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Ageing and recovering of glass RPC

A. Candela[a], M. De Deo[a], A. Di Giovanni[a], N. Di Marco[a], M. D'Incecco[a], C. Gustavino[a,*], N. Redaelli[b], A. Tonazzo[d], G.C. Trinchero[c]

[a]INFN, Laboratori Nazionali del Gran Sasso, S.S. 17 bis 18,910, Assergi 67010, Italy
[b]INFN and Università di Milano Bicocca, Italy
[c]IFSI and INFN, Torino, Italy
[d]INFN and Università di Roma Tre, Italy

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Abstract

The glass Resistive Plate Chambers efficiency before and after water vapour flushing have been studied. The efficiency has been observed to rapidly drop to the level of 30% after a few days. After few hours of ammonia flushing, a full recover of the device occurred. Surprisingly, further flushing with water vapour had no effect on the efficiency, suggesting a treatment before the use in an experiment and/or whenever the performance is poor. In this work experimental results on tests at high temperature (up to 55 °C), high rate (up to 100 Hz/cm^2) and ageing (up to 10 mC/cm^2) are reported.

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Keywords: Glass RPC; Ageing; Rate capability; Temperature

1. Introduction

Resistive Plate Chambers (RPCs) are gas detectors widely used as active elements in particle physics experiments [1–9]. They are composed of two parallel plates generating a uniform electric field. When a particle ionizes the gas between the electrodes, an avalanche process occurs, eventually developing into a streamer. The electrodes are usually made of bakelite or float glass. A deterioration of RPC performance has been observed in several running experiments, after operation at high temperature or with water contamination in the gas mixture [10–13]. Both the detectors with bakelite electrodes and the ones with float-glass electrodes are affected by such problems. This indicates that, in spite of the widespread use of RPC detectors, further

*Corresponding author. Tel.: +39-0862-437586; fax: +39-0862-437-588.
E-mail address: gustavino@lngs.infn.it (C. Gustavino).

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investigations on this device are still of utmost importance. The test program presented here is focused on glass RPC detectors.

2. Bakelite vs. float glass

Bakelite is available at relatively low resistivity ($\rho \sim 10^{10}$– $10^{12}\,\Omega\,\mathrm{cm}$), but its resistivity increases with the RPC operation due to the ionic conductivity of this material. Conversely, float glass is characterized by higher resistivity ($\rho \sim 10^{12}$–$10^{13}\,\Omega\,\mathrm{cm}$), stable with operation because of its hopping conductivity [14,15]. The volume resistivity of float glass as a function of temperature is reported in Fig. 1. The resistivity decreases exponentially with temperature according to the following relationship

$$\rho = \rho_{20} 10^{(20-T)/25}$$

where T is the temperature in °C and $\rho_{20} = 10^{13}\,\Omega\,\mathrm{cm}$ represents the glass resistivity at 20 °C. The different behaviour of glass and bakelite was verified by measuring the resistivity of samples of the two materials. Fig. 2 shows the resistivity of the two samples, corrected for the temperature, as a function of the integrated charge. The glass resistivity was not altered after operation, proving the absence of any ageing effects. On the contrary, the bakelite resistivity increased by an order of magnitude. This effect reduces the rate capability of the detectors, and must be taken into account in some experimental applications.

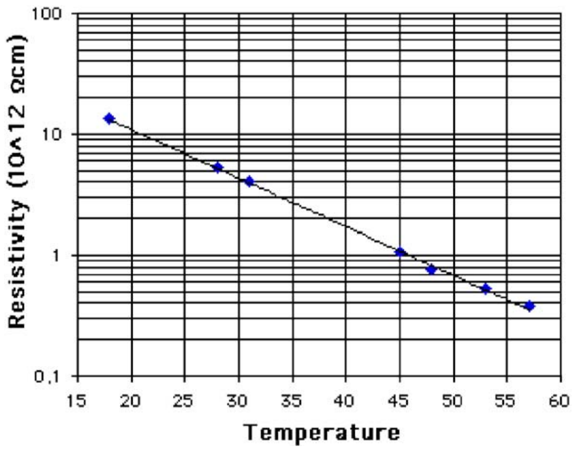

Fig. 1. Float glass resistivity behaviour as a function of temperature.

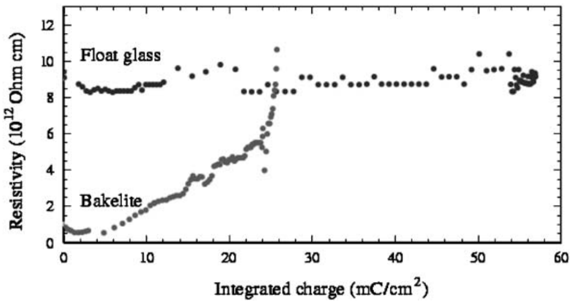

Fig. 2. Resistivity of float glass and bakelite vs. integrated current flown through the compounds. The resistivity of float glass is stable, while the resistivity of the bakelite increases with time, since it is related mainly to the drift of ionic carriers.

3. Short-term operation test

It is a matter of fact that the behaviour of the glass RPC is reliable and well reproducible at the beginning of operation [17]. As an example, Fig. 3 shows the single counting rate as a function of the applied voltage observed in 128 glass RPC of the type described elsewhere [18].

4. Temperature and irradiation tests

Temperature and irradiation tests were performed at the CERN Gamma Irradiation Facility (GIF), using a ^{137}Cs gamma source and a muon beam. The glass RPCs were housed in an insulating box, provided with a warming system and three thermometers. The beam muons were selected by two plastic scintillation detectors, selecting an area of $5 \times 5\,\mathrm{cm}^2$. The glass RPCs were placed at a distance of about 4 m from the ^{137}Cs source that, by means of a set of passive filters, allows to uniformly irradiate the detectors up to $100\,\mathrm{Hz/cm}^2$ m.i.p. equivalent. The discrimination threshold is fixed at 2 pC. The gas mixture was $TFE/IsoC_4H_{10}/SF_6 = 95/4.5/0.5\%$ throughout all the measurements. The applied voltage was

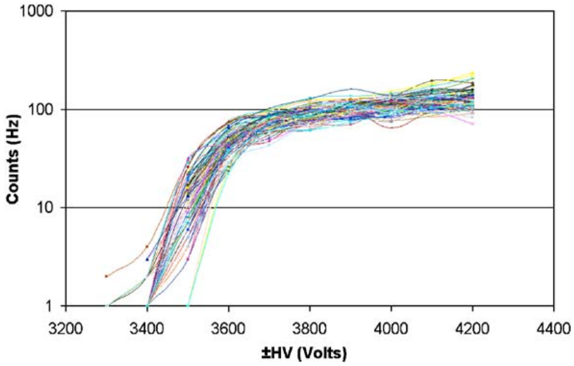

Fig. 3. Single counting rate as a function of the applied voltage for the 128 glass RPCs of the OPERA trigger walls.

re-scaled for the measured temperature and pressure according to the following relationship, to account for the change of gas gain

$$V^* = V_0 \frac{T}{T_{\mathrm{ref}}} \frac{P_{\mathrm{ref}}}{P}$$

where V^* is the effective voltage, V_0 is the applied voltage. The reference temperature T_{ref} is 297 K and the reference pressure P_{ref} is 964 mbar. The temperature inside the box was varied according to the following cycle: 24, 31, 40, 26 °C. For each temperature the radioactivity level was varied up to 100 Hz/cm^2. The efficiency as a function of the effective voltage for different temperatures and with the source off is shown in Fig. 4(a). The behaviour of the efficiency curves is the same at all temperatures, after re-scaling the operating voltage as described above. The single counting rate curves are shown in Fig. 4(b). The heating resulted not to have permanent effects on glass RPCs, as can be inferred from the curves representing the detector's behaviour after returning to room temperature. While the efficiency is unaffected, the single counting rate is decreased. This rate reduction is due to the reduction of spurious pulses (conditioning), and is not related to an increase in the glass resistivity after the high-temperature operation, as shown above. The increase of the chamber's counting rate with temperature can be ascribed to the increase of spurious pulses due to the decrease of glass resistivity, as shown in Fig. 1. A similar behaviour has been obtained by operating the glass RPC in streamer mode [16]. We conclude that, differently from bakelite RPC [12,13], the behaviour of glass RPC is not affected by high temperatures.

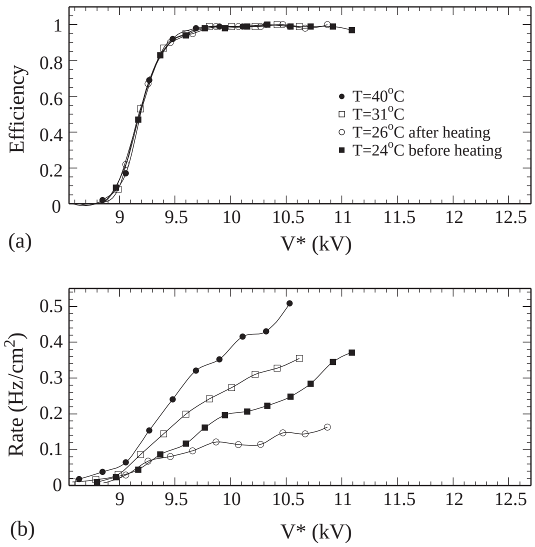

Fig. 4. Efficiency (a) and single counting rate (b) as a function of the effective voltage. The measurements have been performed at different temperatures and with the radioactive source off.

The efficiency as a function of the effective voltage at $T = 24\,^\circ\mathrm{C}$ and $T = 40\,^\circ\mathrm{C}$ are shown respectively in Figs. 5(a) and (b). The effect due to the higher temperature is clearly seen: the detector rate capability is higher by about a factor of 5 (compare for example the efficiency curve of Fig. 5(a) at 20 Hz/cm^2 and the one of Fig. 5(b) at 100 Hz/cm^2). An efficiency greater than 95% is reached even at 100 Hz/cm^2.

A long term test was carried out on two chambers operating in streamer mode at the GIF facility at CERN. The gas mixture was argon/TFE/isoC_4H_{10}/SF_6 = 48/47/4/1%, the temperature was about $T = 55\,^\circ\mathrm{C}$. The efficiency of the chambers as a function of the integrated charge is shown in Fig. 6. As result of this test, no loss of efficiency due to radiation was observed over the period considered. Moreover, the test further demonstrates that glass RPCs cannot be damaged while operated at the high temperature.

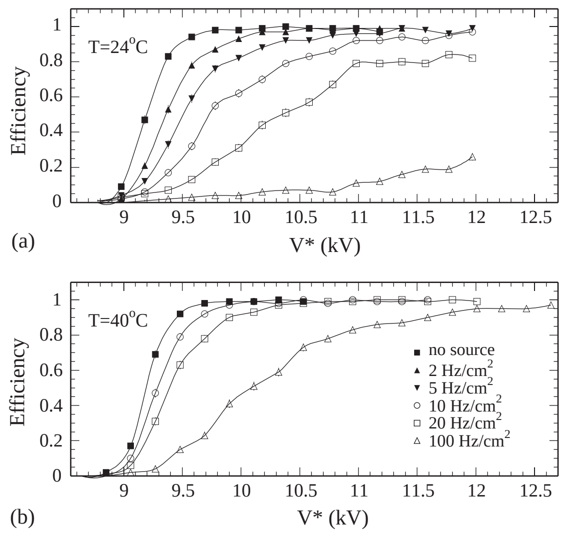

Fig. 5. Efficiency as a function of the effective voltage at different irradiation rates and with $T = 24\,^\circ\mathrm{C}$ (a) and $T = 40\,^\circ\mathrm{C}$ (b).

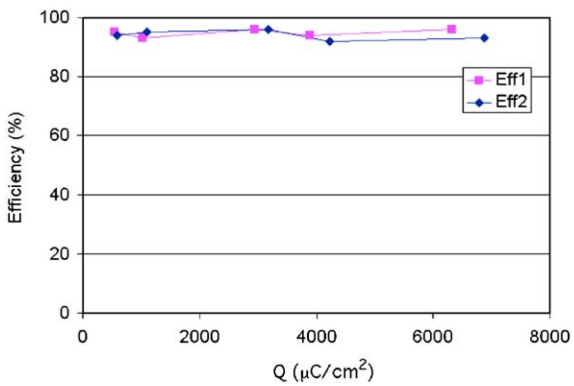

Fig. 6. Efficiency as a function of the integrated charge. The measurement has been performed at about 300 V above the efficiency knee, in streamer mode, $T = 55\,^\circ\mathrm{C}$, argon/TFE/IsoC_4H_{10}/SF_6 = 48/47/4/1%.

5. Humidity tests

The glass RPCs of the Belle experiment were deteriorated by water contamination in gas mixture [10]. Similar effects were observed on glass RPC detectors operated in streamer mode [16]. A test to check this ageing effect and the possible recovery with glass RPCs in proportional mode

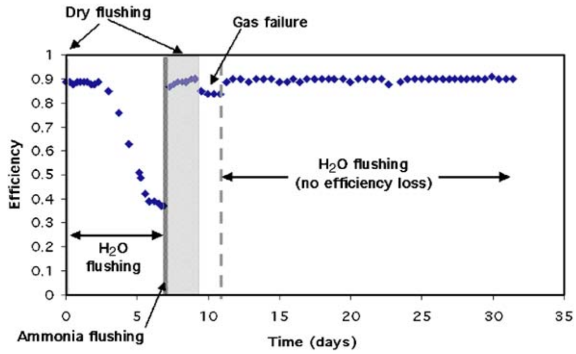

Fig. 7. Efficiency during the damaging (recovering) with water vapour (ammonia). The ammonia flushing allows a full recovering of the chamber. Moreover, further water vapour flushing does not affect the efficiency of the glass RPC.

has been performed. The behaviour of efficiency of a glass RPC flushed with water vapour is shown in Fig. 7. The experimental conditions were: 2000 ppm of water, normal temperature and pressure, 8.4 kV of supplied voltage, argon/TFE/IsoC_4H_{10}/SF_6 = 38/57/4/1%. After a few days, a sudden decrease of efficiency and an increase of single counting rate was observed. Following the recovery method described in Ref. [19], after the damaging we flushed the gas in a 30% ammonia water solution at $T = 6\,^\circ\mathrm{C}$, for about 8 h. The result is shown in Fig. 7: the ammonia flushing not only allows a full chamber recovering, but also seems to prevent loss of efficiency even flushing water vapour for about 1 month.

6. Conclusion

Different from bakelite, the resistivity of glass is stable with the integrated charge. No ageing effect has been observed on glass RPCs at high temperature (up to $T = 55\,^\circ\mathrm{C}$ for about 2 months), probably because glass electrodes do not need a surface treatment with linseed oil. As expected, the rate capability of glass RPCs improve with temperature, due to the lowering of glass resistivity. Finally, no efficiency drop has been observed during the irradiation at the GIF facility, for a total integrated charge of about $7\,mC/cm^2$.

The only ageing effect observed was due to the water vapour contamination. However, by flushing ammonia for a short period, we found the full recovering of the chambers and an increased resistance to the water vapour damaging.

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