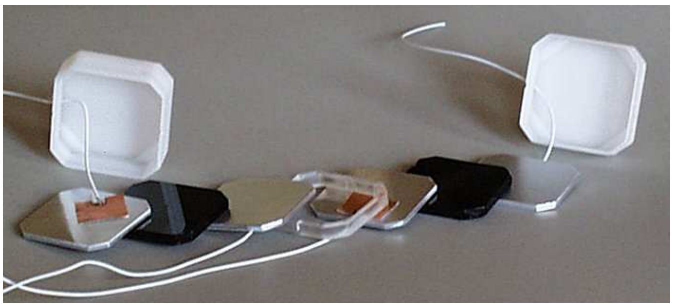


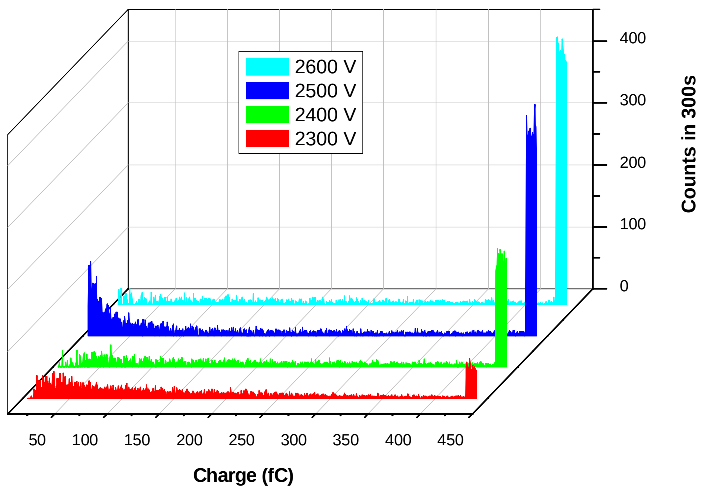
Figure 1. Elements that constitute the thin gap RPC.

The RPC was housed in a stainless steel chamber with a mica window (3 mg/cm^2) for the entrance of γ-rays from a ^{60}Co source. The pulses from the preamplifier were shaped and amplified by an ORTEC-572 amplifier with adjustable time constant. The pulse height distributions were measured with a computer-based multichannel analyzer (ORTEC Spectrum Ace-8k).

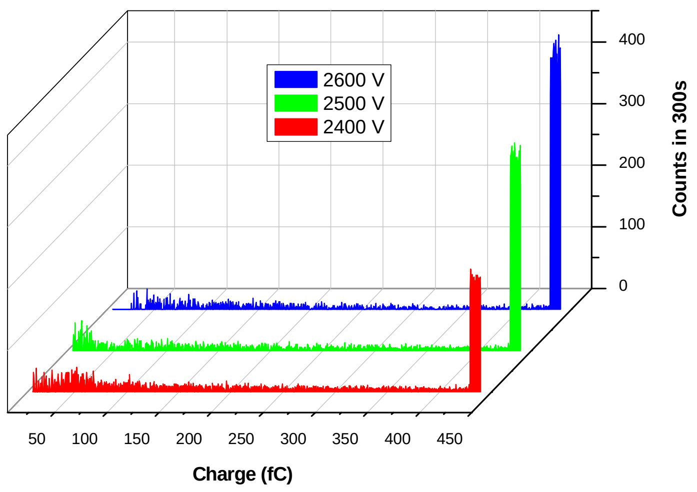
3. RESULTS

In order to verify the quenching properties of sulphur hexafluoride, SF_6, we studied the response of the thin gap RPC for two gas mixtures: 69 % iC_4H_{10} + 30 % Ar + 1 % SF_6 and 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6. All the measurements were performed at atmospheric pressure and at room temperature, under gas flow regime.

Fig. 2 shows the charge spectrum as a function of the anode voltage for the two gas mixtures. All the spectra exhibit, as expected by the Townsend theory, the exponential behaviour and the coexistence of both avalanche and saturated regime.



(a)



(b)

Figure 2. Charge spectrum as a function of the anode voltage for (a) 69 % iC_4H_{10} + 30 % Ar + 1 % SF_6 and (b) 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 gas mixtures.

Otherwise, for an anode voltage of 2500 V, the charge spectra for the two gas mixtures (Fig. 3) shown the benefits of SF_6, even at small concentrations. The data obtained with a 70 % iC_4H_{10} + 30 % Ar gas mixture are presented for comparison. It is notorious the participation of the SF_6 in the reduction of charge gain (by the reduction of saturated pulses) and in the stabilization of the operation of RPC. These effects can also be seen in the curve of counting rate versus anode voltage for the 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 mixture (Fig. 4), where a patamar is reached with an inclination of only 0.03 %/V.

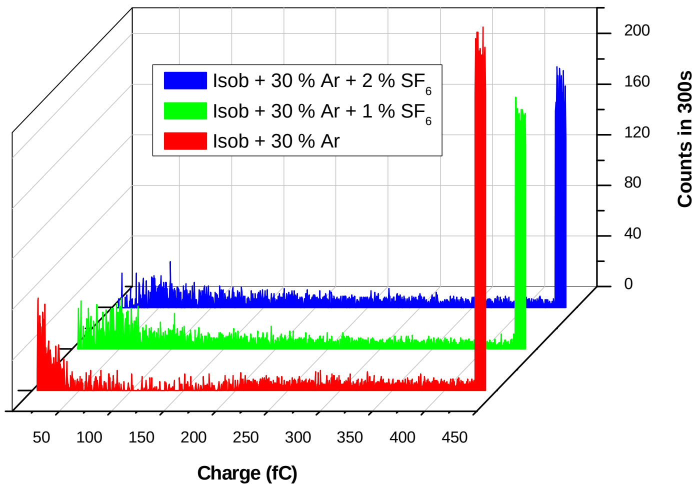


Figure 3. Charge spectrum for 69 % iC_4H_{10} + 30 % Ar + 1 % SF_6 , 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 and 70 % iC_4H_{10} + 30 % Ar gas mixtures, all of them at anode voltage = 2500 V.

The transition from avalanche to streamer was also studied for these mixtures and the results for 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 mixture are presented in Fig. 5. The curves indicate clearly that SF_6 extends the region of avalanche by enhancing the voltage of transition to Self-Quenching Streamer (SQS) regime, once for 70 % iC_4H_{10} + 30 % Ar mixture the transition voltage occurs at 2200 V.

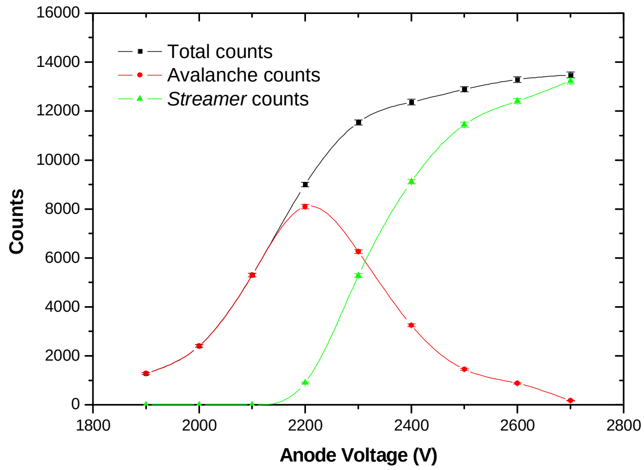


Figure 4. Counting rate *vs* anode voltage curve for 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 gas mixture.

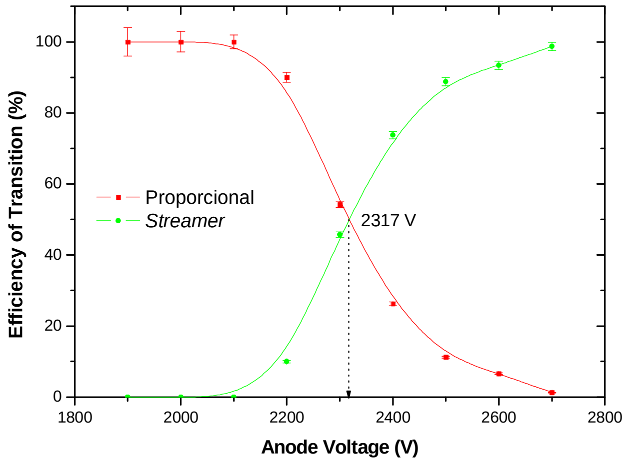


Figure 5. Transition efficiency from avalanche to streamer regime as a function of anode voltage for 68 % iC_4H_{10} + 30 % Ar + 2 % SF_6 gas mixture.

4. CONCLUSIONS

The addition of small quantities of SF_6 as a quench gas in RPC of thin gap shown to be more efficient than isobutane on the reduction of saturated pulses and, as a consequence, on the stabilization of the chamber.

The results obtained until now allow us to infer that the principal process involved in the inhibition of streamers is the negative ions production, determining a reduction of the RPC charge gain and an expansion on the voltage range operation of the RPC. It is also important to note that the photoionization events were very inhibited with SF_6 addition.

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