New development and surface characterization of bakelite-based Resistive Plate Chamber

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The Resistive Plate Chamber (RPC) detector, first developed by Santonico et al. [1] are being used extensively in high energy physics and neutrino physics experiments. RPC is a gas-filled detector utilizing a constant and uniform electric field produced by two parallel electrode plates made of a material of high bulk resistivity ($\sim 10^{10} - 10^{12}\Omega - \text{cm}$, e.g. Glass, Bakelite) separated by insulating spacers. The large area RPCs are used in experiments like BELLE, BaBar, BESIII, and several LHC experiments (ALICE, ATLAS, CMS etc.) mainly for a) relatively low cost of materials used in making RPCs, b) robust fabrication procedure and handling and c) good time and position resolutions. RPCs are used in neutrino experiments like OPERA where its excellent time resolution and tracking capabilities are exploited.

During the last few years at SINP/VECC, significant work on the prototype silicone coated bakelite based RPC for the Iron Calorimeter (ICAL) of the proposed India-based Neutrino Observatory (INO) has been carried out. Bakelite RPC detectors of various sizes from 10 cm ×10 cm to 1 m × 1 m have been fabricated, characterized and optimized for efficiency and time resolution, and are reported earlier[2–5]. The current paper deals with the development of 1) instruments and methods for the measurement of surface resistivity of the inner electrodes of the bakelite RPCs, and 2) alternative design and characterization of the RPC read-out strips. Incidentally, these developments are complimentary to the development of glass-based RPCs in other collaborating institutes of the proposed INO project.

Thin layers of different grades of silicone compounds are applied to the inner electrode surfaces to make them smooth and also to reduce the surface resistivity. Before fabrication of each RPC module, the surface resistivity of bakelite sheets and also of silicone coated surfaces are measured using the set-up shown in the Fig. 1. The set-up consists of a jig with two aluminium bars having V-shaped sections and soft-padded conducting edges at the bottom, which are placed on the surface under measurement. The bars, forming the opposite sides of a square shape, were mounted on a G-10 insulating plate having very high resistivity ($> 10^{14}\Omega/\Box$). A current to voltage converter circuit, made out of TL082CN FET input OPAMP, with provisions to cover 3 decades of surface resistivity measurement ($\sim 10^{10} - 10^{12}\Omega/\Box$), was made.

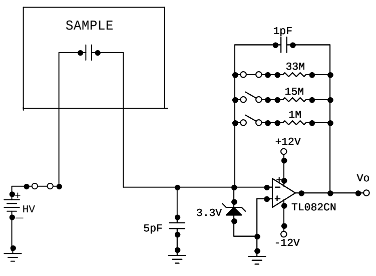

FIG. 1: Schematic of the experimental setup for surface resistivity measurement.

Measurements were done on the innner surfaces of the bakelite electrodes (silicone coated or uncoated) before assembly of the RPCs. A DC bias voltage $\sim 50 - 600$ volt was applied

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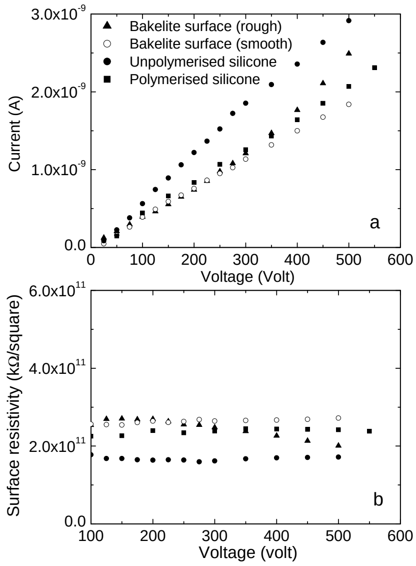

FIG. 2: (a) The surface current & (b) the surface resistivity versus the applied voltage for different samples.

on the jig, and the leakage current ($\sim$ nA/pA) flowing across the terminals of the jig through the bakelite surface was measured. The surface resistivity was obtained from the leakage current and the applied bias voltage.

The variation of surface current and surface resistivity with the applied voltage for different coated and uncoated bakelite electrodes are shown in Fig. 2. A look at the I-V plots for the surface resistivity of uncoated bakelites having two different surface textures (rough and smooth) shows a non-linear trend for the rough surface, resulting in an apparent reduction of surface resistivity at higher bias voltage. This is likely to be correlated with the relatively high occurence of micro-discharge across the surface due to the roughness. This finding correlates with the reduction of efficiency and increase of RPC noise rate at higher bias voltages for the bakelite RPCs, made with the rough variety in our earlier studies[3]. In addition, comparison of the two different grades of silicone coating (unpolymerized and polymerized) on the bakelite electrode surface shows that 1) the surface resistivity is less by a factor of $\sim$ 2 for the coated surface compared to the uncoated surface, and 2) the surface resistivity for the polymerized silicone coating is $\sim$ 1.5 times higher than that for the unpolymerized variety. Lower value of surface resistivity is expected to help in reducing the space charge effect because of quicker dissipation of accumulated charge through the surface layer.

In a parallel development, capacitive read-out strips for the RPCs were made out of 16-conductor ribbon cable (20 mm wide and 1 mm thick), which is commercially available. The cables, cut in proper size, were placed side by side and glued to a mylar sheet, cut out according to the size of the RPC. 15 conductors of each ribbon cable, forming a read-out strip, were shorted and connected to a signal transmission cable, and the 16th conductor grounded for strip isolation. 2 mm layer of foam was pasted on the mylar sheet, with a ground plane placed on the opposite foam surface. Two sets of read-out strips for the x- and y-axes were made. Characteristics of the pick-up pulses, impedence of the strips, efficiency and time resolution of the RPC were studied. The results indicate that while the measured efficiency of the RPC remains unaltered, the time resolution is degraded as compared to the pick-up strips used earlier, which is likely to be due to larger capacitance and variation of the characteristic impedence. Further studies are in progress.

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