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RESEARCH ARTICLE
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TO STUDY THE ULTRA-VIOLET RADIATION MONITORING BY USING THE GAFCHROMIC EBT3 FILMS FOR CLINICAL PURPOSES

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Introduction

Radiation is to describe the energy that is created and emitted as electromagnetic waves or particles. Electromagnetic radiation includes gamma rays, X-rays, ultraviolet (UV), visible light, infrared light waves, microwaves, and radio waves. Radiation may be classified as either ionizing or non-ionizing depending on its propensity to irradiate materials. The practical barrier between ionizing and non-ionizing radiation is about 13.6 eV, which is the energy required to ionize a hydrogen atom. The electromagnetic spectrum's ultraviolet (UV) radiation, which has wavelengths between 100 and 400 nanometers, is becoming more widely acknowledged for its dual effects, which include both possible risks and useful uses. It is essential in fields like industrial processing, disinfection, medical treatment (like phototherapy), and environmental monitoring. On the other hand, prolonged or excessive exposure to UV radiation, especially in the UVB (280–315 nm) and UVC (100–280 nm) ranges, may have negative biological consequences, such as immunological suppression, DNA damage, skin cancer, and cataracts. According to material science, UV rays cause structural damage, color fading, and polymer degradation. Radiation dosimetry analysis is used to quantify and track UV exposure accurately because of these wide-ranging impacts.

The quantitative measurement of the amount of ionizing or non-ionizing radiation that a material or biological tissue absorbs is known as radiation dosimetry. Dosimetry, as it relates to UV radiation, is the measurement of incoming energy over a surface area, usually represented in terms of radiant exposure (J/m2) or irradiance (W/m2). These factors are essential for determining the long-term effects of UV exposure, directing safety regulations, and guaranteeing the effectiveness of UV-based technology. High-precisionspectro radiometers, electronic UV sensors, and inexpensive passive dosimeters that use photosensitive materials are only a few of the dosimetric techniques that have been developed for UV measurement. Depending on the application, spectral range, accuracy needs, and environmental factors, each approach has pros and cons. To guarantee accurate dosimetric readings, it is also necessary to carefully consider the calibration, spectral sensitivity, angular response, and environmental conditions including cloud cover and air absorption. To assess any possible dangers, a thorough knowledge of the UV dosages deposited in a material is required. Solar ultraviolet radiation is the primary source of ultraviolet (UV) radiation. On the other hand, human skin illustration on figure 3.1, the immune system, and the eyes may all suffer from excessive radiation exposure. The biological effects, however, depend on the UV wavelength, exposure site, and duration. The solar ultraviolet spectrum is divided into three regions: ultraviolet A (UVA; 315-400 nm), ultraviolet B (UVB; 280-315 nm), and ultraviolet C (UVC; 100-280 nm) based on their effects on people. The remaining UVB energy is present, whereas 95% of the solar UV light that reaches Earth is UVA. Even in North America and Australia, UV light is known to be carcinogenic since it increases the chance of developing skin cancer. More than 90% of melanomas and cortical cataracts linked to UV radiation are caused by solar UV exposure. It is estimated that UV exposure causes 85,000–2,00,000 occurrences of cortical cataract events, which accounts for a 1.3%–6.9% increase in incidence. According to the World Health Organization's global sickness data, excessive sun UV exposure caused around 70000 premature deaths and 1.5 million impairments in 2000. The most common diseases are sunburn, malignant melanoma, and cortical cataracts. Underexposure to UV radiation may have health impacts hundreds of times more severe than overexposure due to vitamin D deficiency, and there are presently no risk management strategies in place to regulate this condition. As latitude decreases and altitude increases, UVC intensity rises. The zenith angle determines its intensity. As a result, the intensity varies with the day and the seasons. During the midday hours of 11:00 AM to 1:00 PM, UVC is very strong. The yearly seasons are the other factor that most affects UV intensity. The intensity reading is greatest in the summer, followed by spring and autumn, and winter, when it is lowest. Numerous dosimeter kinds are available for measuring ultraviolet doses. Although they are costly, electronic dosimeters measure UV irradiance in real time but not exposure. Gafchromic films are radiation-sensitive. A lasting alteration in their visual hue is a representation of this sensitivity. UV irradiance, UV wavelength, and exposure duration

Fig 3.1 Shown the effect on UV Radiation on Human Skin

all affect film discolouration. The concentration of light absorbed by the film's substance directly correlates with the films' blackness. External beam treatment, or EBT, EBT2, and EBT3, created three generations of Gafchromic films. The two primary advantages of EBT3 films over EBT2 are the film's symmetry and the removal of the Newton ring coating. To prevent the negative consequences of the high dosage, one must be aware of the dose of x-ray radiation. High doses of x-rays may have biological consequences, such as deterministic affects like cataracts or erythema or random effects like neoplasms in cancer. There is a threshold for seeing a biological response in tissue responses, meaning that the number of cells is impacted before the response occurs. In contrast, a single cell exhibits the radiation-induced alterations in the cancer impact. The biological process that causes the impact may be started by these modifications. The absorbed dosage may be measured using a variety of x-ray detector types, such as ion chambers, semiconductor detectors, and thermoluminescent detectors. The EBT3 films are known to have high sensitivity for measuring nonionizing UV doses and may be utilized as x-ray dosimeters is shown in the figure 3.2. Because gafchromic films are sensitive to ionizing radiation, they were first developed to measure clinical x-ray dosages. Because of their high spatial resolution, low energy dependency, and near-tissue equivalency feature, radiochromic films in general have resolved a number of issues pertaining to traditional 2-dimensional radiation detectors. Additionally, this is a benefit for measuring SUVs as opposed to traditional UV meters, which measure radiation in units of power per unit area (Wm/cm2) rather than cumulative power over time (Wm/cm2). A film-based dosimeter makes it possible to measure UV concurrently across a large area, which would be expensive if an electronics UV meter were used. The dosage ranges that these films can measure are 0.2 to 100 Gy for x-rays and up to 30 J/cm2 for UV. Designing an effective optical densitometer and obtaining a precise sense of the dosimetric film system need knowledge of the absorption spectra of EBT films. Additionally, the flatbed scanner is still the most often used tool for characterizing the color changes of EBT3 films for UV or x-ray measurements. The red component of the pictures typically yields the greatest response. Numerous published studies described EBT3 dose assessments for UV20 and x-rays and

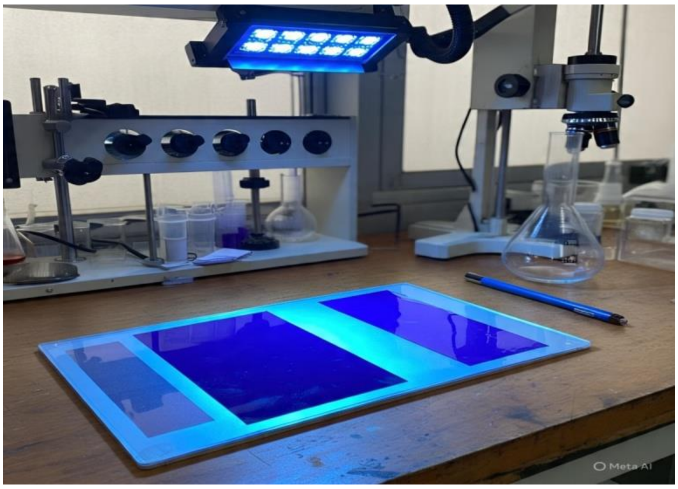

Fig 3.2 EBT3 films for measuring non-ionizing UV Radiation

developed a method for employing EBT3 to quantify SUV radiation using red LEDs. Both UVA and UVB might affect EBT3. An investigation of the EBT3 spectra exposed to x-rays with a notional energy of 6 MV was conducted by Leo´n-Marroquı´n et al.15. Despite the fact that there are several articles on the use of EBT3, there is currently no comparison examination of the films' reactions to UV and x-ray doses. Therefore, this study's goal is to examine how EBT3 films discolor when exposed to low SUV and x-ray dosages using absorbance spectroscopy measurement.

Methods & Material

Gafchromic EBT3 film finds extensive use in radiation dosimetry, particularly for ionizing radiation such as electrons and X-rays. It is less common to use it for UV (ultraviolet C, ~200–280 nm) radiation monitoring, however, and needs cautious thought. For UV monitors, gafchromic films such as EBT3 include radiosensitive dyes is shown in the figure 3.3, when exposed to radiation, change color and density.

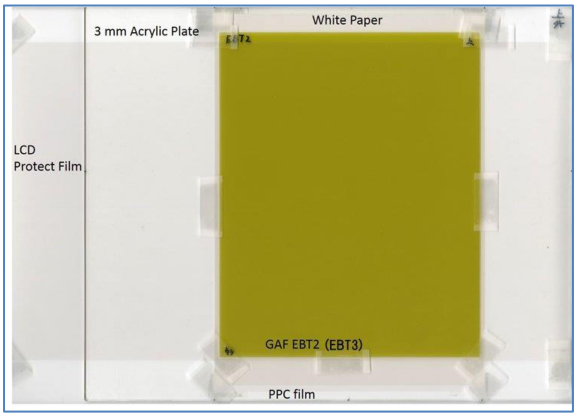

Fig 3.3 Gafchromic films such as EBT3

Despite being made for ionizing radiation, some research indicates that they are not very sensitive to high-energy UV, especially UVC (e.g., 254 nm). The main traits in response to UVC include EBT3's low sensitivity makes it much less sensitive to UVC than ionizing radiation. Threshold effect: Usually, only at higher UVC doses (>100 mJ/cm2) can a discernible color shift take place. Because of the larger reaction at shorter UV wavelengths (particularly around 254 nm, which is often employed in germicidal lamps), the nonlinear response of OD change vs. UVC dosage is typically nonlinear, saturates fast, and exhibits wavelength dependency. The following formula is used to determine a substance's optical density (OD), which is a standard way to measure how much light a material absorbs.

$OD = \log_{10}(I_0/I)$

Where,

OD: Optical Density

I_0: Incident light intensity

I: Transmitted light intensity

Polynomial Regression

A polynomial equation is used to represent the connection between the independent variable (x) and dependent variable (y) in polynomial regression, a form of regression analysis. Non-linear connections between variables are captured via polynomial regression. The complexity of the model is determined by the degree of the polynomial. Complex data sets are fitted using polynomial regression. It uses input factors to predict continuous outcomes. The advantages of polynomial regression include its ability to accurately forecast non-linear data and describe intricate connections. An effective method for examining and simulating complex data sets is polynomial regression.

$$Y = A + B1 \times X + B2 \times X^2$$

Exposure Setup:

1. Use a calibrated UVC source (e.g., 254 nm lamp).
2. Expose EBT3 films at known dose levels (e.g., 50, 100, 200, 400 mJ/cm²).
3. Ensure uniform exposure and avoid heat buildup.

Scanning Devices

1. Use a flatbed scanner (e.g., Epson V700) in transmission mode.
2. Scan in 48-bit RGB TIFF format for better precision.
3. Avoid scanner auto-corrections (disable color correction, etc.).

Results

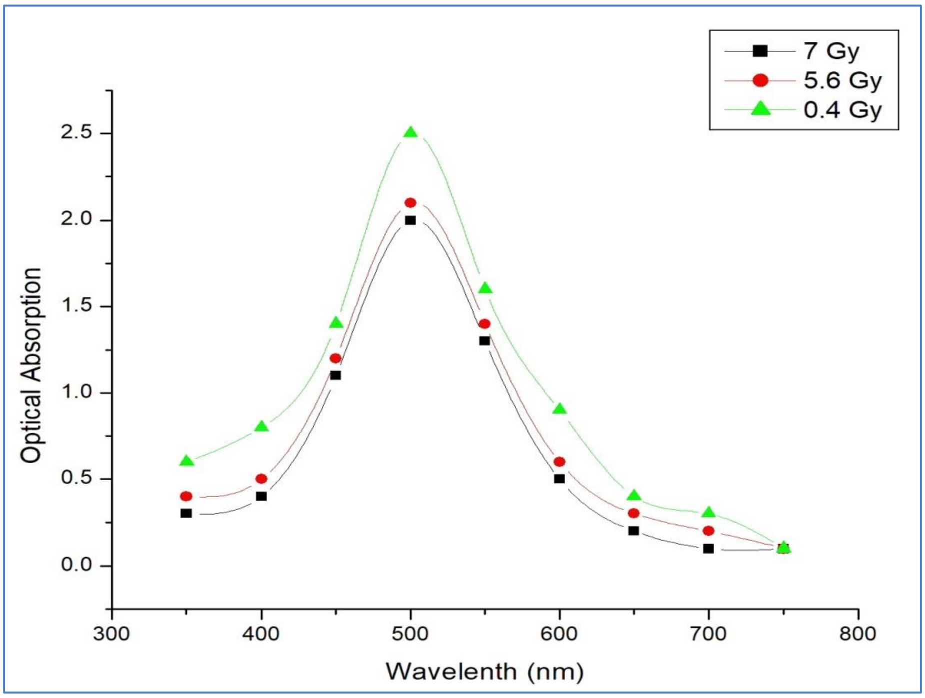

Fig 3.4 Optical Responses of Gachromic EBT 3 films

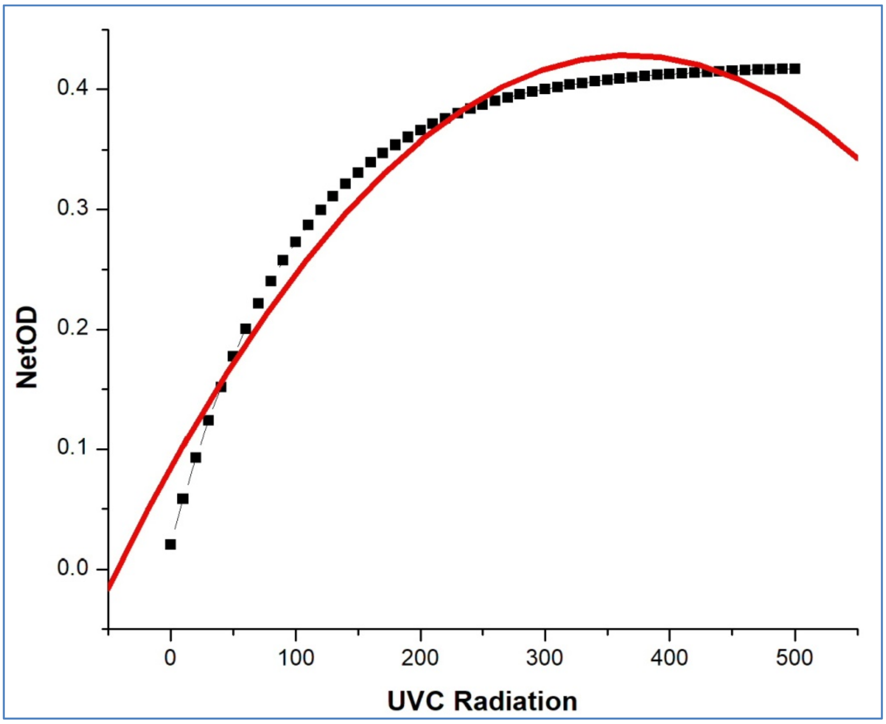

Fig 3.5 Net OD responses during UV radiation with curve fitting model

In the figure 3.4 shown that the optical absorption represents as a function of wavelength for three different radiation dose levels: 7 Gy, 5.6 Gy, and 0.4 Gy. The key observations are

Peak Absorption:

All three curves show a distinct peak in optical absorption at around 500 nm. The highest peak is for the 0.4 Gy dose, followed by 5.6 Gy, then 7 Gy.

Trend with Dose:

At each wavelength, the absorption is highest for the 0.4 Gy dose (green triangles), followed by the 5.6 Gy (red circles), and lowest for the 7 Gy (black squares). This inverse relationship implies that radiation reduces the material's ability to absorb light, possibly due to structural or compositional changes in the films .

Wavelength Dependence:

Absorption starts low around 400 nm, increases sharply to a peak near 500 nm, then gradually decreases toward 750 nm. The shape of the curve is roughly Gaussian or bell-shaped, indicating a single dominant absorption band.

Separation of Curves

The curves are well-separated, especially near the peak (~500 nm), indicating a strong dose-dependent optical property that may be useful for dosimetric or sensing applications.

In the figure 3.5 shows the relationship between UVC Radiation (x-axis) and Net Optical Density (NetOD) (y-axis). The black squares represent observed data points, while the red curve appears to be a fitted model to those data points. In this resultsinitial increase of Net OD increases rapidly with increasing UVC radiation up to ~300 rad. The plateau region observed after ~300 rad, the Ne tOD begins to level off, approaching a maximum around 0.42. A fitted curve shown the decline trend beyond ~450 rad, the red curve starts to decline, suggesting the fitted model predicts a decrease in NetOD with excessive radiation, although the data points themselves do not show much decline. Selected models tailored for saturation behavior (e.g., exponential saturation or Michaelis-Menten type) rather than high-order polynomials. After the the numerical analysis of the UVC vs. NetODcurve, represents the steepest rise in the NetOD, typically indicating the region of greatest sensitivity to UVC exposure.

1. Maximum NetOD: 0.4265
2. Occurs at UVC Radiation: 329.2 units
3. Maximum Rate of Change (Slope): 0.00393 NetOD/unit of UVC
4. Occurs at UVC Radiation: 17.8 units

Analyze the red channel, as EBT3 is most responsive here, computed net optical density (net OD) is shown in the figure 4.5

Parameter	Value	Error
A	0.08439	0.00846
B1	0.00187	7.8271E-5
B2	-2.5545E-6	1.51388E-7

R-Square(COD)	SD	N	P
0.96106	0.02094	51	<0.0001

Summary & Conclusion

EBT 3 UVC disinfection dosage verification is primarily used for surface uniformity mapping of UVC systems, relative comparisons between various UVC sources, and N95 mask reuse methods. Low sensitivity makes it unsuitable for low-dose UVC (less than 50 mJ/cm²). Because EBT3 is not UV-ionizing, results may differ from batch to batch, and environmental factors like heat and humidity may have an impact on the formation of OD. The computed findings may be used to predict the anticipated film reaction under certain UV doses or to estimate dose-to-OD models. In radiation dosimetry, gafchromic EBT3 film is often used, particularly for ionizing radiation such as electrons and X-rays. It is less common to use it for UVC (ultraviolet C, ~200–280 nm) radiation monitoring, however, and needs cautious thought. Radiosensitive dyes included in gafchromic films, such as EBT3, alter color and density when exposed to radiation. Despite being made for ionizing radiation, some research indicates that they are not very sensitive to high-energy UV, especially UVC (e.g., 254 nm). After rising quickly at first, the curve peaks at around 330 rad of UVC before plateauing or slightly declining. The reaction is most sensitive and dynamic (highest slope) in the area prior to 100 rad of UVC. If used as a sensor or dosimeter, this area is perfect for calibration limits since the response saturates after 300 rad. Dose-dependent optical absorption is shown by the gafchromic EBT 3 films, where increased absorption results from lower radiation doses. In radiation sensing or dosimetry, where optical characteristics are utilized to estimate absorbed dosage, this behavior may be helpful. The shift or alteration in peak absorption may be a sign of electrical or structural alterations brought on by radiation exposure. This implies that when radiation dosage increases, optical absorption falls. This dose-response curve is often seen in sensor calibration or radiography dosimetry investigations. A photochemical or photophysical response to UVC exposure is suggested by the rise in Net OD. The plateau shows that the substance or sensor has attained saturation, or its highest detectable response. The mathematical model used may have overfitted or applied a polynomial or Gaussian-type fit beyond the range of the data, which would explain the fall in the red curve (which is not represented in the data). According to the results, gafchromic films are UV-sensitive and may be used to measure doses up to around 300–400 rad. If this range is exceeded, either the film material is saturated or offers no more detectable reaction.