GafChromic® EBT2 and EBT3 Films for Ball Cube II Phantom

Introduction:

These EBT2/EBT3 films, shown in Figure 1a-c, are specially sized and formatted to uniquely fit the Accuray Ball Cube II Phantom. Each package contains equal numbers of Axial and Sagittal films. Individual Axial and Sagittal films have slits cut across half their width enabling pairs of the films to interlock and fit in the phantom. In addition to these accurately formatted films each package contains a number of rectangular Calibration strips which are intended to be used for calibration and application of the "One-scan" dosimetry protocol.

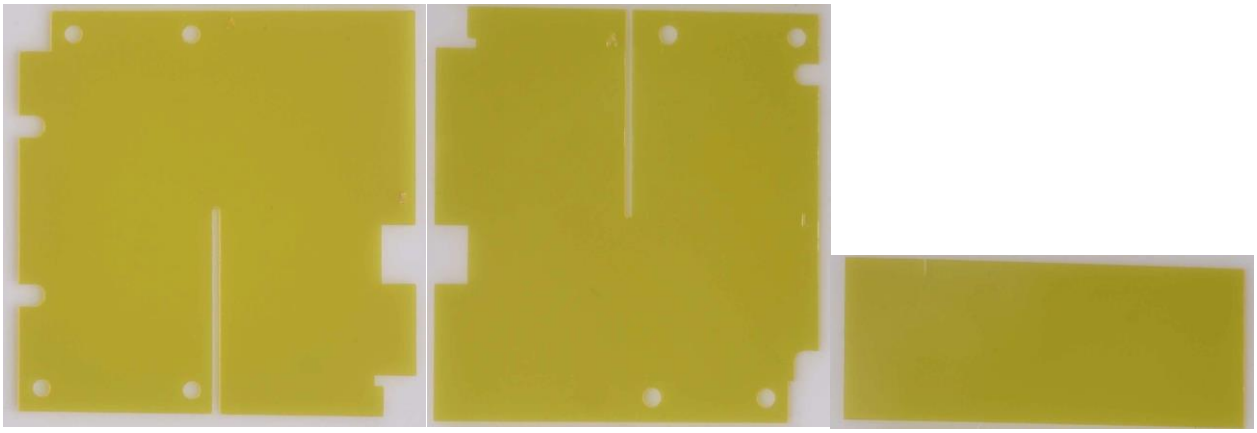

Figure 1a-c: Axial and Sagittal Films and Calibration Strips

The cross-sectional structures of EBT2 and EBT3 films are shown in Figure 2a and 2b. The active layer is the same in both films, but EBT3 is symmetrical while EBT2 is asymmetric. A second difference is that EBT3 has a matte polyester substrate as opposed to the smooth polyester in EBT2 film. The advantage of the matte polyester is that it has microscopic silica particles embedded in the surface. When EBT3 film is placed on a flatbed scanner the treatment keeps a gap of several microns between the film and the glass window preventing the formation of Newton's Rings interference patterns.

Matte Polyester - nominal thickness 50 microns
Acrylic adhesive - nominal thickness 20 microns
Active Layer - nominal thickness 28 microns
Smooth Polyester - nominal thickness 175 microns

Figure 2a: Cross section of EBT2 film

Matte Polyester - nominal thickness 125 microns
Active Layer - nominal thickness 28 microns
Matte Polyester - nominal thickness 125 microns

Figure 2b: Cross section of EBT3 film

The sheet is intended for exposure with the treatment plan while the strip is for the exposure of a reference dose. With this arrangement the reference and treatment films are in perfect correspondence and by scanning the two films together with a strip of unexposed film (also included in a box) and using FilmQA Pro film dosimetry software, all the advantages of the "One-Scan" protocol are available. These include the elimination of scan-to-scan variability caused by a number of factors and the mitigation of scanner and film artifacts.

Most importantly the "One-scan" measurement protocol accommodates the post-exposure changes of the exposed film and permits measurement results to be obtained within a few minutes of an exposure. The result is more reliable dosimetry, accuracy better than 1% and faster turnaround. Waiting overnight for results is no longer necessary.

Key technical features of EBT2/EBT3 films include:

- High spatial resolution – can resolve features to at least 25μm;
- Low energy-dependence and near water and tissue equivalent;
- No angular dependence of dose response;
- Measure with an economic flatbed color scanner;
- Dose range: up to 50 Gy;
- Develops in real time without post-exposure treatment;
- Active layer incorporates a yellow dye:
    - Enables multi-channel dosimetry;
    - Decreases UV/light sensitivity;
- Follow "One-scan" measurement protocol to obtain dose measurement with better than 1% accuracy within a few minutes of exposure;
- Water resistant, can be immersed in water phantoms;

GAFCHROMIC EBT2/EBT3 films contain a yellow marker dye. Used in conjunction with an *rgb* film scanner and FilmQAPro™ 3.0 software, the marker dye enables all the benefits of multichannel dosimetry.

- Separates each film image into a dose-dependent and a dose-independent part;
    - Compensates for film and scanner-related artifacts;
    - Compensates for lateral response variations on CCD scanners;
    - Compensates for dust, scratches, fingerprints etc. on the film and scanner;
- Calculates dose consistency maps from all calibration film and treatment film images. This unique feature puts you in control by evaluating the reliability and integrity your entire film dosimetry process;

To learn more about FilmQAPro software, multi-channel film dosimetry and dose consistency maps visit www.FilmQAPro.com For more details on GAFCHROMIC EBT2/EBT3 obtain copies of the White Papers posted at www.gafchromic.com or at www.FilmQAPro.com

Figure 3 shows a typical dose response for EBT2 and EBT3 films measured in transmission on an rgb scanner. Note that the slopes of the response curves are different for each color channel. In general any measured response is comprised of a dose-dependent and a dose-independent portion. The dose-dependent part of the response in each color channel behaves exactly as described by the calibration functions while the dose-independent part of the response can be considered as a part of the signal common to all channels. The FilmQAPro software application separates any image into its dose-dependent and dose-independent portions before calculating a dose-map. The theory behind multi-channel dosimetry has been described in a recent paper by A. Micke et al., published in Medical Physics, Volume 38(5), p2523, 2011

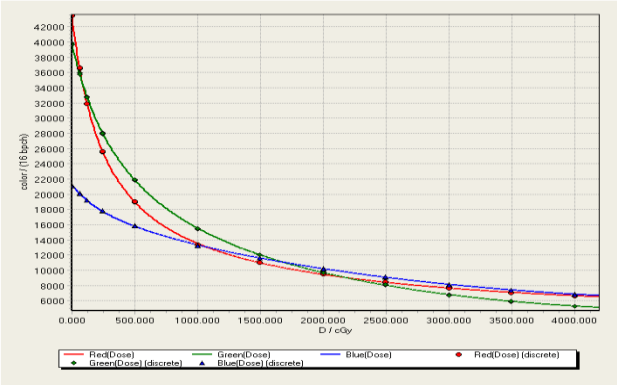

Figure 3: Typical response of EBT2/ EBT3 films in all color channels (Epson 10000XL scanner)

Figure 4 shows the response of both types of film are dependent on the orientation on the scanner. This behavior results from the needle-like shape of the particles of active component and their preferential alignment parallel to the short edge of the film. As a result, all films must be scanned in the same orientation. To help with this each Calibration strip is marked with a slit parallel to the short side while Axial and Sagittal films have the long slits previously described. Always place the films with their slits pointing in the same direction and never mix orientations. The choice is up to the user, but we recommend scanning with the slits parallel to the scan direction as in Figure 5 since this maximizes the number of film that can be scanned together. The films for the Ball Cube II phantom are intended to be used in their formatted forms, but if any film is to be cut to a different shape/size it is essential to mark each piece so it can be placed in the correct orientation for scanning.

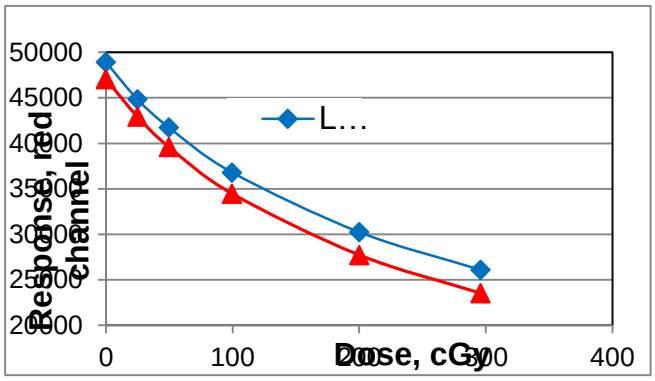

Figure 4: Responses of GAFCHROMIC EBT2/3 films are orientation dependent

Menegotti et al., Medical Physics, Vol. 35(7), p3078-85, 2008 pointed out the lateral scan artifact on CCD scanners. This established the importance of placing the film at the center of the scanner in the direction perpendicular to the scan direction to minimize the artifact. Further mitigation is provided by the multichannel dosimetry method in FilmQAPro software. Figure 5 illustrates the correct central placement on the scanner.

Figure 5: Film placement on the scanner

Calibration

For calibration, the goal is to determine the **average response** of the film over the desired dose range. To achieve this we recommend exposing the film strips to known doses at the center of a large uniform irradiation field. The beam quality for calibration should be chosen so that film response is the same under calibration and measurement conditions or the relative responses to the two beams has been determined. Using calibration strips exposed at the center of a 10cm x10cm should provide a uniform area of at least 25 cm^2 for measurement.

The best way to do calibration is to use the "One-scan" calibration protocol as described below together with FilmQAPro software. The software offers the preferred class of rational fitting functions for calibration. The simplest function has the form $X(D,n) = a + b/(D-c)$ where X(D,n) is the response of film in scanner color channel n at dose D and a, b, and c are the coefficients to be fitted. This function usually provides the best fit for doses up to about 10 Gy, but for higher doses the function $X(D,n) = (a + bD)/(D+c)$ is often preferred. Both functions are asymptotic which is to say that response approaches a constant value at high dose just as the changes in optical absorbance of film decrease with each dose increment. Since the shape of the functions fit the general behavior of film relatively few data points are needed to adapt to the manner of a specific film. This contrasts strongly with the behavior of polynomial functions which have little correspondence to the characteristics of film even though perfect correlation between N calibration doses and responses results from using an Nth order polynomial. While there can be perfect correlation at the calibration points the polynomial functions characteristically oscillate between data points and are not correctly descriptive of the physical response of film to radiation dose.

Another benefit is that the preferred fitting functions are more economical of time and materials. Since only three coefficients need to be defined as few as three data points is sufficient. However adding an extra point or two allows a quantitative evaluation of the goodness of the fit and bad data points to be excluded.

For calibration the data points and fitting should be optimized for the dose range. A common practice would be to calibrate from zero to dose D and use one calibration function for the whole range, but a better approach would be to select and fit dose response data for selected portions of the range. For example if the focus is on measurements from 10–30 Gy then spread most of the doses over that range. Whereas if another goal is to measure doses from 0-10 Gy then the calibration doses should restricted to that range.

The "One-Scan" Protocols

FilmQAPro software and EBT2/ EBT3 are specifically designed for the "One-scan" protocols - Med. Phys., Volume 39(10) p6339-50, 2012. White papers describing the protocols can be downloaded at www.filmqapro.com By combining measurement with calibration, and eliminating inter-scan variables, the "One-Scan" measurement protocol improves dose accuracy to better than 1%. And because it allows scanning within a few minutes of exposure there's no more waiting overnight for your results. By using multi-channel dosimetry you automatically correct film and scanner artifacts and you get immediate feedback on the integrity of your measurements by using the consistency maps to display the correspondence of the doses from the color channels. You get three sets of measurements - three gamma maps, three DTA maps, three iso-dose maps, etc., and consistent values signify reliable dosimetry, while differences warn of possible errors. Together with high spatial resolution, water/tissue equivalence, minimal energy dependence and no angular dependence these advantages make EBT2/EBT3 and FilmQAPro the ideal way for Cyberknife QA.

GafChromic: Product code 64410467157

Box contains: Ten Axial/Sagittal film pairs formatted for insertion in Ball Cube II phantom plus twelve 15x23 mm calibration strips