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RPC electrode material study

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ABSTRACT

Various aspects of RPC electrode material, such as surface smoothness, surface UV sensitivity and its resistance to HF attack, have been studied. Based on these studies we can direct our R&D effort to some of the most critical issues related to RPC performance and aging.

1. Introduction

Due to the wide application of RPC technology the R&D on further understanding the basic building material—Bakelite electrode—is urgently needed. The surface quality of Bakelite sheet has been progressively improved, a new type of Bakelite sheet that does not require Linseed oil coating has been successfully developed at IHEP, Beijing [1]. With this Bakelite sheet IHEP has produced more than 1300 m^2 of RPC chambers and installed on BESIII detector.

As we know that the majority of RPCs, which were built by an Italian company General Technica, used Italian Bakelite sheet. They require the inner surfaces of the electrodes to be coated by 2-propanol (or similar chemical solution) diluted Linseed oil, otherwise its huge noise rate prohibits the chamber from any practical application. The IHEP's technique made a big step forward to avoid this labor intensive and usually troublesome oiling step.

In this paper we are going to report our study on several related issues, such as why the original non-oiling RPC is so noisy, what roll the Linseed oil plays, etc.

2. How the surface quality affects the RPC noise rate

We use an Atomic Force Microscope (AFM) to study the surface morphological structure of the Italian Bakelite sheet. A 3-D image is shown in Fig. 1.

From Fig. 1 we can see that the feature structure of the surface defects could be categorized into four types shown in Fig. 2: "pin," "ball," "dome," and "ridge." We have used finite element analysis (FEA) software ANSYS to calculate the electric field variation due to these defects.

The FEA results listed in Table 1 show that the most serious defect type is the "pin". We also use AFM to look at the Linseed oil coated Italian Bakelite surface shown in Fig. 3. The bare surface shows rough structure, coated with thinned Linseed oil (B) the surface becomes smoother, coated with less thinned Linseed oil the surface becomes very smooth. Therefore we can definitely see the important roll of Linseed oil coating: it covers the surface morphological defect, makes the surface less sensitive to the field emission, a like source of high dark current and high single rates.

2. Surface UV sensitivity

RPC is a parallel plate chamber. Between two electrodes the electric field is constant. The strong electric field presented on the surface would help to enhance the photoelectric efficie ncy. The UV photon created in every avalanche or streamer can hit the large surface of the cathode. To reduce the afterpulse/noise rate we would like to have the least UV sensitive material for the electrode. Therefore test the UV sensitivity of different materials and various surface treatment can give us some hints to this issue.

The test device, a McPherson VUV monochromator coupled with a 2-step avalanche chamber, is shown in Fig. 4. In this test the UV light splitter (5) and the PMT (6) are not used.

The monochromatic light hits the front surface of the test sample, of which the back surface is coated with graphite paint that contacts the metal side of a G-10 plate and serves as the cathode of the 2-step avalanche chamber. The first part of the chamber, between the mesh electrode and the cathode, is a drift region, in which the E-field is rather low, the UV-photoelectrons from the cathode are drifting away from the cathode, but no gas avalanche. Very little photocurrent will be flowing through the

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test sample. The voltage drop across the test sample due to the photocurrent is completely negligible. Following the drift region, there is a second avalanche stage between the mesh and the anode. In this region the electric field strength is much higher than the drift region. Most of the drifting electrons would be crossing the mesh (90% of transparency), and entering this avalanche region. A Keithley electrometer is used to measure the total current flowing through this region. The monochromatic wavelength scans from 160 to 220 nm and the photocurrent response curve is recorded.

The test results are shown in Fig. 5. In the figure we compare the UV response of the surfaces with and without Linseed oil coating. It can be clearly seen that the Linseed oil coating dramatically cuts the surface UV sensitivity. The bare IHEP BESIII Bakelite surface has similar UV sensitivity as bare Italian

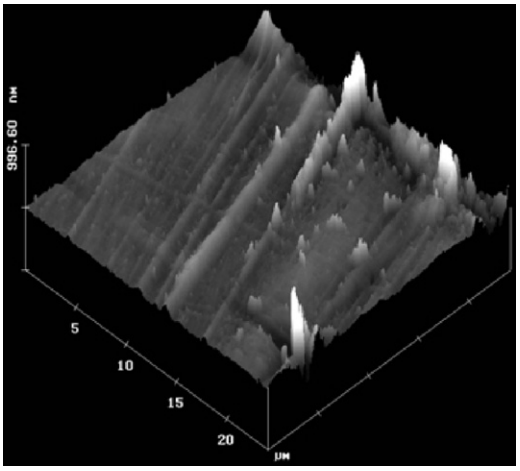

Fig. 1. AFM image of the BaBar Bakelite surface morphological structure.

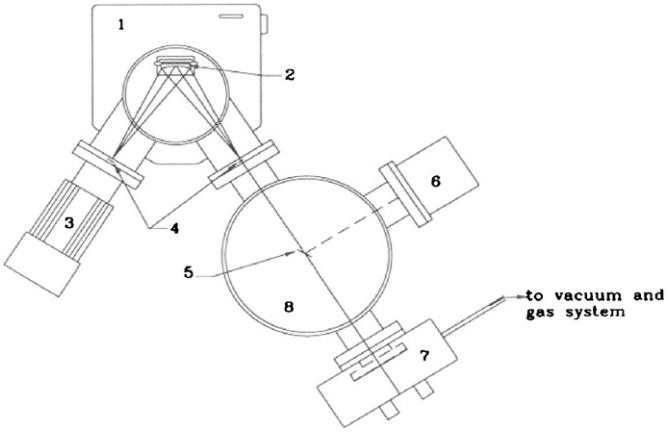

Fig. 4. McPherson VUV monochromater used in UV sensitivity test for various RPC electrodes: (1) Model 234/302 0.2 m vacuum monochromator; (2) halographic grating; (3) Model 632 deuterium lamp; (4) entrance and exit slits; (5) UV light splitter; (6) Model 654 side-on PMT with sodium salicylate screen; (7) 2-step avalanche chamber; (8) vacuum compatible sample chamber.

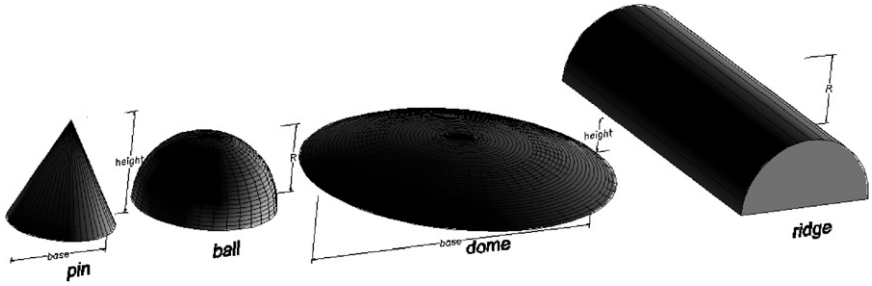

Fig. 2. Illustration of the parameters of the surface defects used in the finite element analysis calculation.

Table 1
Maximum electric field at the defect, for V=1000 V in a 2 mm gap.

	"pin"				"ball"		"dome"	"ridge"	
Height (mm)	0.010	0.010	0.010	0.002	0.01	0.002	0.01	0.01	0.002
Base (mm)	0.004	0.010	0.020	0.002	0.02	0.004	0.06	0.02	0.004
E_{max} (MV/m)	23.6	8.58	5.75	3.25	1.49	0.976	0.871	0.999	0.976

Note: In a real RPC the voltage between two electrodes is usually 8000 V, almost an order of magnitude higher than 1000 V.

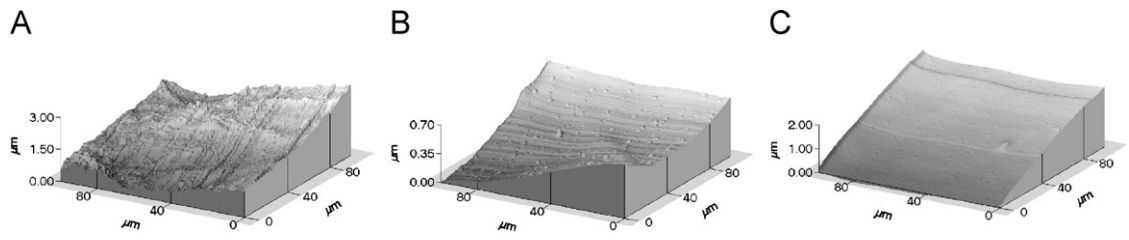

Fig. 3. Italian Bakelite surface morphology: (A) bare surface; (B) coated with 30/70 of Linseed oil/2-propanol; (C) coated with 70/30 of Linseed oil/2-propanol.