Glass characterisation techniques used in the Resistive Plate Chamber development

B.Satyanarayana
Tata Institute of Fundamental Research, Mumbai, 400005
For India-based Neutrino Observatory Collaboration

Abstract

Resistive Plate Chambers (RPCs) will be the active elements in a neutrino detector which is proposed to be built by the India-based Neutrino Observatory (INO) collaboration. We have employed a number of techniques to study, compare and characterise the glass which was used to fabricate the prototype chambers. We will describe these techniques and illustrate how the same were employed during our RPC detector R&D programme.

1 Introduction

India-based Neutrino Observatory (INO) collaboration is proposing a large magnetized iron tracking calorimeter of total weight 50 kton, using atmospheric neutrinos as source[1]. The proposed detector will have modular structure of lateral size 48 m $\times$ 16 m and will consist of a stack of 140 layers of 6 cm thick iron plates interleaved with Resistive Plate Chamber (RPC) detector layers. A dedicated effort for development of RPC detectors, leading to their large scale production is in progress. The INO detector will need about 27,000 RPCs of dimension 2m $\times$ 2m and hence will use 2mm thick float glass of about 216,000 m^2 in area. As part of a dedicated R&D programme to develop and study the RPCs, we have built a number of prototype RPCs and studied their performance extensively. While the performance of these chambers in general was satisfactory, we had faced problem with their long term stability. The chambers have suffered from sudden aging when they were put in continuous operation for a few months [2, 3]. We have used a variety of float glasses manufactured by different vendors. After a considerable R&D in trying to understand the reason for this problem, we have come to the conclusion that quality of the glass which is used as chamber electrodes could be the major factor affecting the longterm stability of these chambers.

2 Characterisation based on physical properties

Thickness variation of the glass sheets was measured by using an ultrasound gauge. The measurements were cross-calibrated by a vernier. We had found that the variation on the thickness among various glass samples was limited to about 100 microns. We have also compared various glass samples based on their density measurements. It was reported in the literature that minute variations in its density show up as significant differences in the behaviour of glass. We have computed density of glass sheets by performing simple measurements on the volume of the glass samples and their weight. We had found that glass samples procured from Germany had showed the lowest density of about 2.22gm/cc, while the Indian glass samples such as Modi and Asahi Float glass brands have shown a density of 2.51gm/cc. The Japanese glass samples have shown a density of 2.49gm/cc. It may be noted that we had found that the RPCs fabricated with Japanese glass have survived the aging phenomenon.

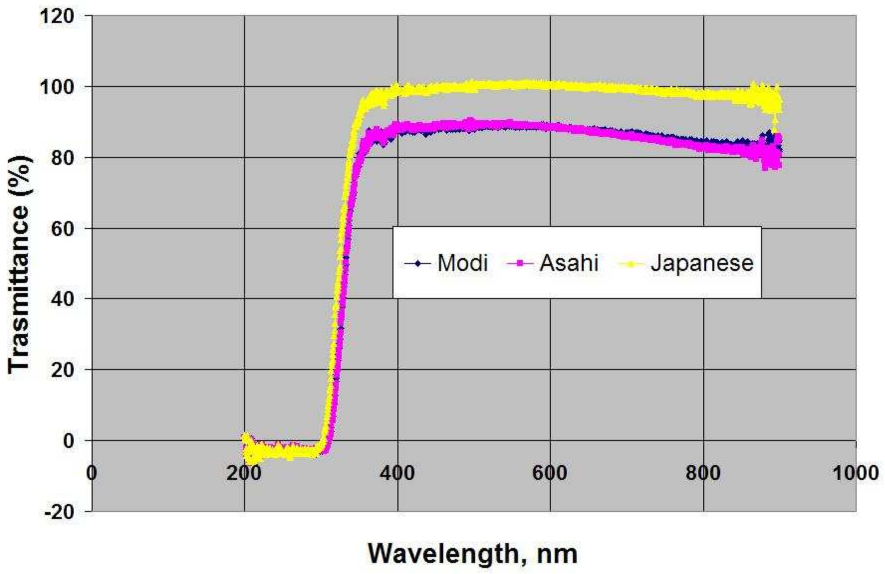

Figure 1: Transmittance study of glass samples

3 Surface characteristics of glass

We have used surface characterisation tools and methods such as Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) extensively to study and compare the surface qualities of various glass samples. The studies have shown that the Japanese glass scores the best among various samples in these tests. These studies have also shown surface cracks, structural defects and diffraction patterns in the Indian glass samples. Apart from characterising the raw glass samples, these tests were also used to study the damage on the glass samples when the Resistive Plate Chambers, which were fabricated using these glass electrodes have *aged*. AFM studies on the glass electrodes of a damaged RPC have shown variations on the defect patterns on anode and cathode electrodes, which is indeed expected from the operation of the chamber.

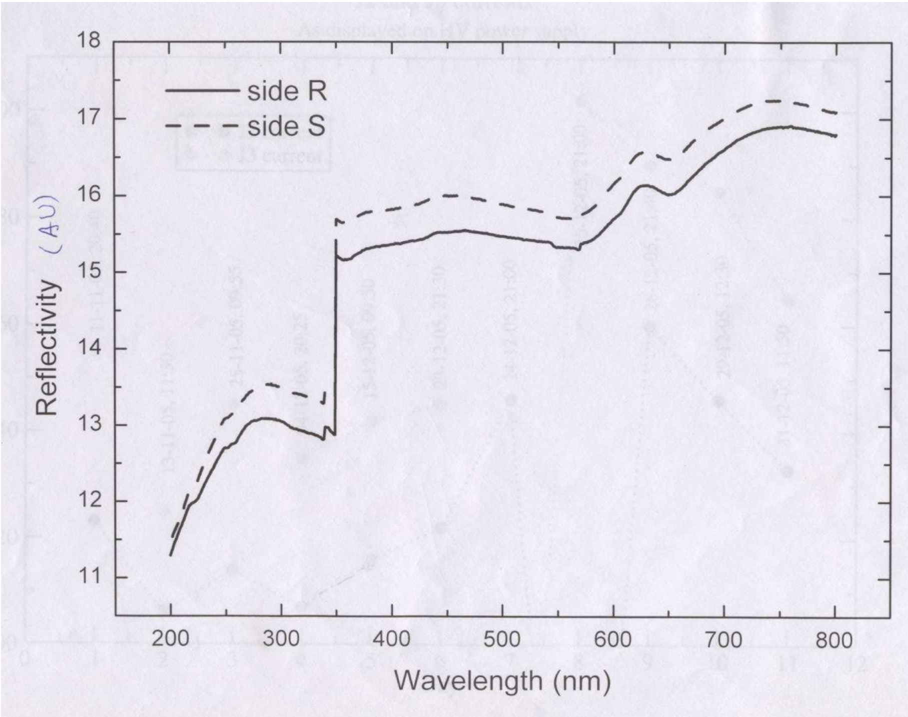

Figure 2: Reflectance study of a glass sample

4 Study of optical characteristics

Transmittance test of various glass samples over the UV to visible light spectrum was carried out. This test will indicate general bulk quality of the glass and gives a measure of the level of impurities in the glass. As shown in the Figure 1, the Japanese glass shows about 10% better transmittance over local brand glasses.

Due to the technique of float glass making, the quality of two glass surfaces is not identical. While the surface in touch with the molten tin bath is smooth, the other surface left to the air is relatively rough. It is advisable to keep two smooth surfaces of the top and bottom electrode glasses, facing the gas volume. We have devised a scheme using the reflectance of glass surfaces for the UV radiation to mark the smooth and rough surfaces (Fig. 2.

5 Elemental and composition studies

Shown in the Figure 3 are fractional percentages of weights of various elements present in the glass samples obtained using Energy Dispersive X-ray Spectroscopy (EDS) technique. Within the instrument tolerances, we find that the glass samples show consistent values of various constituent elements among them. We have also used X-Ray Diffraction (XRD) technique to study the elemental composition of the glass used for making the RPC prototypes. We have used the same technique to study and conclude that the damaged electrode surfaces contains a factor 10 higher Florine concentration than that of raw glass. Again this observation is consistant with the underlying chemistry of the glass electrode damage, if the RPC is operated with moister contaminated Freon (R134a) gas.

Element	Modi		Asahi		Japanese	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Oxygen	71.0	72.6	69.9	70.1	72.9	73.4
Sodium	8.6	3.3	7.7	7.8	7.6	7.2
Magnesium	1.8	1.8	2.3	2.4	1.9	1.5
Silicon	17.8	15.7	19.0	18.6	16.9	17.1
Calcium	0.9	-	0.7	0.7	-	0.4
Carbon	6.7	-	-	-	-	-
Aluminium	-	-	0.5	0.4	0.7	0.5

Figure 3: EDS study of various glass samples

6 Summary and conclusions

Many of the material science tools were used successfully during the development of Resistive Plate Chambers. They are found useful both for characterisation of raw glass electrodes as well as for analysis of damaged samples. We are also using the same techniques and instruments during the RPC production, for example to determine the appropriate glass surface ? rough versus smooth.

References

[1] India-based Neutrino Observatory, INO Project Report, INO/2006/01, June 2006

[2] VIII Workshop on Resistive Plate Chambers and related Detectors, Korea University, Seoul, October, 2005

[3] National Symposium on Science and Technology of Glass/glass-ceramics, BARC, Mumbai, September, 2006