Development of large area (1m x 2m) bakelite gas-gaps in India for INO and related experiments

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Introduction:

Resistive Plate Chambers, in general, employ either bakelite or glass as the resistive material. BARC (NPD) had significantly contributed to the RE4 upgrade of the CMS experiment at the LHC facility at CERN, thereby building, characterizing, successfully installing and commissioning, 50, RE4/2 RPCs at CERN during the Long Shutdown1 (2013-2014) [1, 2]. The experience gained in the project in handling large area (~ 2 m^2) bakelite gas-gaps, which were built in KODEL, South Korea gave us enough confidence to initiate fabrication of large area bakelite gas-gaps and corresponding RPCs for INO and neutrino related experiments. For INO, glass has been chosen as the resistive material, nevertheless, seeing the volume of the glass RPCs to be fabricated, it is worthwhile enough to parallely start the fabrication of large area bakelite gas-gaps too, which have wider applications, apart from basic research, in the field of homeland security, medical imaging and muon tomography too. Bakelite gas-gaps have certain advantages over glass as follows:

(i) Bakelite has excellent mechanical strength and good machinability compared to glass

(ii) For larger areas, one has to use glass with a thickness of 3 mm, whereas for similar area, one can use bakelite sheets of 2 mm thickness. This grossly reduces the overall weight of the gas-gaps by a factor of 1.5

(iii) Handling, testing, shifting and final transportation of bakelite gas-gaps (RPCs) is much more easier vis a vis glass gas-gaps (RPCs), as can be seen for a 1m x 2m gas-gap in Fig.1

(iv) As bakelite ($\rho \sim 10^{11}$ Ω.cm) has an order of magnitude lower resistivity compared to glass ($\rho \sim 10^{12}$ Ω.cm), it can withstand larger count rates compared to glass, which may not be a compelling factor for experiments which are based on cosmic events. However for other accelerator based neutrino experiments with much higher neutrino flux, bakelite RPCs, do have an edge over the glass RPCs.

BARC (NPD) has initiated the fabrication of large area bakelite gas-gaps in three stages:

(i) The first stage, which is complete, involved procurement of bakelite gas-gaps and bakelite sheets from General Tecnica, Italy, who are the pioneers in this field and have built bakelite gas-gaps for several experiments around the globe (CMS, ATLAS, OPERA etc.). The bakelite gas-gaps (ρ = 1 - 6 x 10^{11} Ω.cm) and bakelite sheets from GT are expected in the lab by Oct 2015. These will be used for benchmarking the bakelite gas-gaps that would be eventually developed in India. The gas-gaps from GT have qualified all the required QA/QCs as regard to mechanical and electrical tests [2].

(ii) In the second stage bakelite sheets procured from GT will be employed for building the gas-gaps in India &

(iii) Finally, in the third and last stage bakelite sheets procured form Indian markets will be used for fabricating large area Bakelite gas-gaps (RPCs).

We report in this paper, the resistivity and surface roughness measurements for the bakelite sheets procured from Indian market. It is quite important for the resistivity of the bakelite sheets to remain stable, as the performance parameters of the RPCs, thus configured, such as efficiency, cluster size and noise rates etc. should remain stable, over an extended lifetime of 5-10 years, wherever they are employed in caverns or overground sites.

Fig. 1: Bakelite gas-gaps (1m x 2m) procured from GT, Italy

The resistivity measurement set up in the RPC lab at BARC (NPD) is shown in Fig. 2, consisting of 11 cm × 11 cm of 2 mm (±0.03 mm) thick bakelite sheet, grade P-201, with a quoted volume resistivity of 2×10^{11} Ω.cm, kept in an RH and temperature controlled environment in the lab. The resistivity, ρ, is calculated using the formula

$$\rho = \frac{RA}{l} = \frac{VA}{Il}$$

where, R is the resistance, l = 0.2 cm is the thickness of the bakelite sheet, A = 121 cm^2 is the area of the sheet, V = 24 V is the constant applied voltage and I is the measured current.

The measured bulk resistivity of Indian bakelite is shown in Fig. 3 and seems to remain quite stable $(1.02 \pm 0.01) \times 10^{11}$ Ω.cm, over extended period of measurements. Another important parameter w.r.t selection of the bakelite panels is its surface roughness, R_a. The observed values of the R_a, with Handysurf E-35B, are found to be in the range of 0.06 to 0.09 μm, which are an order of magnitude better compared with the surface roughness of bakelite from GT. At the time of writing this abstract, the first indigenously developed 1m x 2m bakelite gas-gap is under production and the linseed oil treatment facility is also built up for the same. The graphite coating procedures on bakelite have been standardized giving a uniform coat varying from 80 to 100 μm, conforming with a graphite resistivity of ~ 1 MΩ/□. The performance of this large area bakelite gas-gap, built indigenously, with G-10, Cu read out panels [3] shall be reported during the time of symposium.

Fig. 2: The resistivity set up in RPC lab. (NPD)

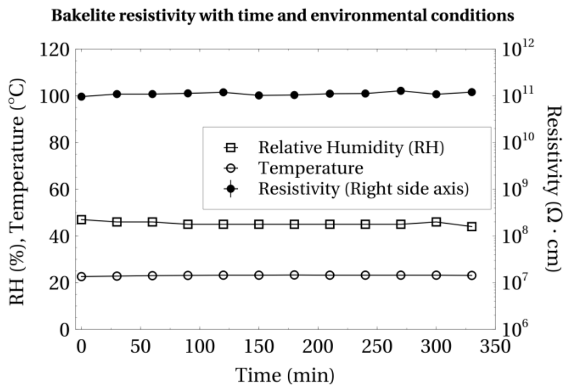

Fig. 3: Variation of bakelite resistivity, procured from Indian market, with time in an RH and temperature controlled environment

The present limitations in building still larger area RPCs are in the fabrication of the overall bakelite panels in the Indian industries, which are limited to 1m x 2m. Industries will need to be pruned if larger area (> 2 m^2) bakelite sheets are to be manufactured.

References:

[1] CMS Technical Design Report on Muon End Cap Upgrade

[2] *CMS RPC commissioning of the existing detector during the long shutdown*, 2014 JINST 9 C10043

[3] S. T. Sehgal *et al.*, Proceedings of the DAE Symp. on Nucl. Phys. 59 (2014) 922