Development of 1mm low resistivity bakelite plate for thin-gap RPC detector

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Introduction

As part of the R&D efforts for ATLAS Forward Muon detector upgrade, we are developing low resistivity Bakelite plate with about 1mm thickness for thin-gap RPC as the added level-1 trigger system aiming to provide high rate capability and small cluster size to achieve fine granularity required for the upgrade in super-LHC running environment. The resistivity and surface quality, as well as the long term stability with respected to temperature and humidity variance are under studying in the laboratory.

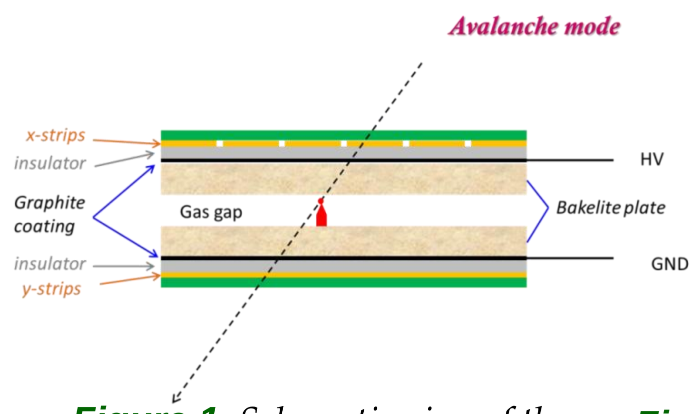


Figure 1: *Schematic view of the Thin gap Resistive Plate chamber*

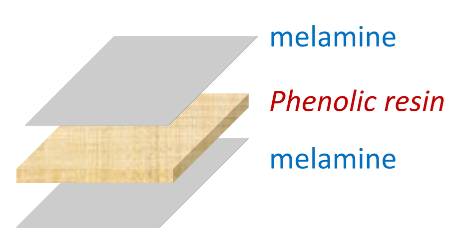


Figure 2: *Bakelite samples are made of phenolic resin sandwiched by thin melamine layers*

Surface Study

The surface of the low resistivity plates along with pure phenolic plate, Daya Bay Neutrino experiment (China) bakelite sample made at same company and a Italy reference no-oil coated plate are investigated by an optical gaging system and a profiler meter.

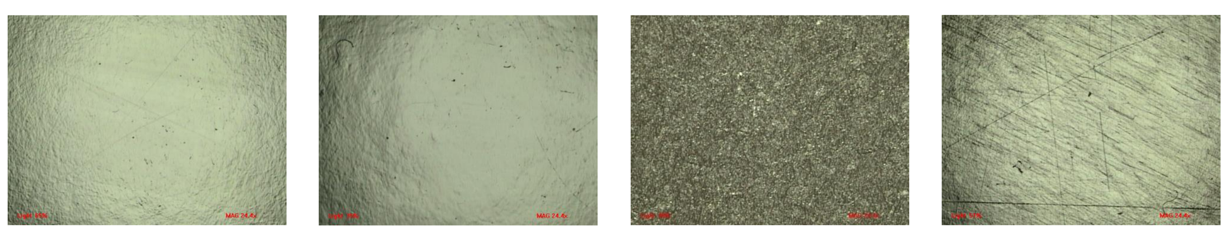


Figure 3 *From left to right: Image of the surface of DayaBay sample, low resistivity, pure phenolic and Italy reference plate (Zoom ×24).*
Low resistivity plate with melamine coating has superior surface smoothness than pure phenolic plate and similar quality as DayYa Bay sample. Tiny nicks are observed for Italy reference sample.

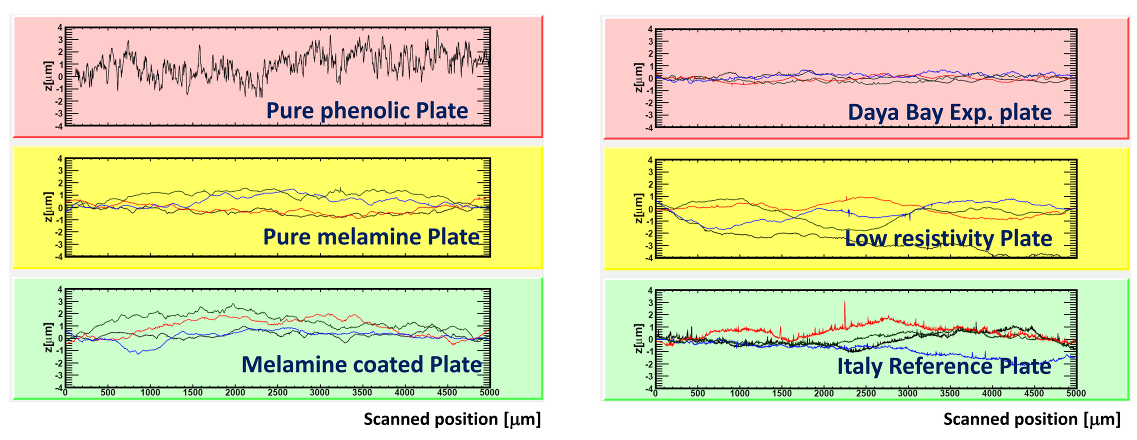
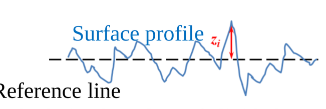


Figure 4 *Scanned surface profile by a surface profile meter (Ambios XP-1)*

- arithmetical mean of surface roughness:

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|Z_i|$$



Reference line (calculation based on 10 divided parts of 5mm scanned range)

Table 1 *Comparison of Surface Roughness of several samples (unit in μm)*

Line #	Pure Melamine	Pure Phenolic	Melamine coated	DayYa Bay Plate	Low Resistivity Plate	Italy Reference Plate
1	0.083	0.55	0.086	0.065	0.086	0.088
2	0.081		0.052	0.055	0.052	0.102
3	0.089		0.067	0.075	0.067	0.062
4	0.084		0.078	0.062	0.078	0.076

Resistivity Study

Both bulk and surface resistivity of bakelite samples are investigated. A press machine which can generate pressures up to ~10 atm is employed to keep the test electrodes in well contact with the specimen. Several types of conductive electrodes are tried (Fig.7) during the resistivity measurements, Measurement with one of conductive sponges gives the lowest resistivity value which indicate its good contact capability with the bakelite specimen under pressure, as depicted in Fig.8. The low resistivity plate charging behavior is shown in Fig.4. About 30 minutes is needed for the current flow through the plate to reach a stable value during the bulk resistivity measurement (HV=500V). Though there is no direct link between material bulk and surface resistivity, usually the bulk resistivity is found to be an order higher than surface resistivity. Stability of bulk and surface resistivity against charging time, i.e. 200 hours, is depicted in Fig.9.

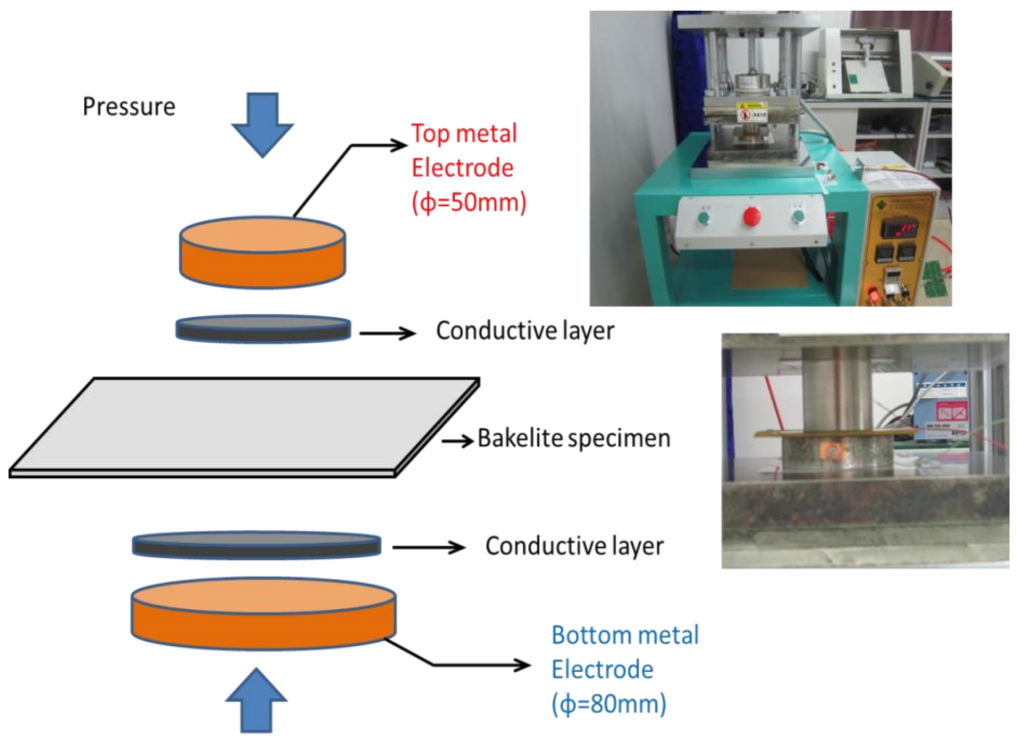


Figure 5 *Methodology for bakelite resistivity measurement*

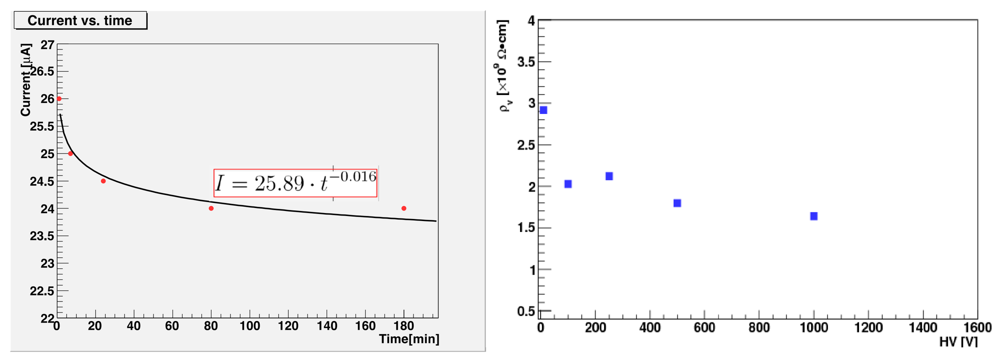


Figure 6 *(left) Current flow through vs. Charging time (right) Measured Bulk Resistivity at different HV*

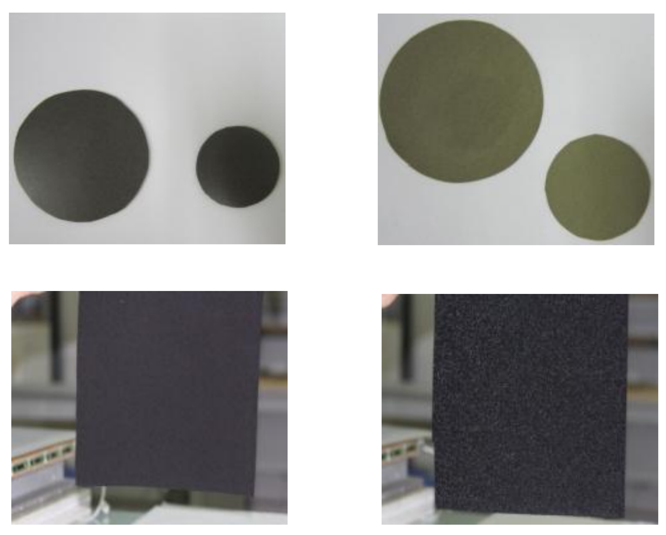


Figure 7 *Several kinds of conductive layer (Top: conductive rubbers, Bottom: conductive sponges)*

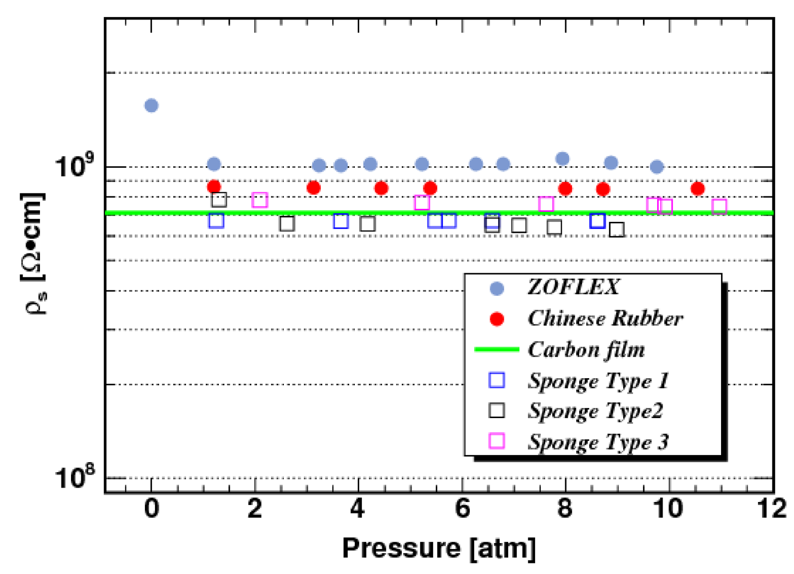


Figure 8 *Resistivity vs. pressure measured with different kinds of conductive layer. Results are compared with the value obtained with carbon film electrodes*

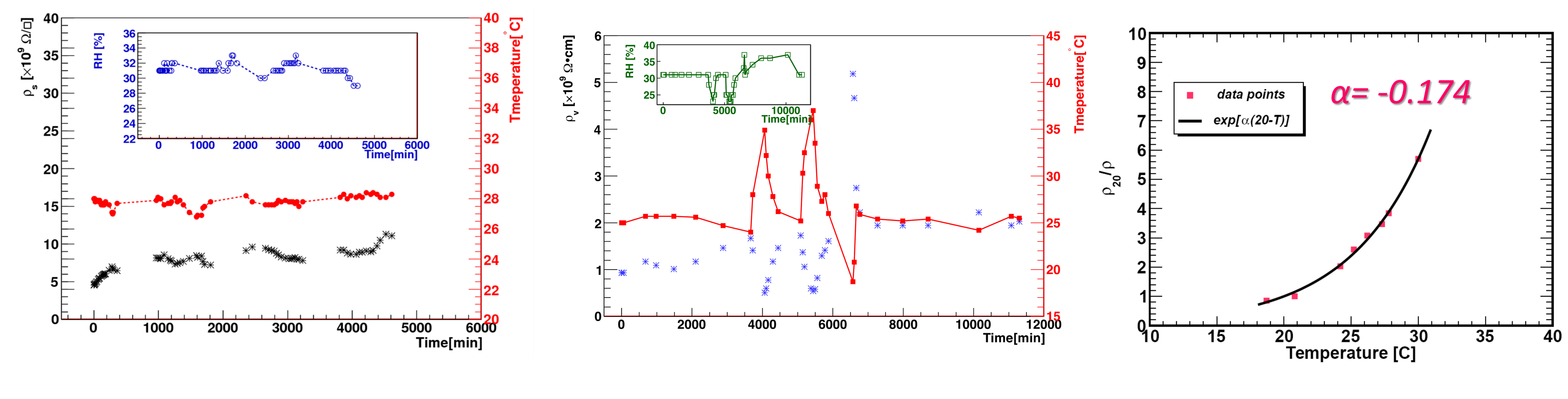


Figure 9 *Evolution of Bulk (Left) and surface resistivity (Middle) with charging time for two different plates are shown. Relative Humidity of the environment is kept around 30%. Resistivity at different temperatures compared with the value at 20 C are plotted (Right)*

Prototype R&D

Small prototype is made to test its basic performance. Bakelite plates and readout board are attached to support honeycomb plates and keep a distance of 1.2 mm apart. Chamber is enclosed in a metal vessel. All signals from anode along with coincidence signals from two small scintillators are digitized and sent to mezzanine card.

- Bakelite Plates: 20cm×20cm, ~10^9 Ω cm, 1mm thick, melamine coated
- Gas gap: 1.2mm
- Gas: Freon:iC_4H_{10} 95:5
- Electronics: mezzanine card for ATLAS MDT chamber

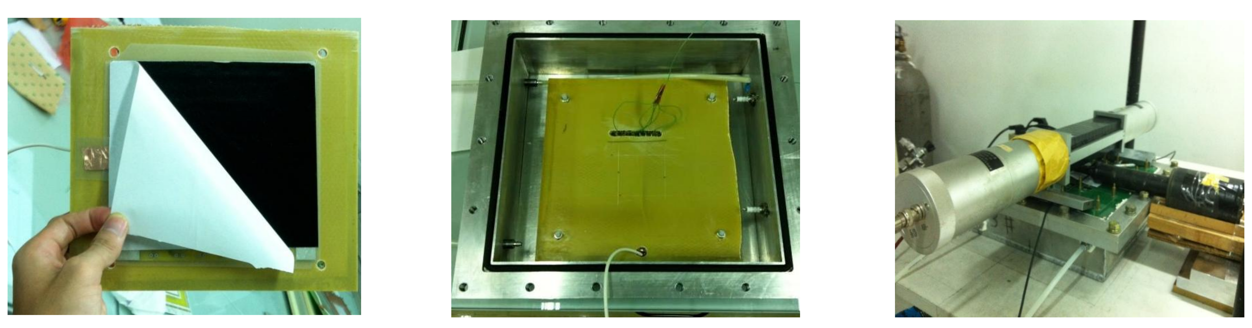


Figure 10 *Prototype fabrication and cosmic test setup*

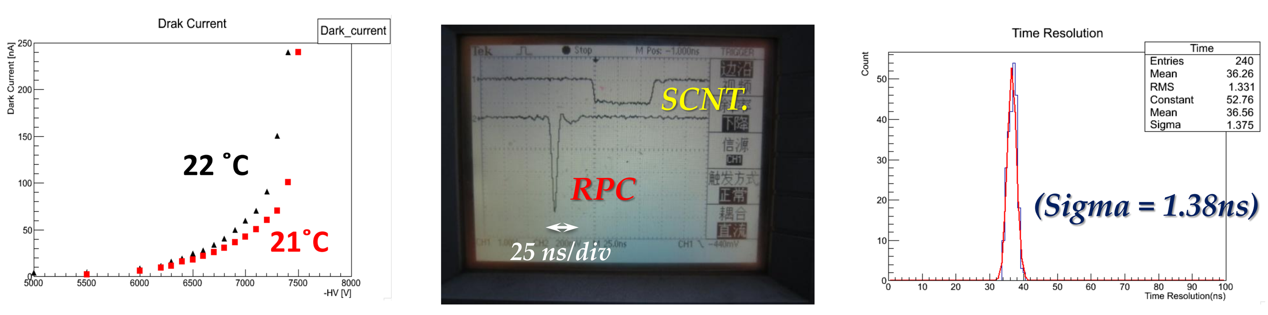


Figure 11 *Whole chamber dark current(21,22C), typical avalanche signal (from a fast amplifier, gain ~200) and time spectrum at HV=-6500V*

Summary

Bakelite plates up to square-meter scale with high resistivity have been developed by the same China company for RPC used in the BES system and Daya Bay Neutrino Experiment successfully. The new type of low resistivity bakelite plates with melamine coating show reasonable surface quality as those high resistivity plates. Prototype RPC with 1.2 mm gap using such kind of 1mm thick plates are tested with a time resolution ~1.4 ns which are parted limited by the electronics precision. Long term stability against environment variation and radiation will be further studied.

XI workshop on Resistive Plate Chambers and Related Detectors (RPC 2012 Workshop) @ Frascati, Italy Feb 7th 2012