gafchromic™ ebt-xd films

self-developing film for the quantitative measurement of absorbed doses of ionizing radiation

description

Gafchromic™ EBT-XD is designed for the measurement of absorbed doses of ionizing radiation. It is particularly suited for high-energy photons. The dynamic range of this film is specifically designed for best performance in the dose range from 0.4 to 40 Gy, making it most suitable for applications such as SRS and SBRT. The use of Gafchromic™ MD-V3 or HD-V2 films should be considered for measurement of doses >50 Gy. The structure of Gafchromic™ EBT-XD radiochromic film is shown in Figure 1. The film is comprised of an active layer, nominally 25µm thick, sandwiched between two 125 µm matte-polyester substrates. The active layer contains the active component, a marker dye, stabilizers and other components giving the film its near energy-independent response. The thickness of the active layer will vary slightly between different production lots.

matte surface clear polyester base, 125 µm
active layer, 25 µm
matte surface clear polyester base, 125 µm

figure 1. structure of Gafchromic™ EBT-XD dosimetry film

key features and benefits

- dynamic dose range: 0.1 Gy to 60 Gy
- optimum dose range: 0.4 Gy to 40 Gy, best suited for applications such as SRS and SBRT
- develops in real time without post-exposure treatment
- energy-dependence: minimal response difference from 100keV into the MV range;
- near tissue equivalent
- high spatial resolution – can resolve features down to 25µm, or less
- proprietary technology incorporating a marker dye in the active layer:
  – enables non-uniformity correction by using multi-channel dosimetry
  – decreases UV/light sensitivity

The yellow marker dye incorporated in EBT-XD, in conjunction with an RGB film scanner and FilmQA Pro™ software[1-3], enables the dosimetry process to benefit from the application of triple-channel dosimetry.

To learn more about FilmQA Pro™ software and multi-channel film dosimetry, visit https://www.ashland.com/industries/medical/filmqa-pro-software.

performance data & practical user guidelines

Gafchromic™ EBT-XD film can be handled in interior room light for short periods without noticeable effects. However, it is suggested that the film should not be left exposed to room light for hours, but rather should be kept in the dark when not in use. When the active component in Gafchromic™ EBT-XD film is exposed to radiation, it reacts to form a blue colored polymer with absorption maxima at approximately 633 nm.

Gafchromic™ EBT-XD dosimetry film is recommended for use with a 48-bit (16-bit per channel) flatbed color scanner. The Epson* Expression 10000XL, 11000XL, and 12000XL Photo scanner are the recommended models. These are color scanners and measure the red, green, and blue color components of light transmitted by the film at a color depth of 16 bit per channel. These Epson* scanners are particularly recommended due to their large scanning area.

specifications

property	Gafchromic™ EBT-XD film
configuration	active layer (25 µm) sandwiched between 125 µm matte-surface polyester substrates
size	8" x 10", other sizes available upon request
dynamic dose range	0.1 to 60 Gy
energy dependency	<5% difference in net optical density when exposed at 100 keV and 18 MeV
dose fractionation response	<5% difference in net optical density for a single 25 Gy dose and five cumulative 5 Gy doses at 30 min. intervals
dose rate response	<5% difference in net optical density for 10 Gy exposures at rates of 3.4 Gy/min. and 0.034 Gy/min.
stability in light	$<5\times10^{-3}$ change in optical density per 1000 lux-day
stability in dark (preexposure)	$<5\times10^{-4}$ optical density change/day at 23 °C and <2x10-4 density change/day refrigerated
uniformity	better than ±3% in sensitometric response from mean; dose uniformity better than ±2% with FilmQA Pro™ software and triple-channel dosimetry

The typical dose response of EBT-XD film on an Epson* 10000/11000XL scanner is shown in Figure 2.

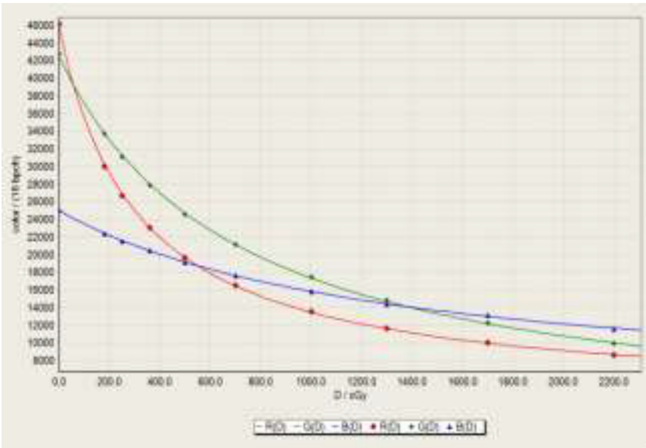
We recommend to fit the calibration curve to a function having the form $d_x(D) = a + b/(D-c)$ where dx(D) is the optical density of the film in scanner channel x at dose D, and a, b, c are the equation parameters to be fitted. The advantages of this type of function are:

- simple to invert and determine density as a function of dose, or dose as a function of density:
- has a rational behavior with respect to the physical reality that the density of the film increases with increasing exposure yet approaches a near constant value at high exposure. Polynomial functions characteristically have no correspondence to physical reality outside the data range over which they are fitted.
- since these functions have the described rational behavior, fewer calibration points are required saving time and film: a typical case would use 6-8 points (including unexposed film) with the doses in geometric progression.

Detailed instructions defining the optimum procedure for scanning radiochromic film, establishing a calibration curve using FilmQA Pro™ software and obtaining dose measurements from an application film are contained in the document Efficient Protocols for Calibration and Dosimetry Films. The procedures described have been thoroughly validated and are in widespread use in the medical physics community providing dose measurement uncertainty at ± 2%.

performance comparison between Gafchromic™ EBT3 and EBT-XD

As mentioned earlier, Gafchromic™ EBT-XD is specifically designed to obtain optimum results for the applications of SRS and SBRT. The high dose associated with these applications poses challenges when using EBT3[3,4]. The two



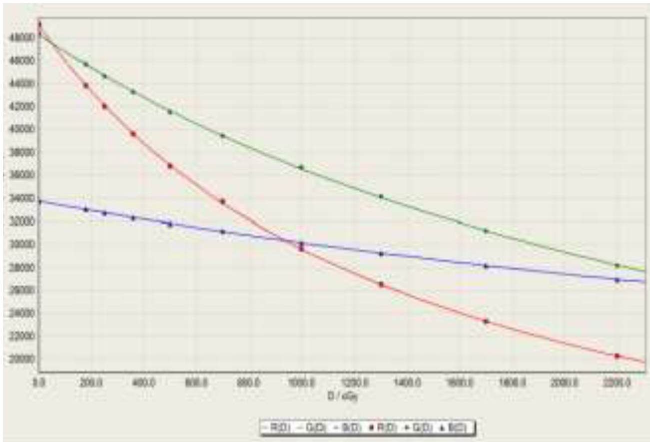


figure 2. Comparison of Calibration Curves of Gafchromic™ EBT3 (top) and EBT-XD (bottom) films

main problems are the increased dose uncertainty at high dose and the impact of the lateral response artifact for wide exposure fields[6-10].

Due to the chromatic nature of Gafchromic™ film, there is no clear color saturation point. This is an advantage when FilmQA Pro™ software is used for the dosimetry analysis, since the use of the three available color channels effectively extends the dynamic range of the film. However, a shallow slope for the dose response curve can cause causes increased dose uncertainty in the high dose region. As seen in Figure 2, EBT-XD film provides steeper slopes of the red and green response functions than EBT3 at higher doses and is therefore more desirable for measurements at doses >10 Gy.

As noted in many publications[6-9], flatbed scanners used for radiochromic film measurement exhibit a lateral scan artifact (LRA), i.e., the color value measured varies depending upon the location of the film placement relative to the center of the scanner. Typically, film scanned away from the center location appears to have greater optical density resulting in a higher calculated dose. The deviation also increases with increasing dose.

The LRA occurs for two reasons. The major cause is the polarization of light transmitted by the film and its subsequent interaction with the mirrors in the optical train of the scanner. Upon exposure, the active component in the film polymerizes to form a colored polymer that polarizes transmitted light[10]. On a flatbed scanner the polarized transmitted light is guided to the CCD detector by a series of mirrors and a lens. At the lateral center of the scan area rays are incident normal to the plane of the mirrors, but the angle of incidence increases as the distance from the center increases. As the rays transmitted by the film pass through the optical system the reflectivity of the mirrors is influenced by the angle of incidence of the polarized light. As a consequence, for films with the same transmission placed at the lateral center and side of the scanner, the detected signal will be greater at the center and diminish towards the side of the scanner. A smaller effect, due to the geometry of the optical system in flatbed scanners, results in an increase in the path-length of light through the film towards the lateral edges of the scanner. By the Beer-Lambert Law, this causes transmission to decrease with increasing distance from the center of the scanner, reinforcing the effects caused by polarization[9].

For a given intensity of transmitted light at a given lateral location, it has been found that the LRA for EBT-XD and EBT3 films is have identical[9]. However, because the response of EBT-XD is smaller than for EBT3 at the same dose, the impact of LRA on dose measurement is reduced. For this reason, EBT-XD is preferred over EBT3 for measurement of doses >10Gy.

references

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