Deeper investigation of *Dow Corning 3145* and *Bayer Silicones rtv 615* glues

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1. Complex refractive index

The deeper investigation has allowed the discovering of a systematic error affecting the previously released values of the complex refractive index of *Dow Corning 3145* (*rtv 3145*) glue. This error was due to the low quality of the air//glue interface planarity of the specimens, arising from the high viscosity of *rtv 3145*. This problem does not affect the results of all the other examined glues, because they are more liquid and the gravity was able to make flat the air//glue interface before the curing. More precisely, for *rtv 3145* the low planarity makes the result of the reflectance measurement sensitively dependent on the specimen orientation around the optical axis, nevertheless the use of the integrating sphere. Deriving the complex refractive index from the numerical inversion of Transmittance and Reflectance spectral measurements, the low planarity of the specimen results as a systematic error.

Now the true value of the refractive index of *rtv 3145* was measured by means of the prism method at the green HeNe laser, $n = 1.416 \pm 0.002$ @ 543.5 nm. Then the reflectance spectrum was repeated orienting the specimen in such a manner to obtain the true refractive index value at λ = 543.5 nm. The transmittance spectrum is almost insensitive to the low planarity of the sample.

Figure 1 compares the new evaluation of the refractive index and absorption length of *rtv 3145* with those of some glues interesting for CMS, that are *Histomount* (lately considered the best), *rtv 615* (used in monitoring 98) and *Epoxy* (the material composing the APD window). Table 1 reports: i) the refractive index at 430 nm, where the PWO scintillation is maximum; ii) the absorption length averaged on the PWO scintillation spectrum $<\Lambda>$; iii) the ratio detected on emitted photons (D/E) averaged on the PWO scintillation spectrum, the incidence angle and the polarisation *s* and *p*, calculated by

$$\frac{D}{E} = \frac{1}{4} \frac{\sum_{s,p} \int_0^{\pi/2} d\theta \int_{330}^{615} d\lambda \; T_j(\lambda,\theta)\, S(\lambda)}{\int_{330}^{615} d\lambda \; S(\lambda)} \qquad (1)$$

where $T_j(\lambda,\theta)$ is the transmittance from PWO to Si of the APD at the incidence angle θ (in PWO), and $S(\lambda)$ the average of the two PWO scintillation spectra reported in TDR97. In this simplified system PWO and Si are semi-infinite media and the interposed layers infinitely extended.

It should be stressed that the scintillation spectra reported in TDR97 represent the normalised number of emitted photons per unitary interval of wavelength. Because APD is a quantum detector, $S(\lambda)$ is the right quantity to evaluate D/E.

The APD spectral quantum efficiency (QE) is another important parameter that must be considered in the calculus of D/E. Reasonably two main factors shape QE(λ): a) the transmittance from the surrounding medium to the Si wafer and b) the QE "intrinsic" to the (doped) Si wafer. The available QE(λ) spectra are measured lightning the APD kept in air, so that such a data are not directly applicable to the case of the optical system considered for the calculus of D/E: here the

APD surface is interfaced to the glue. Equation 1 takes into account the a) factor by means of the transmittance $T_j(\lambda,\theta)$; the second factor could be deduced from QE(λ), when the correlation between QE(λ) and transmittance spectrum, measured in the same condition, i.e. in air, is known. This will be studied in the next months in collaboration with Iouri Moussienko. At the present the "intrinsic" QE is assumed unitary independently from the wavelength.

To make clear the glue effectiveness as coupling medium, table 1 first reports the ratio D/E calculated considering the APD without the protective window, i.e. the system

PWO//glue//Si_3N_4(65nm)//Si.

The comparison between the values obtained with the glue layer 0.3 mm and 1 mm thick, respectively reported in 4th and 5th columns, gives an idea of the role of the glue absorption. Finally, the last column reports D/E for the more realistic system

PWO//glue(0.3mm)//Epoxy(0.3mm)//Si_3N_4(65nm)//Si

In this case, because of the presence of the window, there is not great advantage to use glue with refractive index higher than those of *Epoxy*.

Table 1: main optical characteristics of some relevant glues for CMS

product	***n* @ 430 nm ± 0.01**	**<Λ> (cm)**	**D/E (0.3 mm) (%)**	**D/E (1 mm) (%)**	**D/E (0.3 mm) epoxy window (%)**
Histomount	1.63	> 10	12.0	12.0	11.2
rtv 3145	1.49	1.44 ± 0.06	9.4	9.1	9.4
rtv 615	1.47	> 15	9.4	9.4	9.4
Epoxy	1.57	12 ± 6	10.9	10.9	10.9

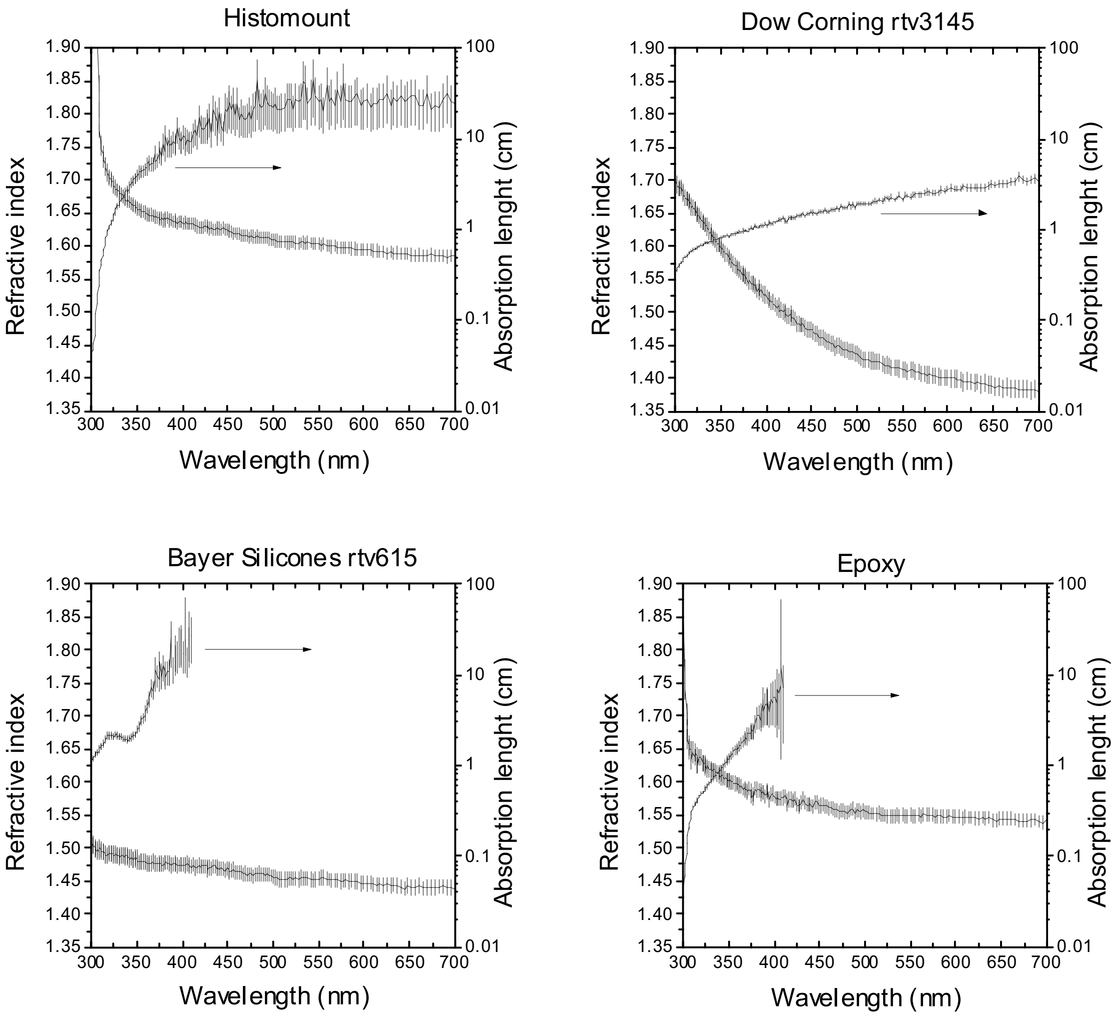

Figure 1: refractive index and absorption length of some relevant glues for CMS

2. Irradiation

Table 2 summarises the results of the irradiation of the glue specimens. In particular the last column reports D/E calculated considering the APD without protective window and the glue layer 0.3 mm thick; the corresponding value before the irradiation is reported in 4^{th} column of Table 2.

Table 2: results of the irradiation accelerated ageing tests; <Λ> is the absorption length averaged on the PWO scintillation spectrum; D/E is the ratio "detected to emitted" photons by Equation (1)

	<Λ> (cm)				
product	**initial**	**gamma** 4000 Gy	**neutron** 2 10^{13} n/cm^2	**proton** 2 10^{13} p/cm^2	**worst D/E** (0.3mm) (%)
Histomount	> 10	12 ± 3	> 10	8 ± 2	12.0
rtv 3145	1.44 ± 0.06	0.79 ± 0.02	1.47 ± 0.06	/	9.3
rtv 615	> 15	> 15	> 15	/	9.4
Epoxy	12 ± 6	8 ± 3	12 ± 6	3.1 ± 0.4	10.9

3. Thermal accelerated ageing

Table 3 reports the final results of the thermal accelerated ageing tests.

Table 3: results of the thermal accelerated ageing tests. E_a is the activation energy; *a* is the accelerated factor respect to ageing at RT; <Λ> is the absorption length averaged on the PWO scintillation spectrum; D/E is the ratio "detected to emitted" photons, Equation (1)

product	**E_a/K (ºK)**	***a* @ 110 ºC**	**after 15 years @ RT**	
			<Λ> (cm)	**D/E (0.3mm) (%)**
Histomount	7120	302	3.6 ± 0.5	11.9
rtv 3145	7440	390	1.36 ± 0.09	9.4
rtv 615	9371	1836	> 15	9.4
Epoxy	7126	303	4.8 ± 1.4	10.9

4. Conclusions

Among the considered glues *Histomount* shoes the largest D/E ratio, even if reduced because of the *Epoxy* protective window. For CMS purposes, *Histomount* can be considered radiation hard and poorly affected by the natural ageing along 15 years.

The performances of *rtv3145* and *rtv615* in terms of D/E are almost identical, even if *rtv615* is less absorbing and less sensitive to both irradiation and ageing.