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NOTE

High sensitivity radiochromic film dose comparisons

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Abstract
This short note investigates the dose characteristics of a relatively new high sensitivity radiochromic film (Gafchromic HS) and compares dose and energy response to various Gafchromic film types and radiographic (EDR-2) film. The original MD-55-1 and two improved sensitivity films, MD-55-2 and HS film, were investigated for energy and dose response. Results show that the energy response of the new HS film is relatively the same as the original MD-55-1 and MD-55-2 films with a decrease in sensitivity at lower x-ray energies, with response decreasing down to approximately 0.64 (normalized to 1 for a 6 MV beam) for a 28 keV effective energy beam. This is compared to an over response of 9.2 at the same energy for EDR-2 film. The dose response at the maximum absorption peak was found to be approximately 3.8 and 1.9 times more sensitive than MD-55-1 and MD-55-2 films, respectively. At the absorption peak yielding the maximum optical density change, HS was found to be approximately 0.2 to 0.25 times the sensitivity of EDR-2.

1. Introduction

Due to its relatively low energy dependence compared to radiographic film, Gafchromic MD-55-2 film has become a significant dosimetry tool in high-energy radiotherapy (Klassen *et al* 1997, Niroomand-Rad *et al* 1998, McLaughlin *et al* 1991). One of its shortcomings for use in both in-phantom and *in vivo* dosimetry, however, has been its low sensitivity, normally requiring large doses (5 Gy or more) to produce acceptable results. The introduction of a new film type, Gafchromic HS, is designed to increase dose response to high energy x-rays. This note investigates the dose and energy response properties of this new film and compares results to existing Gafchromic films and EDR-2 radiographic film which is used in IMRT applications.

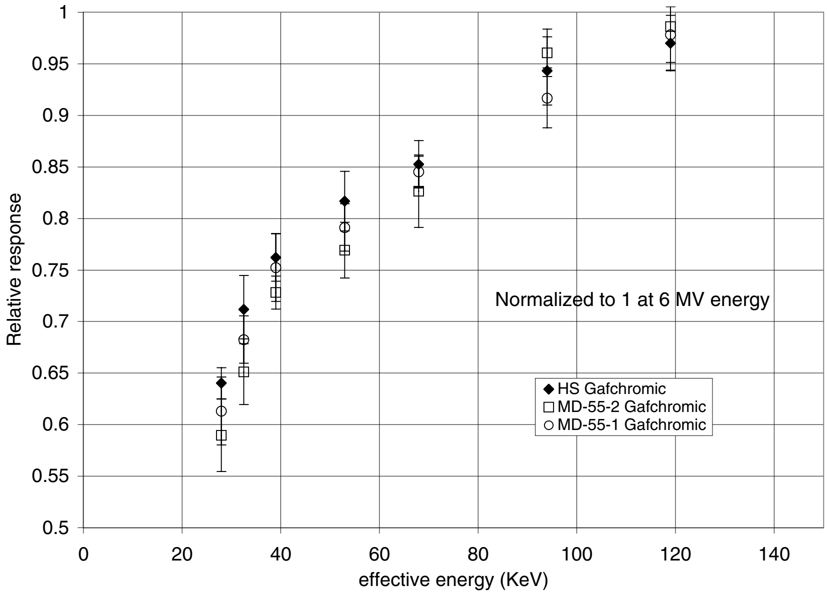
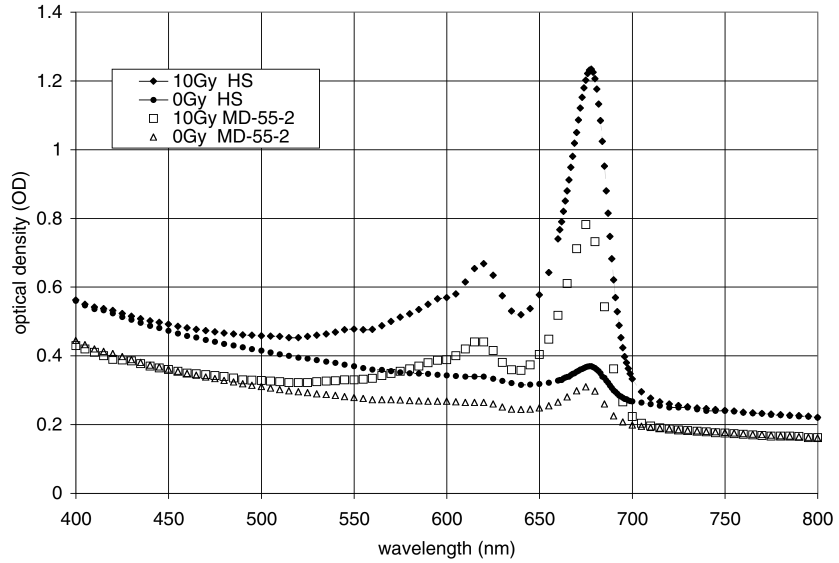


Figure 1. Energy response of HS, MD-55-2 and MD-55-1 Gafchromic film at superficial and orthovoltage energies.

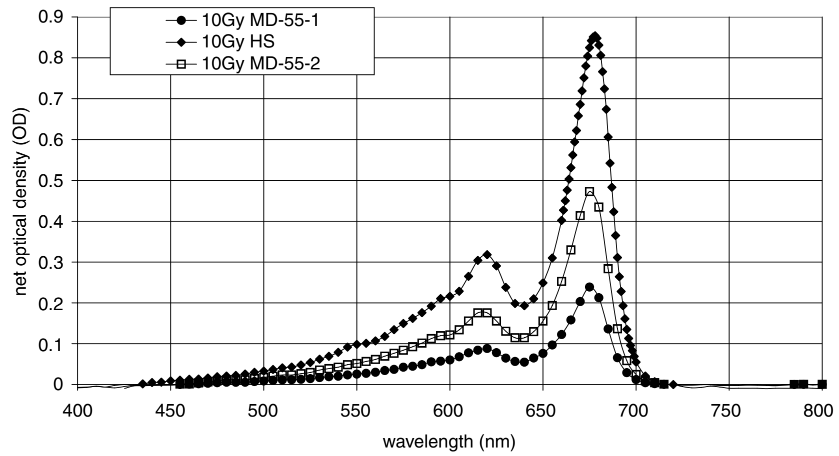
2. Materials and methods

Gafchromic HS film consists of an active dosimetric layer sandwiched between two sheets of transparent 97 μm polyester. The active layer has the same components as in MD-55-2 and is approximately 40 μm thick. The new HS film also varies from its predecessor, MD-55-2, as it does not employ an adhesive layer, which was used in the MD-55 films to bond the two coated substrates. This feature provides a more flexible film.

Dose and energy dependence measurements were performed on a Varian 2100C accelerator at photon energies of 6 MV and a Pantak 300DXT orthovoltage x-ray machine (Butson *et al* 1995) using beams with effective energies ranging from 28 keV up to 123 keV. An RMI 30 $\times$ 30 cm^2 solid water (Constanitinou *et al* 1982) slab phantom was used. The radiochromic films used were Gafchromic HS Lot no I0144HS, Gafchromic MD-55-2 Lot no 37350 and MD-55-1 (Lot no Unknown). The films were irradiated up to doses of 10 Gy in 1 Gy intervals. Precautions in handling of radiochromic film outlined in TG-55 (Niroomand-Rad *et al* 1998) were used. The film during experiment, storage and analysis were kept in temperatures of 22 °C $\pm$ 2 °C thus reducing the effects of time- and temperature-dependent evolution and readout (Meigooni *et al* 1996) of the absorption spectra of the film. The film is only removed from a light tight envelope during irradiation and readout to reduce the effects of ambient light (Butson *et al* 1998). The absorption spectra and sensitivity to dose of the radiochromic film was measured using a Shimadzu UV-160 UV-visible recording spectrophotometer in the wavelength range of 400–800 nm. The spectral bandwidth is 3 nm, the wavelength readout $\pm$0.1 nm, and has a wavelength accuracy of $\pm$0.5 nm. It uses a double beam system and can measure optical density (OD) within 0.005 OD units. Dose comparisons were also made using Kodak EDR-2 radiographic film. This film was also irradiated to 10 Gy in 1 Gy intervals.



(a)



(b)

Figure 2. (a) Absolute optical density absorption spectra for HS and MD-55-2 Gafchromic film. Doses applied are 0 Gy and 10 Gy. (b) Net optical density absorption spectra for HS, MD-55-2 and MD-55-1 Gafchromic film irradiated to 10 Gy applied dose.

3. Results and discussion

Figure 1 shows the energy dependence of the Gafchromic films tested in the low energy range. The results are normalized to 1 for a 6 MV linear accelerator beam. The three energy dependences are relatively the same within error measurements. The active layer used in all three films is quoted as the same material by the manufacturer. The substrates and binding materials are different for each film, however, results show that these materials do not significantly affect the energy response of the film. At 28 keV effective energy the response for HS film is approximately 0.64 increasing to 0.75 at 39 keV. These values produce

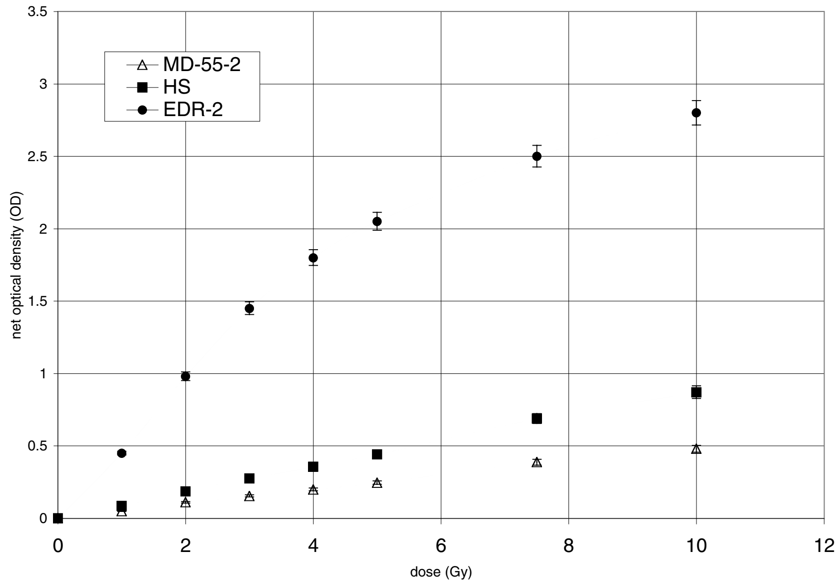


Figure 3. Dose response characteristics for HS and MD-55-2 Gafchromic film compared to EDR-2 radiographic film.

a significantly smaller energy effect than EDR-2 which was measured to have a normalized dose response of 9.2 at 28 keV, 10.5 at 32.5 keV, 10.3 at 39 keV, 8.3 at 53 keV, 4.8 at 68 keV, 4.3 at 94 keV and 2.8 at 119 keV (1 at 6 MV). This factor may be important for the measurement of dose in IMRT applications near multileaf collimator jaws/penumbral regions where the effective linear accelerator x-ray spectrum comprises a larger component of low energy photons compared to the central axis position.

Figure 2(a) shows the absorption spectrum (absolute optical density) over the wavelength range of 400 nm to 800 nm for HS and MD-55-2 film. Results for an unirradiated film and 10 Gy applied dose are shown. The HS film produces an increased sensitivity over all the wavelengths which is highlighted at the absorption peak. Figure 2(b) shows the net optical density for the HS, MD-55-2 and the MD-55-1 film irradiated to a dose of 10 Gy. These results are the subtraction of absolute OD from an unirradiated piece of film from the irradiated film. Initial film OD variations account for the small negative net ODs recorded at wavelengths around 400 nm and 750–800 nm. The HS film produces a sensitivity increase of approximately 1.9 times above that of the MD-55-2 film and approximately 3.8 times that of the original MD-55-1 film at 675 nm wavelength.

Figure 3 shows a dose sensitivity comparison of HS film to MD-55-2 and EDR-2. The net OD readings were taken at 675 nm for all films. Results show that the HS produces a dose sensitivity which is approximately 20–25% that of EDR-2. The relatively high sensitivity output for HS film along with its relatively low energy dependence means that the film could be advantageous for measurement of doses in IMRT applications or any radiotherapy applications where a variation in energy spectra produced by the linac occurs.

4. Conclusion

Gafchromic HS film produces a higher dose response than its predecessors with a relatively unaffected energy response. That is, lower response for low energy down to 0.64 at 28 keV effective energy. Its dose response is approximately 20–25% that of EDR-2 film but produces a much better energy response (EDR-2 gives an over response of 9.2 at 28 keV) which may prove useful in regions of x-ray spectral ambiguity such as penumbral regions or near MLC jaws.

Acknowledgment

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