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Measurement of Radiation Damage on an Optical Reflector*

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Abstract

We measured the radiation damage on an optical white fluorocarbon reflector called Goretex which is to be used for aerogel threshold counters and crystal calorimeters of the BELLE detector of the KEK B-factory. Reflectance of the Goretex surface was monitored to see any effect of the radiation damage. Maximum equivalent dose was 8.6 MRad. No radiation damage is observed within measurement errors.

1 Introduction

Sheets of white fluorocarbon reflectors, generically named as teflons, are extensively used in high energy particle physics experiments for wrapping a range of optical detectors such as scintillating plastics, crystals and aerogel Čerenkov detectors. Such reflectors have high reflectance, and help contain the light in the detecting volume, thus increasing the number of photons collected.

With the advent of high luminosity particle accelerators, such as LHC and B-factories, radiation damage of detector materials becomes an important issue. The *equivalent dose*[§] in these experiments at a distance of 1 meter from the interaction point can reach the level of a few hundred kilorads. Reports on radiation damage tests on fluorocarbon reflectors however, have not been available. Since Goretex *porous* fluorocarbon reflectors[1] are being considered for wrapping the CsI and BGO crystals, and aerogel Čerenkov counters of the BELLE detector of the KEK B-factory[2, 3], we set forth to measure the degree of its radiation damage.

Fluorocarbon reflectors from Goretex are known to have much higher reflectance than other known reflectors, such as aluminized mylar, paper, polyethelene, polyvinyl diflorane(PVDF), cellulose acetate and cellulose nitrate. A comparison of reflectivities of such materials is given in [4]. In KEK B-factory we use *porous* fluorocarbon sheets since they have less ductility compared to their non-porous counterparts.

[§]We define the *equivalent dose* as the amount of dose that would have been absorbed by *water* if placed at the same position as the sample. *Absolute dose* absorbed by Goretex sheet is estimated to be about 10% more than the equivalent dose.

This is the first reported test of this kind on fluorocarbon reflectors.

2 Experimental Setup

Goretex sheets of thickness 0.25 mm and Spec. No. 116-027 were wrapped around small glass slides(100 mm $\times$ 30 mm $\times$ 2 mm) tightly. Reflectance of the surface was measured by counting reflected photons produced by different LEDs and collected by a Photo-multiplier tube. Schematics of the experimental arrangement is shown in Fig. 1. A light-tight plastic box contained five LEDs of different colors. The wave-lengths were 635 ± 40 nm(red), 610 ± 35 nm(orange), 585 ± 30 nm(yellow), 565 ± 25 nm(green) and 440 ± 15 nm(blue).

Each LED could be pulsed separately by an external pulser. Width of the pulse was typically 700 ns, pulse height was 0.9 to 4.0 volts, depending on the type of LED, and period was 10 ms. Light from the LEDs was guided out of the plastic box by a converging trapezoidal acrylic optical guide. The reflector was placed with its plane at an angle of 45° to the incident light. The reflected light was collected by a photo-multiplier tube (Hamamatsu PMT R1894).

Distances of the reflector from the tip of the light guide and PMT window were about 8 cm each. Tip of the acrylic light guide was a 6 mm $\times$ 6 mm square and base was a 6 mm $\times$ 40 mm rectangle. It was wrapped with aluminized mylar.

The whole system was placed in a light-tight box, which was painted inside with dull black color(Indian ink) to reduce any diffuse light entering the PMT from LEDs.

Number of photo-electrons was counted by the average charge in the pulse produced by the PMT and collected by the LeCroy CAMAC ADC 2249A. The ADC was gated by the trigger signal from the pulser. The CAMAC crate was controlled by a PC-based data acquisition system.

In order to make sure that the PMT collected only reflected light from the reflector, we removed the reflector from the box, and pulsed the LED, upon which no signal over noise was seen in the PMT. We therefore concluded that no diffuse light enters the PMT, and it sees only the reflected light.

Two reflector samples were prepared, one of which would be irradiated and the other would be kept as a reference near the irradiation area, but shielded from the radiation. In this way, reflectance changes due to environmental factors, such as humidity, temperature and dust could be cancelled out.

The γ -ray irradiation was conducted at the irradiation facility of the National Tsing Hua University, Hsin-Chu, Taiwan. The source was ^{60}Co with an activity of 1320 Curie.

Typically, 1 MRad of equivalent dose would be obtained in 1 hour. Immediately after each irradiation, the sample was taken out from the irradiation room to a near-by experimental booth where reflectance measurements were carried out.

We define *relative reflectance* as the number of photons collected by the PMT (spectral efficiency of PMT times the number of photo-electrons as calculated above)from irradiated surface to that collected from the reference (not irradiated) surface. This quantity was measured after each irradiation.

3 Results

The relative reflectance of the irradiated sample as a function of *equivalent* radiation dose (in Mega Rad) is plotted in Fig. 2. Relative reflectance is shown for different colors of light. The shaded region is the $1\text{-}\sigma$ limit of the measurement at the beginning of the experiment, *i.e.*, when the sample was not irradiated at all.

The error bars include the statistical and systematic errors. Errors are mostly systematic. The major systematic error is in placing the reflector at the right place. We can place the reflector with a translational precision of 0.5 mm and an angular precision of 4 milli-radian.

From Fig. 2 we conclude that for the Goretex fluorocarbon reflector, upto 8.6 MRad equivalent dose, there is no change in reflectance in the visible range of light(425–675 nm).

4 Summary

The Goretex fluorocarbon reflector is radiation hard upto 8.6 MRad of *equivalent dose* as far as reflectance in visible range(425–675 nm) is concerned.

This makes it fit for use in high irradiation environments, such as detectors in LHC and B-factories.

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Figure 1: Schematic diagram of the experimental set-up for relative reflectance measurement. This setup was placed inside a light-tight box.

Figure 2: Relative reflectance of the Goretex sheet as a function of irradiation dose for different visible colors. The shaded region shows the 1- σ region of the measurement before any irradiation. The left-most point for each color actually corresponds to 0 Rad, although it is plotted at a non-zero value for the sake of visibility.