Iranian Journal of Science & Technology, Transaction A, Vol. 32, No. A3
Printed in the Islamic Republic of Iran, 2008

DOSE RESPONSE OF IRRADIATED XRCT RADIOCHROMIC FILM*

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Abstract – Gafchromic XRCT radiochromic film is a self developing high sensitivity radiochromic film product which can be used for assessment of delivered radiation doses which could match applications such as Computed Tomography (CT) dosimetry. The dose response of Gafchromic XRCT radiochromic film has been measured with reflectance spectrophotometry and desktop scanners. The film automatically changes colour upon irradiation, changing from a yellow to a green/brown colour. Results show a high sensitivity to delivered dose compared to other conventional radiochromic films which is well suited to CT applications where lower applied doses are delivered. Sensitivity is found for this film with a 1cGy applied dose, producing an approximate net optical density change of 0.3 at 636nm and 0.2 net OD using broad band white light. This high sensitivity combined with its relatively energy independent nature around the 100kVp to 150kVp x-ray energy range provides a unique enhancement in dosimetric measurement capabilities over currently available dosimetry films for CT applications.

Keywords – Radiochromic film, Gafchromic XRCT, radiation dosimetry, absorption spectra

1. INTRODUCTION

Radiochromic film has been extensively used over the past few years for industrial applications and therapeutic treatments [1-7], where higher dose levels are normally delivered. In the last few years, International Specialty Products Inc (ISP Corp) has developed radiochromic films suited for analysis in the lower x-ray energy range relating to areas such as diagnostic X-ray machines, CT and superficial/ orthovoltage therapy [8]. Manufacturers have been continually improving the sensitivity of radiochromic film products to x-ray radiation [9-12] in the pursuit to provide accurate dosimetry tools for low dose applications such as Computed Tomography dose assessment. These films have found clinical applications from verification of patient doses in-vivo and in phantom situations [13-20]. One such film is Gafchromic XRCT. This has been made possible due to higher dose sensitivities and a film emulsion, which allows reflective assessment of the absorbed dose. Most Gafchromic film products have relatively low energy dependence but are also relatively insensitive to radiation and do not match the requirements for low dose assessment. Manufacturers state that XRCT film exhibits a relatively energy independent response to x radiation in the 100kVp to 150kVp energy range and a high sensitivity. This note investigates the dose response of Gafchromic XRCT film when irradiated with kilovoltage x-ray radiation.

*Received by the editor May 10, 2006 and in final revised form September 6, 2008
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2. MATERIALS AND METHODS

Gafchromic XRCT radiochromic film (Lot No. 3514600728XRCT) was used for the dose measurement study. For dose delivery, the films were positioned in a solid water [21] phantom of dimensions 30cm x 30cm x 30cm. The phantom was placed on a Gulmay D3300 superficial/ orthovoltage x-ray machine and doses ranging from 0cGy to 20cGy, according to the IPEMB protocol [22], were given using x-rays of energies ranging from 50kVp to 250kVp. The therapeutic x-ray machine was chosen to deliver radiation doses due to its accurate dose calibration and ability to deliver at kilovoltage energies. The films were irradiated placed perpendicular to the central axis of the beam. Standard precautions in handling radiochromic films such as not touching active film surfaces and keeping film temperature controlled as outlined in TG-55 were used [23]. Absorption spectra results were measured using an Avantes AvaSpec-2048 reflectance spectrophotometer. The AvaSpec-2048 device is a fibre optic Spectrometer with a 300lines/mm grating. The bandwidth of operation is from 327nm to 1100nm and the light source has a FWHM resolution of 2.4nm. Measurements were made in absorbance mode, which provides directed measurement of reflected "optical density" [24] in absorbance units. From these results a set of net absorption spectra measurements were obtained over the wavelength region of 550nm to 700nm, which includes the two main absorption peaks of XRCT radiochromic film. These absorption spectra show the dose response of the detectors. Net OD's have also been integrated over the fluorescent light band pass to provide an analysis of the dose. The dose response has been measured for x-ray energies of 50kVp to 250kVp.

3. RESULTS AND DISCUSSION

Figure 1 shows the net optical density dose response for Gafchromic XRCT film in the wavelength region of 550 to 700nm. Results are given for films ranging in applied doses of 0cGy to 20cGy produced by a 125kVp x-ray beam. As can be seen, the film produces two marked net absorption peaks upon irradiation, which are located at 636nm and 585nm. These two absorption peaks are similar to another Gafchromic film product, EBT [25]. Within this Figure it is noted that the main absorption peak at 636nm begins to saturate in response to the 20cGy dose level. This is seemingly the flattening of OD response at this dose level. This is assumed to be due to a combination of film saturation as the polymer reaction sites saturate, as well as densitometer response saturation. When the dose response is integrated over a wide visible absorption range, Fig. 2 is produced showing the mean dose response of the detector to 125kVp radiation. Also shown on Fig. 2 is the dose response curve over the same visible waveband for XRCT film irradiated with 50kVp, 100kVp, 150kVp and 250kVp x-rays. This highlights the different dose responses obtained with differing energies of the x-ray beam. Results can be fitted with a 2nd order polynomial to allow for accurate calibration of net OD to dose response. 2nd order polynomial fits are shown for 150 kVp and 250 kVp x-ray beams. As such, calibration curves need to be produced for each energy beam used. Variations between 100kVp and 150kVp are relatively small and the calibration curve differences are less than 6%. This highlights the fact that the film is well suited for dose assessment within this energy range without further energy corrections and calibration requirements.

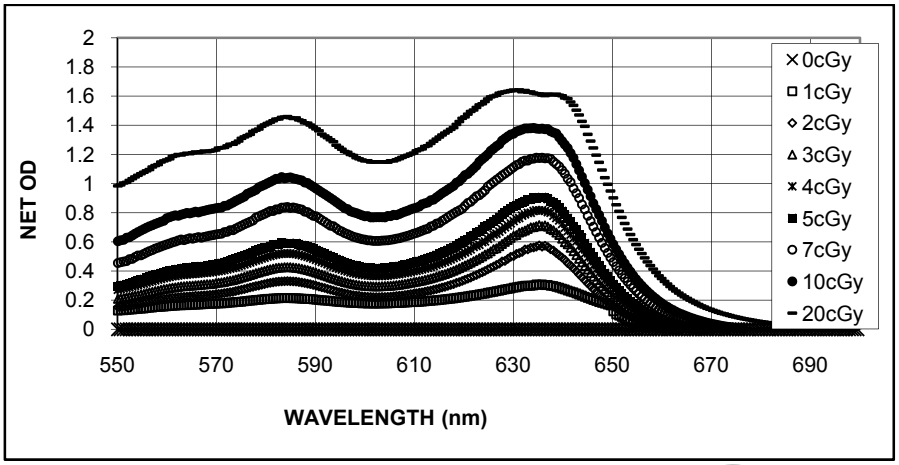

Fig. 1. The net optical density dose response for XRCT radiochromic film exposed to 125kVp x-rays

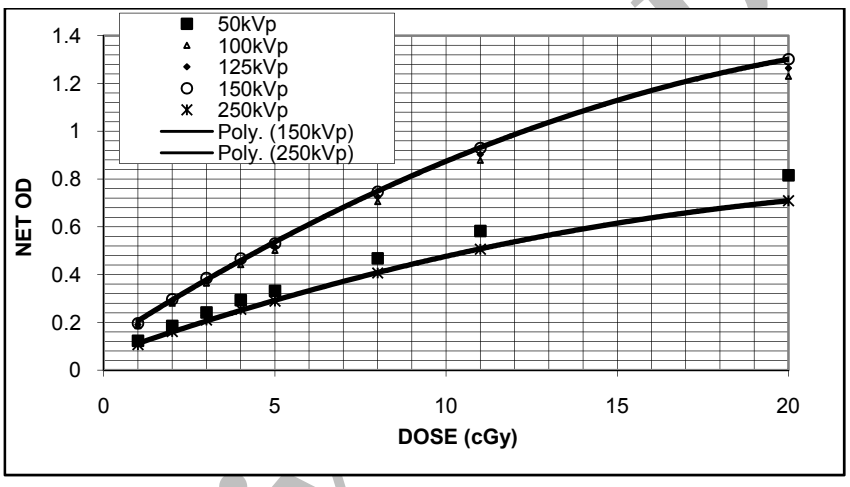

Fig. 2. Dose response curves for XRCT radiochromic film when analysed using different energy x-ray beams

Table 1 shows the dose required to produce a net optical density change of 1 for XRCT film and other radiochromic film products when irradiated with 125kVp x-rays. Net optical density change is measured over a 400nm to 700nm band pass range (broad spectrum, visible light range). Results show that the XRCT film produces the highest level of dose sensitivity compared to all other products. These results show that the Gafchromic film range of radiochromic film detectors can be used for various measurements and can be tailored for use depending on the absorbed dose or exposure delivery requirements. The high sensitivity, together with its relatively energy independent dose assessment feature in the 100 kVp to 150 kVp range [26] makes XRCT radiochromic film an appealing tool for assessment of low radiation doses at kilovoltage x-ray energies which would prove beneficial for dose measurement in applications such as CT dosimetry.

Table 1. Dose required for net optical density change of 1 for various radiochromic films

Film Type	Dose required (cGy)
Gafchromic XRCT	12
Gafchromic EBT	350
Gafchromic XR type T	275
Gafchromic HS	1300
Gafchromic MD-55-2	2300

4. CONCLUSION

Gafchromic XRCT radiochromic film produces a high dose sensitivity to low energy x-rays in the 100kVp to 150kVp range. The colour change is a visible yellow to brown. Up to 0.3 net OD change per 1cGy sensitivity is seen with this film at the peak absorption wavelength. This is approximately 30 times more sensitive than EBT Gafchromic film, which is used extensively in therapeutic applications. Due to its high sensitivity and combined with a low energy dependence [26], XRCT film will provide a new tool for dose assessment in low dose applications such as CT x-ray dosimetry.

Acknowledgements-This work has been fully supported by a grant from the Research Grants Council of HKSAR, China (Project No. RGC 112108 (CityU 9041337)).

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