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A thin float glass MRPC for the outer region of CBM-TOF wall

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ABSTRACT

A Multi-gap Resistive Plate Chamber (MRPC) made out of thin float glass is proposed for the outer region of the time of flight (TOF) system for the Compressed Baryonic Matter experiment at FAIR. Usually MRPCs are assembled with ordinary glass plates of 0.5 mm or more thickness, but their rate capability is less than the CBM requirement (1.5 kHz/cm^2). There are two ways to improve the rate capability. The first way is to reduce the bulk resistivity of the glass plates. The second is to reduce the thickness of the glass plates. Tsinghua University has made significant progress in the development of low resistive glass and high rate MRPCs. In this paper we report on three MRPCs produced with float glass plates of 0.7 mm, 0.5 mm and 0.35 mm thickness. Tests with cosmic rays and X-rays were performed at Tsinghua University. The results show that thin float glass MRPCs work well and have the rate capability necessary to meet the demands of the CBM-TOF outer region. Further studies were performed using a continuous 1 GeV deuterium beam at the Nuclotron accelerator at the Joint Institute for Nuclear Research (JINR). Time resolution of about 70 ps and efficiency higher than 90% were obtained for flux densities up to 3 kHz/cm^2, exceeding the requirement for the CBM-TOF outer region.

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1. Introduction

Multi-gap Resistive Plate Chambers (MRPCs) are planar, gaseous detectors made with resistive electrodes and glass plates that form very thin and accurately defined gas gaps. Such detectors are known to deliver timing accuracies below 50 ps σ for minimum ionizing particles (MIP) [1]. These excellent timing characteristics together with high detection efficiency, relatively low cost, and the possible coverage of large areas make MRPCs a valuable instrument for time of flight (TOF) systems used for particle identification, particularly in high-energy heavy-ion physics. This TOF technology was first introduced in the 1990s [2] and used at the STAR [3,4] experiment at RHIC. The Compressed Baryonic Matter (CBM) experiment at the future Facility for Anti-proton and Ion Research (FAIR) accelerator in Darmstadt, Germany is planning to build a 150 m^2 TOF wall based on MRPCs. The aim is to obtain good identification for hadrons in fixed-target heavy-ion collisions at projectile energies up to 25 GeV/A. According to simulations, the expected particle flux will be approximately 20 kHz/cm^2 in the center of the CBM-TOF wall and decrease nearly exponentially to 500 Hz/cm^2 in the outermost region [5].

The CBM-TOF is divided into different rate regions [5] in the recent conceptual design, as shown in Fig.1. In the inner rate region defined as region 3 to region 1, the particle flux will range from 3.5 kHz/cm^2 to 25 kHz/cm^2. High-rate MRPCs assembled with low-resistive glass plates can work stably in a high rate flux of about 35 to 60 kHz/cm^2 [6] and they are presently the best choice for this high rate region. In the outer region (region 4) with an area of nearly 82.5 m^2, the particle flux ranges from 0.5 kHz/cm^2 to 1.5 kHz/cm^2. MRPCs made out of float glass might be used in this region. However, the counting rate capability of MRPC assembled with commercial available glass can only reach a few hundred Hz/cm^2 [2], which cannot meet the requirement of the CBM project. To improve the counting rate capability of float glass MRPCs, warming-up technology was proposed. But warming up such a large area is not easy and this method is of questionable feasibility. The warming technology may also lead to some other problems (increasing dark current, background count rate, gas pollution and so on). Thin glass MRPCs are another choice for the CBM TOF wall. This paper presents the result of three MRPC prototypes made of float silicate glass. Cosmic ray tests and X-ray tests have been performed in our laboratory at Tsinghua University and beam tests were performed at the Nuclotron accelerator at JINR in Dubna

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using a 1 GeV deuterium beam. The structure of the MRPCs and the test results are described in this paper.

2. Rate analyses

The counting rate capability of MRPCs is limited by the time interval needed for a localized discharge to dissolve from the plate electrode. A DC model, the only available analytical description of rate effects, was used to study the process. In this model, the average voltage drop on the gas gap RPC at "high rate"ϕ is given by [7]:

$$\overline{V}_{drop} = V_{ap} - \overline{V}_{gap} = \overline{I}R = \overline{q}\phi\rho d \tag{1}$$

where $V_{ap}$is the externally power supply voltage, $\overline{V}_{gap}$the true effective voltage applied on the gas gap of RPC, $\overline{I}$ the current drawn by the detector which is proportional to the average charge per avalanche $\overline{q}$, ρ the volume resistivity of the plate, and d the thickness. It is obvious that the rate capability of the RPC depends mainly on the resistance of the plates (rate capability $\phi \propto 1/R$). To improve the rate capability we should reduce the resistance of the plates, which is proportional to $\rho d (R \propto \rho d)$. It is clear that to lower the resistance, we can lower theρ (adopt low resistivity electrodes) or reduce d (reduce the thickness of electrodes). To lower the resistivity of electrodes, we have previously developed a kind of semi-conductive glass (the counting rate capability of which can reach 35–60 kHz/cm^2).

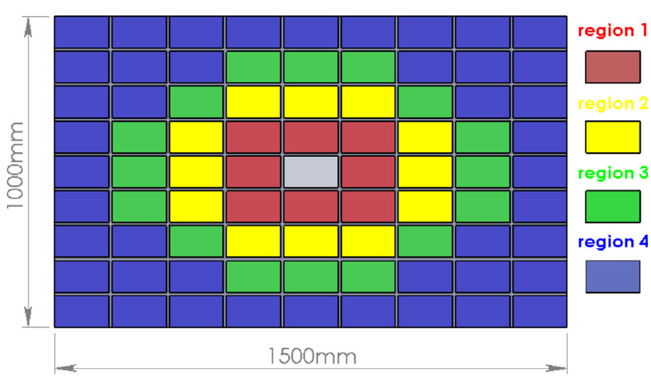

Fig. 1. Particle rate distribution in the full area of CBM-TOF.

This development was enabled by the work of Ammosov [8]. In this new research, we will reduce the thickness of the glass electrodes to reduce the resistance. The counting rate of MRPCs using thicker float glass can reach a few hundred Hz/cm^2. If the rate capability is proportional to $1/d$ we estimate that the rate capability of MRPC can be increased a few times by decreasing the glass thickness.

3. Glass electrodes and structure of counters

Three kinds of glass with a thickness of 0.7 mm, 0.5 mm and 0.35 mm, respectively, were prepared in our laboratory. The 0.7 mm and 0.5 mm glass are commercially available with a bulk resistivity of 4.2×10^{12} Ω cm and 4.3×10^{12} Ω cm, respectively. The 0.35 mm glass (called thin float glass) was obtained by polishing the 0.5 mm glass plates. The measured bulk resistivity remained the same as the 0.5 mm thick glass plate. The thin float glass plate is extremely flexible and the surface smoothness is still very good. It is not too difficult to polish the plates from 0.5 mm down to 0.35 mm, and compared to the cost of semi-conductive glass, the expense is much lower. Three MRPC readout counters based on the three different kinds of glass were assembled. Except for the thickness of the glass, the other factors are kept the same for these three modules. The structure of these three counters is shown in Fig. 2. There are eight readout strips. The size of each strip is 2.2 cm × 12.5 cm. There is a 3 mm interval between each strip. The total active area is 20 cm × 12.5 cm. It is a double stack device consisting two five-gap stacks. The thickness of the gas gap is 250 μm, defined by nylon fishing line. The high voltage electrodes are covered with colloidal graphite, yielding a typical surface resistivity of about 5 MΩ/sq. This mirror-symmetrical structure is operated with the negative HV on the inner electrodes, and the positive HV applied to the outer electrodes. Compared to a single stack module with a similar number of gaps, the double-stack structure can derive a higher voltage for each gas gap with the same voltage supply. We define the three MRPCs as 0.35MRPC, 0.5MRPC and 0.7MRPC for simplicity.

4. Cosmic ray test and X-ray test

We have never assembled a large module using this thin glass plate (0.35 mm) electrode before. To measure the performance of

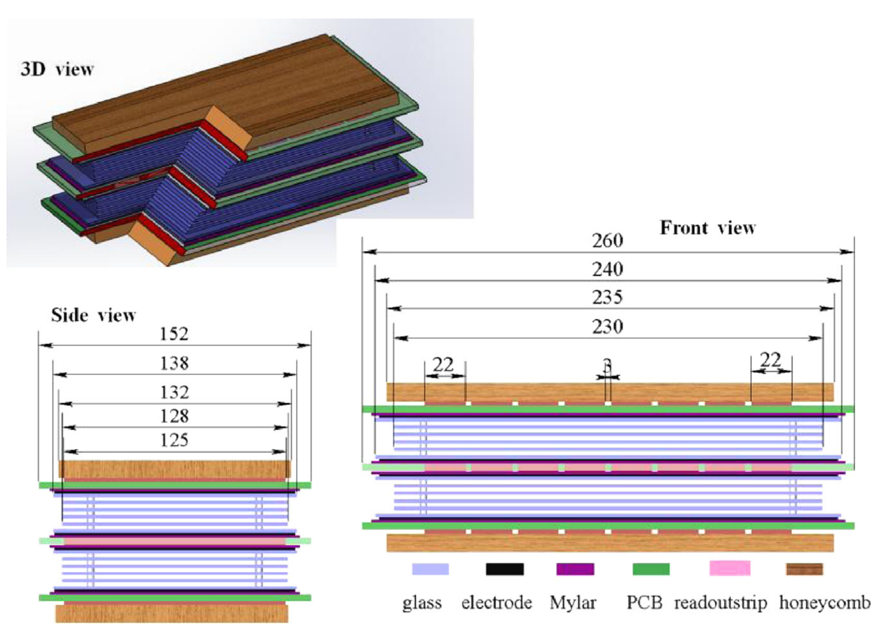

Fig. 2. Structure of the float glass MRPC with 8-strip readout.

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