Characterization of EBT versus MD55 Gafchromic ® films for relative dosimetry measurements

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Abstract

Gafchromic® film model MD55 has been used for several years as a relative dosimeter for analyzing isodose distributions by the Radiological Physics Center (RPC). The newer model EBT provides several advantages: It is available in larger sizes and is suitable for lower dose ranges compared to model MD55.

Important characteristics of the new model such as fading, light sensitivity, temperature effects and energy dependence have been measured and compared against those of MD55.

Both models show similar light sensitivity and fading; however, EBT shows greater energy dependence than does MD55.

Model EBT showed a monotonic response over the measured dose range from 0 to 15Gy.

Our analysis shows that the overall uncertainty in prediction of relative dose using EBT ranges from 1.5 to 3.5 % depending on the dose value of normalization.

Methods and materials

EBT and MD55 films were irradiated to doses ranging from 0-15Gy and 0-40Gy, respectively. Photon beam energies of 6 and 18 MV were used to study dose response and energy dependence. Irradiation were done with a solid water phantom at an SSD = 100cm, 10 cm x 10 cm field size, depth of dmax (1.5cm for 6MV and 3.3 cm for 18MV).

MD55 films were scanned using a 665nm light-emitting diode (LED) diffused light-bed charge-couple device (CCD) densitometer (CCD100 Microdensitometer, Photoelectron Corporation, North Billerica, MA). EBT films were scanned at 636nm. EBT films were corrected with a flat field from an un-irradiated film and a black mask covering the area of the light box outside the film. MD55 scans were corrected with a flat field of the light box alone and films were read with no mask. These difference in procedures were established to reduce noise on EBT scans.

For each condition two pieces of each film (3cm x 3cm) were used. For each value under analysis three reading were taken from each piece of film and the average was used.

Some relevant characteristics were measured and compared.

Fading

The relation between net OD and time after irradiation was analyzed (fading).

Both type of films of were irradiated at 5Gy level on a 6MV photon beam. Readings were taken from 2 to more than 20 days after irradiation. Figure 1 shows the relation.

Materials/Methods continued

Uncertainties in the measurements were in the third decimal place of the OD reading.

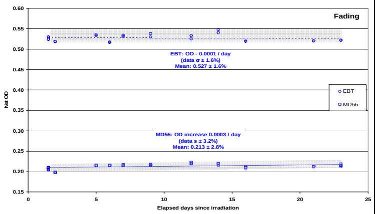

Fig.1: Fading analysis for MD55 and EBT films irradiated at 5Gy with a 6MV photon beam. Gray area represents the range of the measured data.

Light sensitivity

A light effect study was performed. Pieces of both types of films were irradiated to different dose levels and then were exposed to fluorescent light of 40 watts at a distance of 13 cm from the tube for up to 6 hrs. MD55 shows an increase of the net OD of 0.6% per hour of exposure, independent of the dose level. EBT shows a change of 1.2% and 0.2% per hour of exposure at 0 Gy and 5Gy level, respectively. All these corrections are negligible compared with the uncertainty of the reading. Results of light sensitivity measurements are shown in Figure 2.

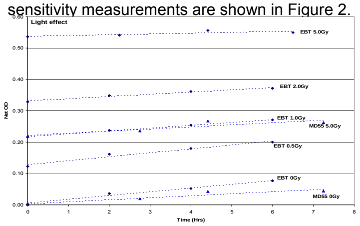

Fig.2: EBT and MD 55 light sensitivity.

Energy dependence

Energy dependence was analyzed based on irradiations performed on 6 and 18 MV photon beams. The measured dose range was from 0 to 40 Gy for MD55 films and from 0 to 15Gy for EBT model.

Materials/Methods continued

Cubic and quadratic fits were used to define the relation between dose and net OD for EBT and MD55 films, respectively. See Figure 3.

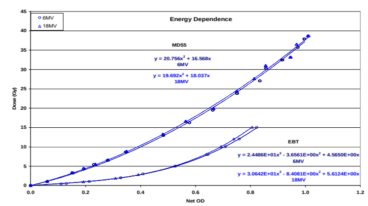

Fig.3: EBT and MD55 dose response at 6 and 18 MV photon beam.

Batch dependence

EBT films from three different batches were irradiated using the same procedures as were used for the energy dependence study. Only the 6MV photon beam was used for this analysis. The relationship between net OD and dose for this study is shown in Figure 4.

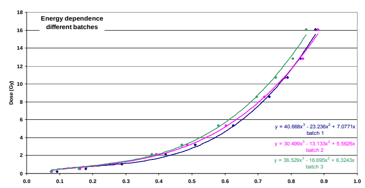

Fig.4: Dose vs. OD for three different batches of EBT film.

Temperature

The effect of temperature was studied by storing EBT films at different temperatures either before or after exposure. Two different EBT batches were used for this study.

The reference temperature was 20°C. Films were exposed for a period of 24 hrs to 30°C or 50°C either before or after irradiation. Films were irradiated to 5Gy with a 6MV photon beam.

An increase in the OD value was noticed for films stored at 50°C after irradiation compared with films kept at the reference temperature. The increase was of the order of 1% of the reading for this level of dose.

Results

No energy dependence was found for either MD55 or EBT films. Both films presented similar behavior for fading and light sensitivity. The EBT film showed less light sensitivity for irradiated films at the 5Gy level than for the unirradiated film or films at a lower dose level. The effects from the fading and light exposure were found to be negligible as well as the temperature effect when compared with uncertainties of the system. The OD versus dose relation varied between batches of the EBT model. The uncertainty of the densitometer readings was 0.1% for both types of films using our scanner system. The reproducibility between different sheets of film was 2% for both types of film.

Discussion

Uncertainty in Isodose determination

The process of isodose determination usually consists of several steps. Scan the film, then determine a point "P" located on the film where absolute value of dose is known. Denote this point's optical density to be "OD_P". Later this point is used for normalization to 100 % dose.

Also selection of a point "Q" on the film where the optical density "OD_Q" is desired to be converted to % dose value.

The OD values "OD_P" and "OD_Q" are then converted to corresponding dose values "D_P" and "D_Q" employing the "dose response" curve.

The % dose value "R", corresponding to the optical density "OD_Q", is then obtained from the dose ratio.

$$R = 100 * D_Q / D_P$$

Values of D_Q and D_P, and hence R depend on the dose response curve. This curve varies with (i) beam energy, (ii) film batch, and (iii) reading session. Data have already been presented showing variation in response with these parameters.

Consider curves A and B to represent the extremes among various dose response curves for the type of film under study. For a specific optical density "OD_Q", the two extreme curves would produce two values for % dose: R_A and R_B.

The difference ($R_A - R_B$) represents the extreme error "Δ" (in % dose value).

Since the fits A and B represent extremes, one standard deviation "σ" would be one fourth of Δ.

$$\sigma = \pm \tfrac{1}{4} (R_A - R_B)$$

Figures 5 and 6 show the error Δ in % dose as a function of OD ratio OD_Q / OD_P for each model of film used in this study.

Discussion continued

A family of Δ curves is presented for various dose levels at the normalization point P.

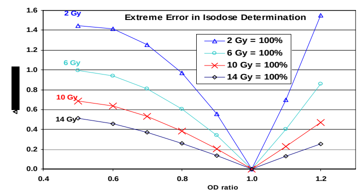

Fig.5: Extreme error in isodose determination for EBT film irradiated with 6MV photon beam. Analysis done for a specific batch.

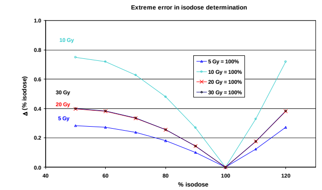

Fig.6: Extreme error in isodose determination for MD55 film irradiated with 6MV photon beam. Analysis done for a specific batch.

For a dose range of 6-14 Gy the extreme error Δ in determination of % dose is below a respectable limit of 1 %. Error Δ decreases with higher dose level, because the slope difference between the extreme fits A and B diminishes beyond the low-dose region. Similar analysis for the MD55 film shows comparable results.

Conclusion

The EBT film was found to be as good a relative dosimeter as MD55 for use by the RPC in its QA program, based on our reading system.

Dose response analysis will need to be done for each batch that will be used to avoid differences related to batch to batch properties.

References

- Gafchromic ® EBT study done by ISP, August 2004

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