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Article

Gamma and Neutron Irradiation Effects on Wavelength Shifting Materials for Nuclear and High Energy Physics Applications

Jessica Scifo ^{1,*}, Beatrice D'Orsi ¹, Francesco Filippi ², Silvia Cesaroni ², Andrea Colangeli ², Ilaria Di Sarcina ¹, Basilio Esposito ², Davide Flammini ², Stefano Loreti ², Daniele Marocco ², Guglielmo Pagano ², Adriano Verna ¹ and Alessia Cemmi ¹

¹ ENEA, Nuclear Department, C.R. Casaccia, Via Anguillarese 301, I-00123 S. Maria di Galeria, (Roma), Italy

² ENEA, Nuclear Department, C.R. Frascati, Via E. Fermi 45, I-00044 Frascati, (Roma), Italy

* Correspondence: jessica.scifo@enea.it

Abstract

Wavelength-shifting (WLS) materials are used in radiation detectors to convert ultraviolet photons into visible light, enabling improved photon detection in systems such as scintillators and optical diagnostics for nuclear fusion devices. However, the long-term performance of these materials under radiation is still a critical issue in high-dose environments. In this work, we investigated the radiation tolerance of three WLS compounds (TPB, NOL1, and SB2001), each deposited on reflective substrates (ESR and E-PTFE), resulting in six distinct WLS/substrate systems. The samples underwent gamma irradiation at absorbed doses of 100 kGy, 500 kGy, and 1000 kGy, as well as fast neutron (14.1 MeV) irradiation up to a fluence of 1.9×10^{13} n/cm². Photoluminescence and reflectance measurements were performed before and after irradiation to assess changes in optical performance. Gamma exposure caused spectral broadening in several samples, particularly those with TPB and SB2001, with Full Width at Half Maximum (FWHM) variations exceeding 10% at the highest doses. Neutron-induced effects were generally weaker and did not exhibit a clear fluence dependence. Reflectance degradation was also observed, with variations depending on both the WLS material and the deposition method. These findings contribute to the understanding of WLS material stability under radiation and support their qualification for use in optical components exposed to harsh nuclear environments.

Keywords: wavelength shifters; gamma radiation; neutron radiation; ultraviolet light; spectroscopic techniques; radiation damage; nuclear physics

1. Introduction

The detection of energetic particles is a fundamental aspect of nuclear physics, high-energy physics, and dark matter research [1–8]. A key component of modern particle detectors is the use of efficient Wavelength-Shifting (WLS) materials [9–14], which convert light from the ultraviolet (UV) region to wavelengths more compatible with the spectral sensitivity of photosensors. These materials are particularly valuable in applications such as helium-4 (⁴He) gas scintillation neutron detectors [15,16]. Detectors based on the scintillation properties of ⁴He are excellent candidates for measurements in fast neutron fields, due to the high elastic scattering cross-section of ⁴He with fast neutrons [17,18]. In this specific application, the ⁴He gas serves both as the interaction and scintillation medium. Since it emits light in the Extreme Ultraviolet (EUV) range (60–200 nm), WLS materials are employed to enhance light detection. These materials absorb the EUV photons and re-emit them in the visible range, enabling effective detection by photosensors. As with other structural and electronic

components [19–21], such detectors are often employed in mixed radiation fields containing both gamma rays and neutrons, which demands the use of high-performance materials capable of withstanding harsh environments. Therefore, to accurately assess the performance of WLS-based optical systems (i.e., thin film substrate + WLS material), detailed characterization of their optical properties before and after irradiation is crucial.

In recent years, significant efforts have been devoted to characterizing and improving the performance of WLS materials, especially in harsh radiation environments [22]. Materials like Tetraphenyl Butadiene (TPB) [23] and Nanostructured Organosilicon Luminophores (NOLs) have emerged as promising candidates for these applications. TPB has been widely used in a variety of detectors [24], while NOLs, a newer class of materials [25,26], have shown potential for overcoming some of the limitations of conventional WLS systems. NOLs combine the properties of quantum dots and organic luminophores, offering high photoluminescence quantum yield, broad absorption spectra, and tunable emission characteristics [25], making them ideal candidates for use in high-radiation environments. These WLS materials are typically coupled with Silicon Photomultipliers (SiPMs) or Photomultiplier Tubes (PMTs), which are sensitive to the re-emitted light.

The optical properties of TPB films are known to vary significantly depending on film thickness, deposition technique, and substrate type. TPB exhibits particularly high fluorescence efficiency in the excitation wavelength range of 90–250 nm, exceeding that of standard reference materials such as sodium salicylate. The emission spectrum of TPB peaks at approximately 440 nm, which closely matches the region of maximum quantum efficiency of most PMTs (around 420 nm) [27]. However, organic WLS coatings such as TPB present several drawbacks, including instability in noble gas environments, photodegradation, and a limited Stokes shift, which results in self-absorption of the emitted light [14].

Beyond TPB, NOL materials have gained attention due to their excellent energy transfer efficiency and their applicability in various systems, including plastic scintillators, luminescent solar concentrators, and photodetectors. NOLs are particularly promising for applications requiring efficient down-conversion of high-energy photons. Their broad absorption spectrum, high absorptivity, and tunable optical properties can be tailored to match the peak detection sensitivity of common photodetectors. In this study, we focus on NOL-1, a specific NOL variant, and its application in shifting EUV light to wavelengths optimal for PMT performance.

This paper investigates various WLS/substrate combinations, including TPB and NOL-1, before and after exposure to radiation. In addition, a new type of WLS material -a mixture of TPB and styrene in organic solvents, referred to as SB2001- was characterized. Six optical systems intended for use in particle detectors were studied, with reflectance measurements performed using a UV-Vis spectrophotometer and fluorescence measurements using a spectrofluorometer. The analysis primarily focused on variations in the optical response around 425 nm. Two identical batches of samples were prepared: the first was irradiated with gamma rays from a ^{60}Co source at total absorbed doses of 100 kGy, 500 kGy, and 1000 kGy, while the second was exposed to 14 MeV-neutrons at fluences of 0.96×10^{13} , 1.45×10^{13} , and 1.9×10^{13} n/cm². Following irradiation, the samples were re-characterized to evaluate how radiation exposure affected the performance of each WLS/substrate combination. The findings presented in this work contribute to a deeper understanding of the suitability and durability of different WLS materials and configurations for use in high-radiation environments, a critical factor for optimizing the design and operation of particle detectors in mixed radiation fields.

2. Materials and Methods

2.1. Samples

The study involved six groups of samples, realized by a private company, each defined by a specific combination of reflective substrate and WLS material. The coatings were fabricated using three different deposition techniques, as detailed in Table 1. Additionally, two uncoated substrate

samples (ESR and E-PTFE) were analyzed to separately investigate their intrinsic properties and the effects of radiation exposure on the bare substrates.

Table 1. Sample compositions and deposition methods.

Reflective substrate	WLS Material	Deposition Method
E-PTFE	TPB	Evaporation
ESR	TPB	Evaporation
E-PTFE	NOL1	Liquid coating
ESR	NOL1	Liquid coating
E-PTFE	SB2001	Spray coating
ESR	SB2001	Spray coating

The components consist of reflective substrates designed to enhance the photon collection efficiency of photomultiplier tubes while also providing mechanical support for the photoluminescent materials, which convert extreme ultraviolet radiation into visible light. A picture of the samples is reported in Figure 1. Two different bulk substrates were used: 3M Enhanced Specular Reflector® (ESR®) [28] and Expanded Polytetrafluoroethylene (E-PTFE) [29]. On each substrate, three different wavelength shifters were deposited using evaporation, liquid coating, or spray coating techniques: TPB, NOL1, and SB2001 (a proprietary blend of TPB and styrene in organic solvents). TPB is a widely used organic WLS, known for its strong fluorescence in the visible range when excited by UV light. It is typically deposited via thermal evaporation, forming a thin amorphous film. NOL1 and SB2001 are commercial organic fluorophores with similar spectral properties, although their detailed chemical composition is proprietary. In this study, these materials are used as functional coatings to convert UV photons into the visible range.

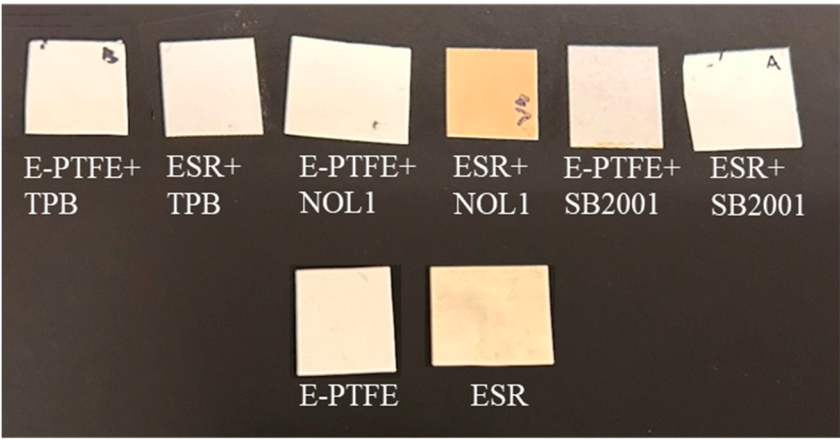


Figure 1. Photograph of one representative sample from each group, with labels.

The WLS coatings have an estimated density of $\sim 1.05 \text{ g/cm}^3$ with a nominal thickness corresponding to a surface loading of $100 \text{ }\mu\text{g/cm}^2 \pm 50\%$.

2.2. Gamma and Neutron Irradiation

Gamma irradiation tests were carried out at the CALLIOPE facility of ENEA Casaccia Research Center in Rome. This pool-type irradiation facility is equipped with a high-activity ^{60}Co gamma source enclosed in a shielded chamber ($7 \text{ m} \times 6 \text{ m} \times 3.9 \text{ m}$) [30]. The source emits two gamma photons with an average energy of 1.25 MeV and a maximum activity of $3.7 \times 10^{15} \text{ Bq}$. At the time of the experiment, the maximum available dose rate was approximately 5 kGy/h; for this study, a dose rate of 4.5 kGy/h was used.

The absorbed dose was measured using an alanine-EPR dosimetry system [31], and the values reported in this paper are referred to silicon. Samples were irradiated in air, at room temperature, and under dark conditions. They were divided into four groups, corresponding to total absorbed doses of 0 kGy, 100 kGy, 500 kGy, and 1000 kGy.

Neutron irradiation was performed at the Frascati Neutron Generator (FNG) of ENEA Frascati Research Center [32]. FNG is an accelerator-driven continuous neutron source based on deuterium–tritium (D-T) fusion reactions that produce quasi-monoenergetic 14.1 MeV neutrons isotropically, with a maximum emission rate of 10^{11} n/s. Deuterons are accelerated up to 300 kV and 1 mA and directed onto a titanium target loaded with tritium. The D-T fusion reactions produce a neutron and an alpha particle (3.6 MeV) emitted in opposite directions [33].

2.3. Optical Characterization Techniques

Reflectance measurements were performed using a Perkin-Elmer Lambda 950 UV-Vis spectrophotometer [34], equipped with an integrating sphere for diffuse reflectance analysis. All tests were carried out in air, at room temperature, and under dark conditions. The spectral range analyzed was 400–700 nm. The integrating sphere, internally coated with Spectralon® [35], enabled the collection of all reflected light with high precision. Spectralon® exhibits >99% reflectance in the 400–1500 nm range and >95% in the 250–2500 nm range [36].

Measurements were performed in relative reflectance mode. Baseline corrections were conducted using a reference sample (Spectralon® or metallic glass). The relative measurement uncertainty was estimated to be 2%.

Photoluminescence (PL) measurements were conducted using an Edinburgh Instruments FS5 spectrofluorometer [37], equipped with two Czerny–Turner monochromators: one for selecting the excitation wavelength and the other for detecting the emitted signal. The emission spectra were recorded in the 350–650 nm range. Specifically, three acquisitions were taken from different areas of each sample, and the average spectrum is reported as the result. The parameters used for the PL measurements are summarized in Table 2. Excitation was provided by a xenon arc lamp, with the excitation wavelength set to 250 nm. The wavelength accuracy of both excitation and emission monochromators was ± 0.5 nm.

Table 2. Spectrofluorometer settings for PL measurements.

Parameter	Value
Excitation λ [nm]	250
Emission range [nm]	350 – 650
Step [nm]	1.0
Dwell time [s]	0.1
Lamp	Xe
Scan slit [mm]	1.0
Emission slit [mm]	2.0

3. Results and Discussion

In this section, we report and discuss the results obtained after gamma and neutron irradiation. Specifically, we first present the outcomes of the photoluminescence (PL) measurements, followed by those of the reflectance measurements, to evaluate the optical behavior of the analyzed samples in radiation-rich environments. Optical analyses were performed on both the front surface (with the WLS layer) and the rear surface of each sample. In some cases, particularly when the WLS layer was degraded, the substrate’s contribution became visible in the optical response, likely due to the

thinness of the coating and the deposition technique employed. The final paragraph of this section addresses qualitative mechanical observations, focusing on embrittlement and detachment phenomena of the WLS layer after irradiation.

3.1. Photoluminescence Analysis

3.1.1. Gamma Irradiation Tests

We first analyzed the optical response of the bare substrates (E-PTFE and ESR), without any WLS coating. The average emission spectra for E-PTFE and ESR, normalized to their respective maxima, are shown in Figure 2 for each investigated absorbed dose. The graphs display three lines in different colors (yellow, orange and blue), each representing a distinct measurement of the same sample.

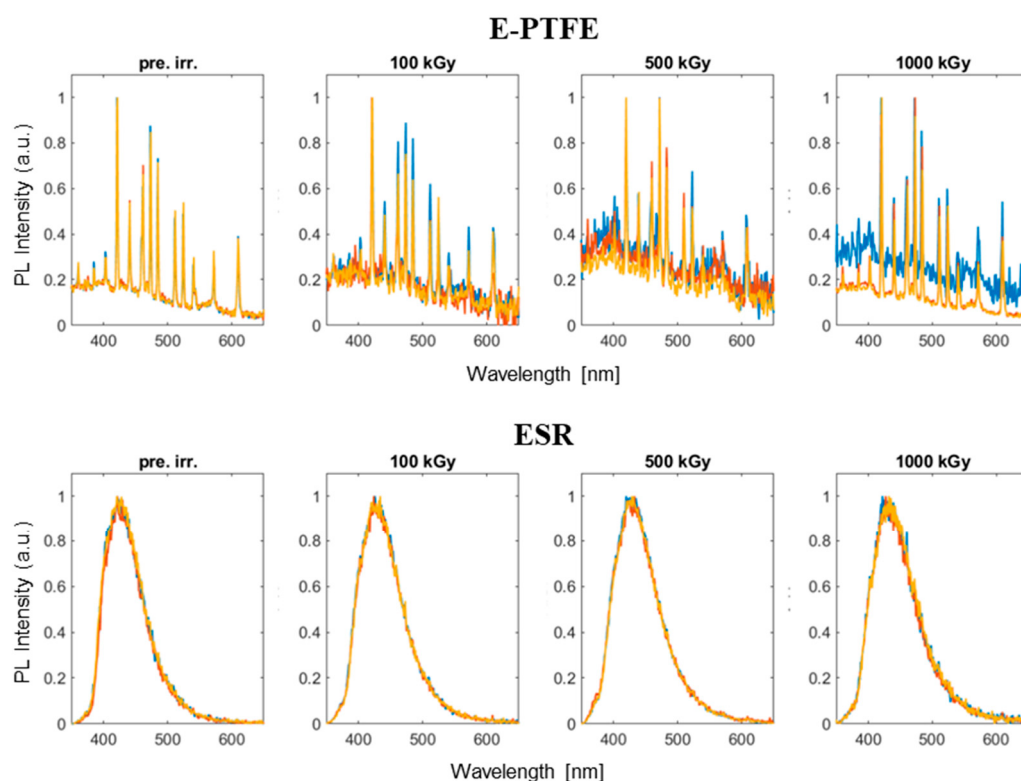


Figure 2. Normalized emission spectra of E-PTFE (top) and ESR (bottom) substrates, obtained using an excitation wavelength of 250 ± 0.5 nm, before and after gamma irradiation. The three distinct colors (yellow, orange and blue) represent three independent measurements performed on the same sample.

The E-PTFE substrate shows no significant emission in the spectral region of interest, and its emission remains unaffected by gamma irradiation. Conversely, ESR exhibits an emission peak around 420 nm, near the maximum quantum efficiency of typical photodetectors, and can therefore contribute to the total WLS signal. The unirradiated WLS/substrate samples display emission spectra qualitatively similar, in shape and peak position, to that of the ESR substrate (see ESR in Fig. 2), and the post-irradiation spectra closely align with their respective unirradiated references (data not shown). Since the spectral shapes remain largely unchanged, only the Full Width at Half Maximum (FWHM) was used as a representative parameter to quantify irradiation-induced variations and is therefore reported in the following. Figure 3 shows the evolution of FWHM as a function of absorbed gamma dose, while Table 3 lists the FWHM value for each sample before irradiation and the corresponding FWHM variations (Δ FWHM) at each dose level.

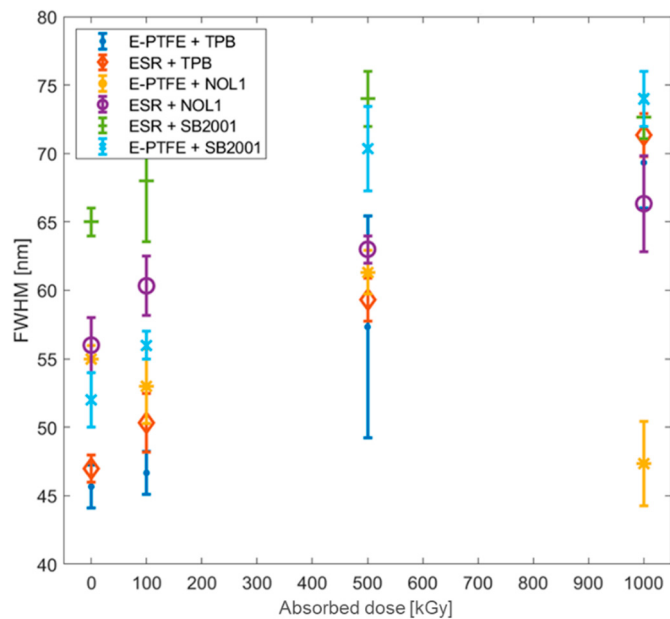


Figure 3. Variation of the FWHM as a function of the absorbed dose for each sample type.

Table 3. FWHM of the emission spectra before irradiation and Δ FWHM (nm) of the emission spectra with respect to 0 kGy for increasing absorbed gamma doses. Uncertainties are propagated from original FWHM error values.

Sample	FWHM @ 0 kGy (nm)	Δ FWHM @ 100 kGy (nm)	Δ FWHM @ 500 kGy (nm)	Δ FWHM @ 1000 kGy (nm)
E-PTFE+TPB (evaporation)	45.7 ± 1.6	$+1.0 \pm 2.3$	$+11.6 \pm 8.2$	$+23.6 \pm 3.6$
ESR+TPB (evaporation)	47.0 ± 1.0	$+3.3 \pm 2.4$	$+12.3 \pm 1.9$	$+24.3 \pm 1.9$
E-PTFE+NOL1 (liquid coating)	55.0 ± 1.0	-2.0 ± 2.9	$+6.3 \pm 1.9$	-7.7 ± 3.2
ESR+NOL1 (liquid coating)	56.0 ± 2.0	$+4.3 \pm 3.0$	$+7.0 \pm 2.2$	$+10.3 \pm 4.0$
E-PTFE+SB2001 (spray coating)	52.0 ± 2.0	$+4.0 \pm 2.2$	$+18.3 \pm 3.7$	$+22.0 \pm 2.8$
ESR+SB2001 (spray coating)	65.0 ± 1.0	$+3.0 \pm 4.6$	$+9.0 \pm 2.2$	$+7.7 \pm 1.9$

As reported in the literature [22], gamma irradiation tends to affect emission properties at total absorbed doses of approximately 500 kGy or higher. This trend is generally confirmed by our data, where most samples show significant spectral broadening (increased FWHM) at or above this dose level. Such broadening may be related to radiation-induced changes in the concentration of structural or molecular defects. According to previous studies, the linewidth of photoluminescence emission is influenced by the presence of impurities or defects, with narrower spectra typically observed in samples with lower defect densities [38]. Therefore, the increase in FWHM observed at higher doses may reflect the formation or activation of radiation-induced traps or localized emissive states, resulting in enhanced energetic disorder within the WLS layer.

3.1.2. Neutron Irradiation Tests

The PL response of the substrates (E-PTFE and ESR) following neutron exposure is reported in Figure 4.

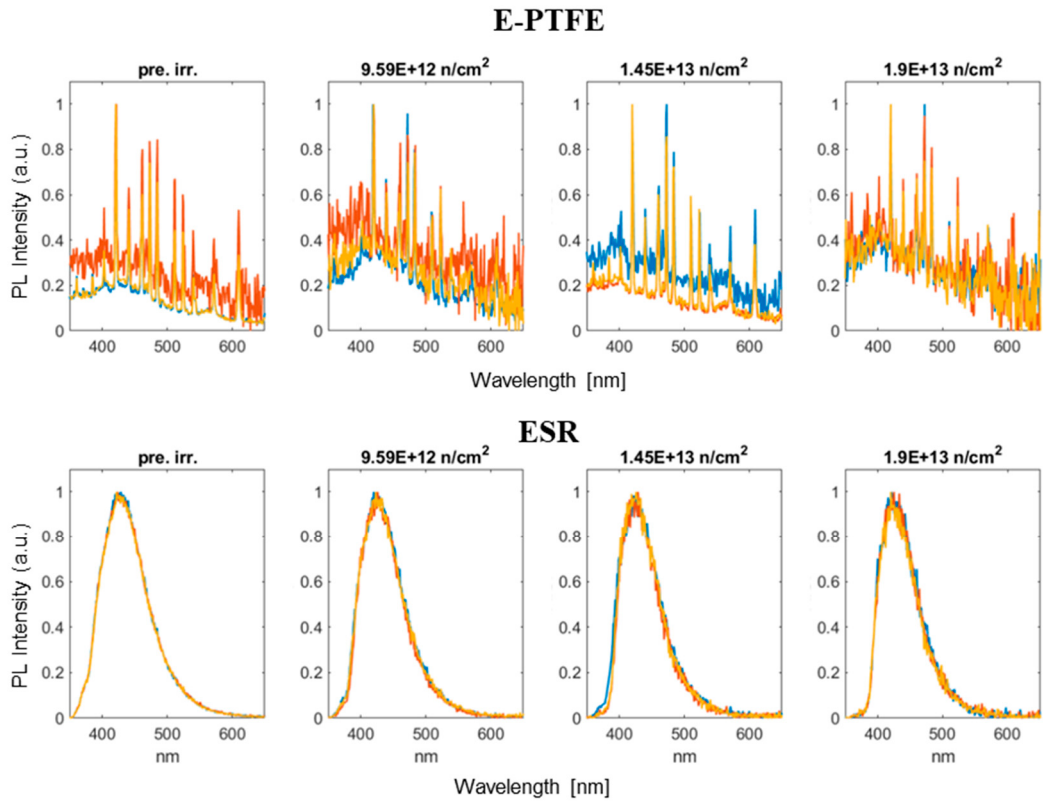


Figure 4. Normalized emission spectra of E-PTFE (top) and ESR (bottom) substrates, obtained using an excitation wavelength of $250 \pm 0.5 \text{ nm}$, before and after neutron irradiation. The three distinct colors (yellow, orange and blue) represent three independent measurements performed on the same sample.

Figure 4 clearly shows that neutron irradiation did not significantly affect the photoluminescence response of either substrate. The spectral profiles remain essentially unchanged, even at the maximum neutron fluence, suggesting that the optical emission properties of the substrates are insensitive to neutron exposure. As already mentioned in the discussion of PL behavior under gamma irradiation, the emission spectra of the WLS-coated samples resemble those of the ESR reference. Therefore, only the FWHM-based analysis is reported here to evaluate changes induced by neutron exposure. The evolution of FWHM is plotted in Figure 5, while Table 4 summarizes the FWHM value before irradiation along with the variations (ΔFWHM) at each neutron fluence level.

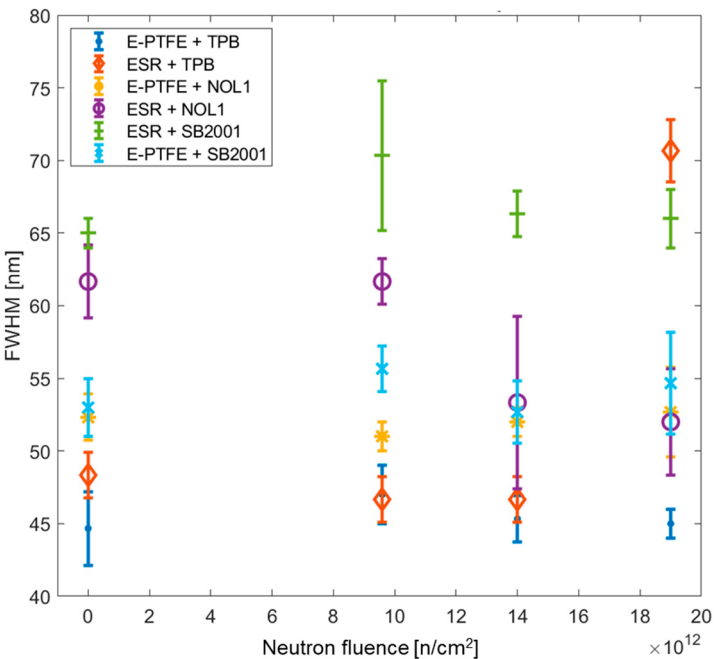


Figure 5. FWHM evolution post neutron irradiation as a function of neutron fluence level.

Table 4. FWHM of the emission spectra before irradiation and Δ FWHM (nm) of the emission spectra with respect to the not irradiated sample for increasing neutron fluence level. Uncertainties are propagated from original FWHM error values.

Sample	FWHM @ 0 n/cm ² (nm)	Δ FWHM @ 9.59×10 ¹³ n/cm ² (nm)	Δ FWHM @ 1.45×10 ¹³ n/cm ² (nm)	Δ FWHM @ 1.9×10 ¹³ n/cm ² (nm)
E-PTFE+TPB (evaporation)	44.7 ± 2.5	+2.3 ± 3.2	+0.6 ± 2.9	+0.3 ± 2.7
ESR+TPB (evaporation)	48.3 ± 1.6	-1.6 ± 2.3	-1.6 ± 2.3	+22.4 ± 2.7
E-PTFE+NOL1 (liquid coating)	52.3 ± 1.6	-1.3 ± 1.9	-0.3 ± 1.9	+0.4 ± 3.4
ESR+NOL1 (liquid coating)	61.7 ± 2.5	0.0 ± 3.0	-8.4 ± 6.4	-9.7 ± 4.3
E-PTFE+SB2001 (spray coating)	53.0 ± 2.0	+2.7 ± 2.6	-0.3 ± 3.0	+1.7 ± 4.0
ESR+SB2001 (spray coating)	65.0 ± 1.0	+5.3 ± 5.3	+1.3 ± 1.4	+1.0 ± 2.2

Except for the ESR+TPB and ESR+NOL1 samples at the highest fluence (1.9×10^{13} n/cm²), which show a marked broadening (Δ FWHM = +22.4 ± 2.7 nm and Δ FWHM = +9.7 ± 4.3 nm, respectively), all samples exhibited good stability under neutron exposure, with Δ FWHM remaining within the uncertainties. No clear fluence-dependent degradation trend is observed, suggesting that neutron-induced damage within the studied fluence range is generally limited or negligible for most WLS/substrate combinations. The spectral broadening observed in a few cases may suggest the formation of additional defect states, although to a significantly lesser extent than that induced by gamma irradiation.

3.2. Reflectance Spectra

3.2.1. Gamma Irradiation Tests

To evaluate gamma irradiation effects, reflectance at 425 nm (the region of peak efficiency for most photodetectors [39]) was studied. The difference Δ R (%) at this wavelength, representing the change in reflectance with dose, was used as a degradation indicator. Figure 6 shows the reflectance

spectra of the bare substrates (E-PTFE and ESR) before and after irradiation at absorbed doses of 100 kGy, 500 kGy, and 1000 kGy, as an example. The two materials display distinct optical behaviors. The E-PTFE substrate exhibits negligible changes in reflectance after irradiation, while the ESR substrate shows a variation of approximately 8% at 425 nm after 1000 kGy of absorbed dose. This difference can be attributed to gamma-induced surface hardening or roughening, which reduces specular reflectance and increases diffuse scattering [40,41].

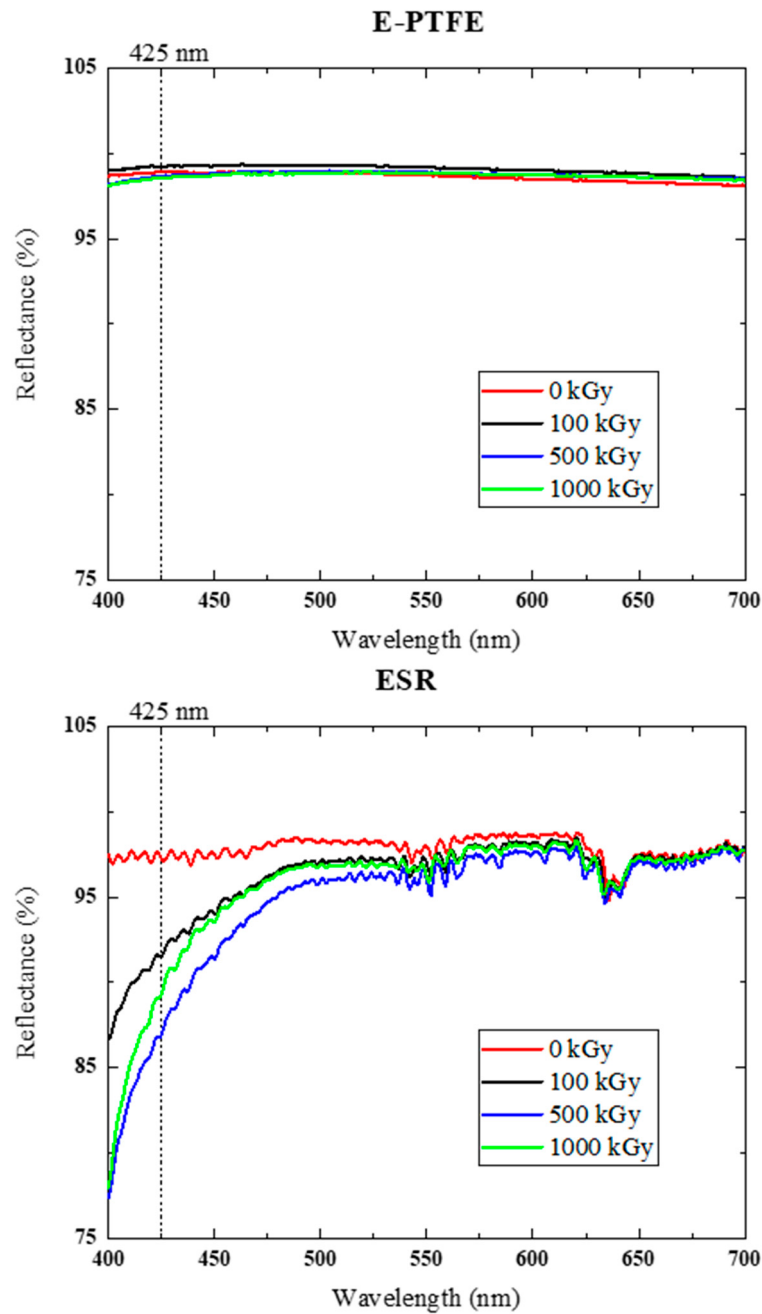


Figure 6. Reflectance spectra of E-PTFE and ESR substrates before and after irradiation. Before irradiation the reflectance values at 425 nm of E-PTFE and ESR were 98.9% and 97.2%, respectively.

Table 5 reports the R (%) values at 425 nm before irradiation for all samples, along with the corresponding ΔR (%) values at 425 nm after the different irradiation steps (100 kGy, 500 kGy, and 1000 kGy), relative to the unirradiated spectrum. Overall, all WLS-coated samples exhibited a ΔR greater than 10% at the highest dose level (1000 kGy), except for the ESR+NOL1 sample, which

showed the smallest variation. These results indicate that gamma irradiation can significantly affect optical properties such as reflectance, through various mechanisms that alter the polymer structure of the substrate or induce the formation of defects that modify the material’s band structure. Such mechanisms may include main chain degradation, chain scission, free radical formation, and cross-linking within the polymer matrix [8,42,43]. Moreover, when WLS layers are deposited on reflective substrates, gamma exposure may also alter these substrates by oxidation or by inducing changes in their microstructure, further affecting the overall reflectance and mechanical stability [44,45].

From Figure 6 it is evident that E-PTFE shows minimal change (<1%), whereas ESR exhibits about 10% change after 1000 kGy, likely due to surface roughening that reduces specular reflectance.

Table 5. Reflectance values R (%) at 425 nm before irradiation and corresponding ΔR (%) variations relative to 0 kGy, for increasing absorbed doses. Measurement uncertainty: ± 2%.

Sample	R (%) @425 nm 0 kGy	ΔR (%) @425 nm 100 kGy	ΔR (%) @425 nm 500 kGy	ΔR (%) @425 nm 1000 kGy
Substrate				
E-PTFE	98.92	0.32	-0.27	-0.34
ESR	97.22	-5.7	-10.30	-7.94
WLS/substrate system				
E-PTFE+TPB (evaporation)	98.14	-4.81	-10.56	-6.44
ESR+TPB (evaporation)	95.66	-7.60	-17.21	-28.98
E-PTFE+NOL1 (liquid coating)	98.05	-9.98	-20.54	-29.45
ESR+NOL1 (liquid coating)	96.69	0.12	-1.039	-5.56
E-PTFE+SB2001 (spray coating)	98.15	-5.97	-9.17	-13.58
ESR+SB2001 (spray coating)	96.78	-4.54	-15.57	-18.86

It is worth noting that some of the observed optical degradation, especially in samples produced via evaporation, may partly originate from pre-existing defects such as non-uniform deposition or weak WLS substrate adhesion, rather than from gamma irradiation alone. In fact, during sample handling we observed partial detachment of the WLS layer, as traces were found on the gloves after manipulation.

3.2.2. Neutron Irradiation Tests

The optical reflectance of all samples was measured before and after neutron irradiation. Figure 7 reports the reflectance spectra for the two bare substrates (E-PTFE and ESR), as an example. In this case, both substrates exhibit stable optical behavior under neutron exposure: the E-PTFE shows a ΔR (%) at λ = 425 nm of less than 1%, while the ESR substrate shows a slightly higher variation, around 1.6%.

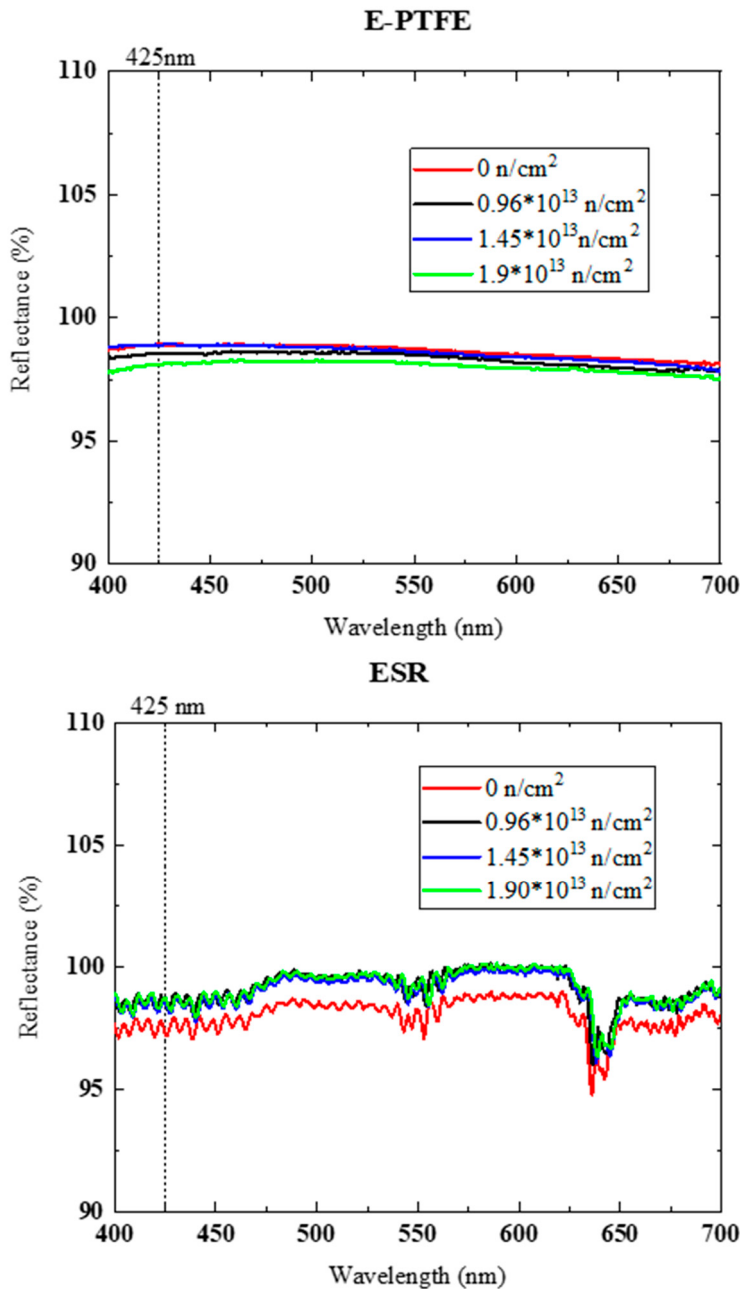


Figure 7. Reflectance spectra of bulk E-PTFE and ESR substrates after neutron irradiation. Before irradiation the reflectance value at 425 nm of E-PTFE and ESR were 98.9% and 97.2%, respectively.

Table 6 summarizes the reflectance values (R %) at 425 nm before irradiation for all samples, along with the corresponding ΔR (%) values after neutron irradiation at different fluence levels.

Table 6. Reflectance values R (%) at 425 nm before irradiation and corresponding ΔR (%) variations relative to the not irradiated sample, for increasing neutron fluence levels. Measurement uncertainty: ± 2%.

Sample	R (%) @425 nm 0 n/cm ²	ΔR (%) @425 nm 0.96 10 ¹³ n/cm ²	ΔR (%) @425 nm 1.45 10 ¹³ n/cm ²	ΔR (%) @425 nm 1.9 10 ¹³ n/cm ²
Substrate				
E-PTFE	98.92	-0.38	-0.04	-0.81

ESR	97.20	1.19	1.40	1.52
WLS/substrate system				
E-PTFE+TPB (evaporation)	98.06	-2.04	-2.30	-2.19
ESR+TPB (evaporation)	95.00	-0.09	-1.33	-0.94
E-PTFE+NOL1 (liquid coating)	97.84	0.29	-1.07	-1.07
ESR+NOL1 (liquid coating)	97.08	0.90	0.57	1.05
E-PTFE+SB2001 (spray coating)	97.84	-15.92	-16.13	-16.66
ESR+SB2001 (spray coating)	87.15	-2.38	-2.75	-2.96

Overall, neutron irradiation at the tested fluence levels did not significantly affect the optical reflectance or wavelength-shifting performance of the samples, with ΔR (%) remaining below 10% in all cases except for the E-PTFE+SB2001 sample. This limited impact is likely due to the relatively low neutron fluence employed in the current study. Higher fluences may be investigated in future work to assess potential long-term effects. The pronounced variation observed in the E-PTFE+SB2001 sample may be attributed more to the specific deposition method and WLS formulation than to neutron-induced damage. In general, neutron radiation in polymers can promote cross-linking or chain scission [46,47], potentially altering surface morphology and reducing reflectance [48,49].

In addition to the optical analyses, some qualitative observations were made on the physical appearance and integrity of the WLS coatings after irradiation. In particular, for samples prepared via evaporation, minor detachment or residue of the WLS layer were occasionally noticed during post-irradiation handling. For example, traces of material were found on gloves after manipulating certain samples, suggesting a possible weakening of the interface between the WLS layer and the substrate. While no systematic mechanical testing was conducted, these observations may point to irradiation-induced effects, such as changes in adhesion or microstructural alterations of the coating, which could contribute to the optical degradation trends described above. Further studies would be required to quantitatively evaluate the mechanical stability of the coatings under irradiation.

5. Conclusions

In this work, gamma and neutron irradiation tests were performed on wavelength-shifting coatings deposited on reflective substrates (E-PTFE and ESR), and their optical properties were characterized through photoluminescence and reflectance measurements. The E-PTFE substrate itself showed negligible photoluminescence in the spectral region of interest, making it unsuitable for direct PL analysis, whereas the ESR substrate exhibited a stable and appreciable PL signal. Regarding gamma irradiation effects, a general trend of degradation was observed in both photoluminescence and reflectance properties, with gamma doses above 500 kGy causing more pronounced spectral broadening and reflectance changes. A comparative analysis of the samples highlights that coatings deposited on ESR substrates generally performed better in terms of mechanical stability, WLS adhesion, and resistance to optical degradation under gamma irradiation. In particular, ESR+NOL1 and ESR+SB2001 samples stood out for their excellent post-irradiation photoluminescence and reflectance retention, while E-PTFE-based samples, especially those coated with TPB and NOL1, showed poor adhesion, increased brittleness, and greater sensitivity to gamma-induced damage.

Results after neutron irradiation showed that, at the tested fluence (0.96×10^{13} , 1.45×10^{13} , and 1.9×10^{13} n/cm²) levels, this type of radiation caused only minor effects on the optical properties compared to gamma irradiation. This behaviour is consistent with the relatively low neutron fluences employed, which are well below those expected in fusion reactor environments. Overall, these results indicate that the choice of substrate and WLS deposition method strongly influences both the optical and mechanical stability of the coatings under gamma irradiation, and that ESR-based samples with carefully controlled WLS layers emerged as particularly promising for radiation-rich applications. Future work will focus on extending neutron irradiation tests to higher fluence levels, more representative of fusion or high-intensity neutron environments. In addition, surface characterization using Scanning Electron Microscopy is planned to investigate gamma-induced morphological changes, such as roughening, which could explain the observed degradation in reflectance and photoluminescence properties.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding authors upon reasonable request.

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