Tailoring the Radiation Hardness of Synthetic Fused Silica

University of Glasgow

Department of Physics & Astronomy

Matthias Hoek for the PANDA Cherenkov Group

Department of Physics & Astronomy, University of Glasgow, Glasgow G12 8QQ, UK

Email: m.hoek@physics.gla.ac.uk

Introduction

Imaging Cherenkov detectors play an important role in modern particle and nuclear physics experiments. DIRC-type Cherenkov counters, pioneered by BaBar[1], allow a very compact detector design by employing solid radiator materials.

Tab. 1 Experiments planning or investigating the use of DIRC-type Cherenkov counters.

PANDA[2]	FAIR
BELLE II Upgrade[3]	KEK
TORCH[4] (proposed LHCb Upgrade)	CERN

The optical quality of any radiator material is paramount and has to withstand the radiation environment of modern high-luminosity experiments without significant degradation. Initial investigations by BaBar[5] showed that synthetic fused silica is the radiator material of choice for these applications.

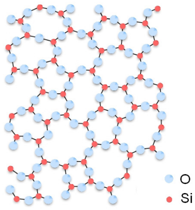

Fig. 1 2D representation of SiO_2 network in synthetic fused silica.

Investigations of the radiation hardness of different types of fused silica showed significant differences especially in the blue-UV region.

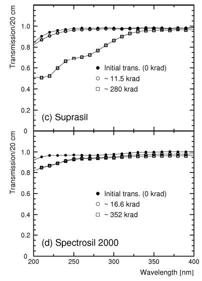

Fig. 2 Change of optical transmission of various types of synthetic fused silica[5] after irradiation. The different behaviour at small wavelengths is clearly visible.

Similar behaviour has been found under intense UV laser irradiation. Defect models indicate absorption bands at 210 nm and 260 nm. The defect mechanisms furthermore predict a dependence on the interstitial hydrogen content of the synthetic fused silica[6].

Measurements & Results

Method

Before Irradiation
- Measure optical transmission
- Measure Hydrogen level (Raman Spectroscopy)

Irradiation
- Using ^{60}Co source
- Dose of 100 krad water equivalent in ~ 4h

After Irradiation
- Measure optical transmission
- Measure Hydrogen level

Measurement Set-up

The optical transmission of a sample in the wavelength interval from 200 nm to 800 nm was measured using a Varian Cary 300 spectrophotometer.

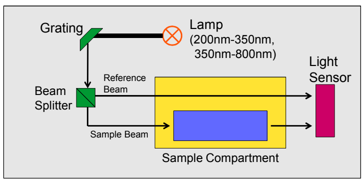

Fig. 3 Sketch of light path in the spectrophotometer.

Samples

Suprasil® 2 and Suprasil® 311 samples with different Hydrogen levels (see Tab. 2) were provided by Heraeus Quarzglas. The cylindrical samples are 100 mm long and have a diameter of 25 mm with both ends being polished.

Tab. 2 Interstitial Hydrogen content of Suprasil® 2A and 311 samples.

Suprasil® 2A	
090BP	< 1.0×10^{15} mol/cm^3
090BL	1.3×10^{16} mol/cm^3
090BN	1.4×10^{17} mol/cm^3
090BK	1.7×10^{18} mol/cm^3
Suprasil® 311	
090BF	< 0.9×10^{15} mol/cm^3
090BG	< 1.2×10^{15} mol/cm^3
090BH	1.6×10^{16} mol/cm^3
090BJ	2.3×10^{17} mol/cm^3

Transmission Loss

The normalised transmission loss ΔT' is computed according to

$$\Delta T' = 1 - \frac{T_{after}}{T_{before}}$$

Errors are estimated by taking multiple readings of each sample.

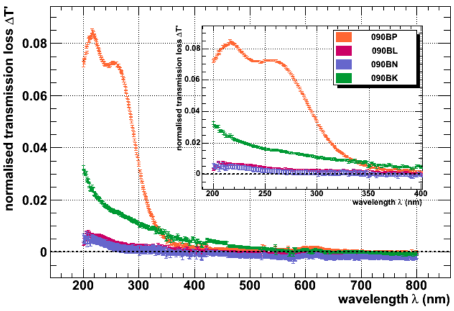

Fig. 4 Normalised transmission loss of Suprasil® 2A.

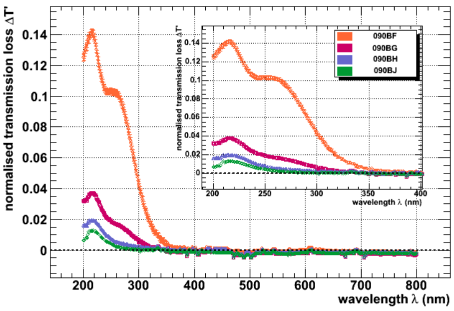

Fig. 5 Normalised transmission loss of Suprasil® 311.

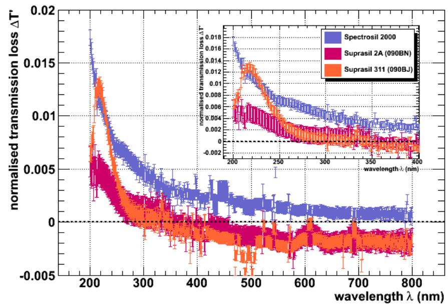

Fig. 6 Comparison of normalised transmission loss of Suprasil® 2A, Suprasil® 311 and Spectrosil 2000.

Absorption Length

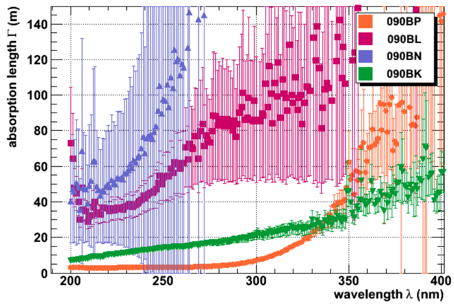

Fig. 7 Absorption length of irradiated Suprasil® 2A.

Conclusions

The obtained results show that
- Absorption length below 400 nm is severely affected,
- Radiation-induced damage depends significantly on the level of interstitial Hydrogen present,
- Very high Hydrogen levels can impair transmission properties,
- Same defect mechanisms apply for UV-laser and ionising radiation damage,
- Further irradiations (500 krad) planned to study Hydrogen consumption

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