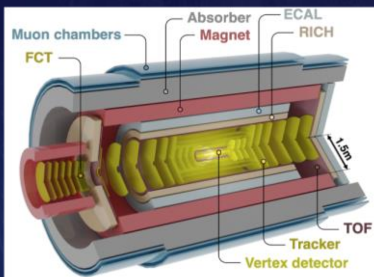
Optical Characterization of Aerogel and Anti-Reflection Coating (ARC) of SiPM for RICH Detector



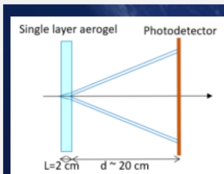
Introduction

In the context of the ALICE upgrade for Run 5, a Ring Imaging Cherenkov (RICH) detector has been proposed to perform charged Particles Identification (PID) in the momentum range 0.5-15 GeV/c. RICH detector consists of an Aerogel Radiator and Silicon Photomultipliers (SiPM) array with sensitivity to single photon in the visible range. The performance of identification particles strongly depends by the amount of Cherenkov photons detected by RICH Detector and is affected by optical properties of both Aerogel and SiPM.

The optical characterization of aerogel tiles of 10x10 cm has been performed in the wide spectrum from 250~800 nm using an Integrated Sphere (IS) setup. In addition, the reflectivity of silicon is under study, using the same set up, to verify the properties of various Anti-Reflection Coating (ARC) procedures of SiPM.

ALICE Detector

RICH Detector



General set-up of radiator in RICH Detector

The principle of RICH detector is based on the Cherenkov radiation emitted as charged particles travel through a medium at a speed larger than the speed of light in the same medium. The charged particles can be identified by measuring Cherenkov angle. So, it is important to optimize the material and its refractive index of detector.

What is ARC on SiPM?

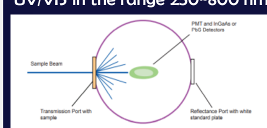
The reduction of photon reflection at the surface is very relevant for SiPM. Using anti-reflection coating at silicon to reduce the reflectance especially the multi-layer ARC on textured silicon surface with upright nano-micro pyramids, allows to increase the photodetector efficiency.

Why using Aerogel?

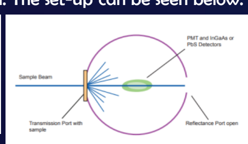
Because aerogel has a net-like structure in which pockets of air are keep statically the dispersion of the light caused by radiator in Cherenkov angle determination. Aerogel can be produced with refractive indices in the range 1.005 – 1.015. In this case, we are focusing on n=1.03 for PID in the momentum range 0.5-15 GeV/c as a good candidate.

Methodology

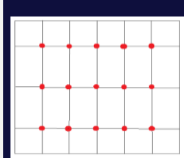
The optical properties (Transmittance and Reflectance) was measured for aerogel and silicon using Perkin Elmer Lambda 650 UV/VIS in the range 250~800 nm. The set-up can be seen below.



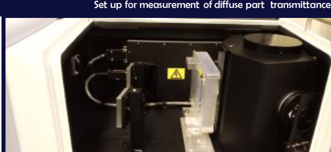
Set up for measurement of total part transmittance



Set up for measurement of diffuse part transmittance



Sampling point

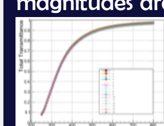


Perkin Elmer Lambda 650 UV/VIS Spectrometer

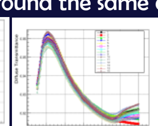
Result and Discussion

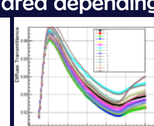
Aerogel

The measurements of %T through several aerogel were obtained by taking the 15 positions to provide information of homogeneity of the transmittance. Transmittance as a function of the wavelength was fitted by the Hunt Formula. In particular, this result show a non-uniform transmittance distribution, but the values are higher for the lower refractive index. As the large difference observed can be concluded that the differences are extremely small (about machine precision). Thus, the fluctuations within each sample could be due to simple measurement uncertainty. However, it must be noted that these fluctuations within each sample seem to occur with similar magnitudes around the same area depending on the position.

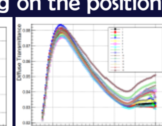


Sample LEC6-1a (n=1.03)

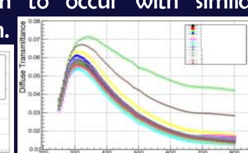




Sample LEC4-2a (n=1.03)



Sample LEC9-2 (n=1.05)



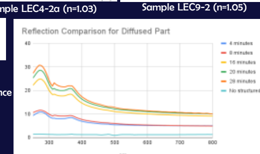
Sample LEC6-1a (n=1.03) *2nd measurement

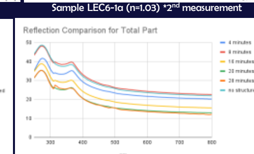
$$T(\lambda) = e^{-\frac{t}{\Lambda_{abs}}} e^{-\frac{t}{\Lambda_{scat}}} = Ae^{-\frac{B\times t}{\lambda^8}} e^{-\frac{C\times t}{\lambda^4}}$$

Hunt Formula for fit the average of transmittance

$$\Lambda_T = -\frac{t}{ln(T(\lambda))}$$

The parameters obtained from the fit of transmittance curve as a function of wavelength from this equation.





Sample Silicon structured of ARC

*times show the duration of etching

SiPM

To enhance the light trapping on silicon wafer, texturing the wafer surface by an anisotropic etching to obtain upright random nano-micro pyramidal structures is an effective approach to reduce the surface reflection. The textured silicon provides a decrease in reflection. Its reflection close to zero for the wavelength above 400 nm. The textured surface can allow the light reflected from the side of pyramids to be reflected downward and then getting a second chance of being absorbed into the silicon bulk. It is better than the bare silicon, we compared to the planar surface where the light reflected from the surface is completely lost.

Conclusion

Aerogel with low refractive index exhibits higher transmittance and transmission length which is promising for the application of aerogel as a radiator in Cherenkov detectors.

Texturing the silicon by anisotropic etching can enhance the light trapping on wafer. It is effective approach to reduce the surface reflection. The textured surface can allow the light reflected from side of pyramids to downward.

This research is still ongoing, with various samples to find the best candidate for RICH detector.

Thanks to:
A Large Ion Collider Experiment (ALICE)
Conseil Européen pour la Recherche Nucléaire (CERN)

Created by:
Almaida Firdaus
almaida.firdaus@cern.ch
Supervisor: Antonello Di Mauro

Furthermore information:
@alice_experiment
or find us on website:
https://alice-collaboration.web.cern.ch