Anisotropy in a Few mm Regions from an Ir192 High Dose Rate Source Measured with a GafChromic Film in Acrylic Phantom

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Radiochromic film has several advantages; high spatial resolution, relatively low spectral sensitivity, near tissue equivalence and requires no special development procedure. The object of this study was to measure the anisotropy of an Ir-192 source (microSelectron manufactured by Nucletron) in a few mm regions from the source, using the GafChromic film. The GafChromic film was calibrated in the range of 0~105 Gy, using a 4 MV photon beam, and the anisotropy function measured in an acrylic phantom using the GafChroimic film. The data obtained gave agreement to within 4.4% of the Monte Calro calculation, by J. F. Williamson, at a radial distance of 2.5 mm with polar angles of 50 to 130°, while a maximum deviation of 17.6% was observed at angles near 140° and agreement within 3.7% at a radial distance of 5 mm at polar angles between 35 to 160° and a maximum deviation of 7.6% was observed at angles near 30°. A GafChromic film can be used as a more efficient detector for measuring the anisotropy of an HDR ^{192}Ir source at close distances than any other detector.

Key Words: GafChromic film, anisotropy function, Ir-192 source

INTRODUCTION

Two main factors of describing the dose distribution for the brachytherapy sources are an anisotropy and radial distance. The anisotropy is distorted by the asymmetry of the stainless steel encapsulation and drive cable. The anisotropy must be taken into account to correctly calculate the delivered dose in various clinical applications. These anisotropy data were reported by Several investigators. In 1992, Moerland et al[1] reported measurement data for the anisotropy of ^{192}Ir source with ionization chamber, semiconductor detector, film and thermoluminescent dosimeter (TLD) chip. In 1994, Muller-Runkel and Cho[2] reported measurements of the source anisotropy with TLD rods at radial distances and polar angles. In 1995, Williamson and Li[3] reported Monte Carlo photon transport calculations of the anisotropy function at radial distances of 0.25 5.0 cm and polar angles of 0° 180°, and Kirov et al[4] reported TLD measurements. Zandona et al[5] reported ionization chamber measurements of the source anisotropy at 3.0, 5.0, and 7.0 cm distance and polar angles of 0° 145°. Also, Vivek Mishra et al[6] reported result of measurement with miniature ionization chamber. These conventional dosimetries such as ionization chambers, semiconductors, TLD, and radiographic film, there are numerous problems associated with the measurement of the anisotropy and radial distance in high-dose gradient regions. Ionization chambers do not provide sufficient spatial resolution near a brachytherapy source. A TLD is cumbersome and time consuming to readout the dose measure-

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ment. Because of large differences in sensitivity to photon energies in the 10~200 keV region even though its relatively high spatial resolution offers an advantage over most other radiation measuring systems, the evaluation of the anisotrophy of brachytherapy sources is difficult by using radiographic film. The energy absorption and transfer properties of radiographic films do not match those of biological tissues. However, the Radiographic films also have the disadvantages of being sensitive to room light and requiring wet chemical processing. Radiochromic film against other dosimeteries has several advantages of high spatial resolution, relatively low spectral sensitivity, and near tissue equivalence, and it requires no special development procedure. Further, it has a low sensitivity to room light, which makes handling easy.

The aim of this work is to measure anisotropy of Ir-192 sources in the mm distance range, using the Gafchromic film.

MATERAL AND METHODS

1. Radioactive source

As illustrated in Fig. 1. The Ir-192 source is encapsulated in stainless steel and welded to a steel cable. The active source consists of a 0.6 mm in diameter by 3.5 mm long cylinder of pure iridium metal within which the radioactive Ir-192 is assumed to be uniformly distributed. The capsule is 5 mm long and 1.1 mm thick.

2. Gafchromic film

In this study we used Gafchromic film MD-55-2 of Nuclear Associates, model No.37-401. The new proprietary radiochromic film MD-55-2 (Fig. 2) consist of double-layer radiochromic sensors dispersion coated on both sides of a polyester base. The colorless and transparent film responds to ultraviolet light and to ionization radiation by turning blue, with two nominal absorption bands (λ_{max}~670 and 610 nm) which depend on the absorbed dose, temperature during irradiation, and postirradiation reading time.[7] The radiation-induced color change is formed directly without thermal, optical, or chemical development and the original blue image is stable at temperatures up to about 50, above which the color of the image change abruptly from blue to red. This film has very little dependence on relative humidity (below 100%) during irradiation.

3. Optical density measurement

The radiochromic film was calibrated in the range of 0-105 Gy with an interval of 5 Gy, using 4 MV photon beam (Siemens Mevatron). A 15×15 cm field size was set at 100 cm source to surface distance. The film was placed perpendicular to the central ray in the acrylic phantom. The Gafchromic film was cut to pieces of 2×3 cm marked to ensure that the media's coating direction and film side were distinguishable. Following a 48-h waiting period for the stabilization of the exposed films, OD measurements were performed.[7] OD was determined using the HeNe laser and a

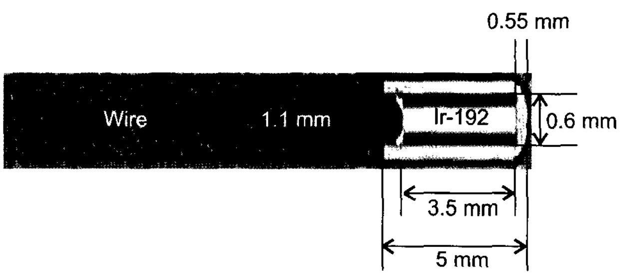

Fig. 1. Internal construction and dimensions of the Ir-192 micro-Selectron HDR source. The figure is not to scale.

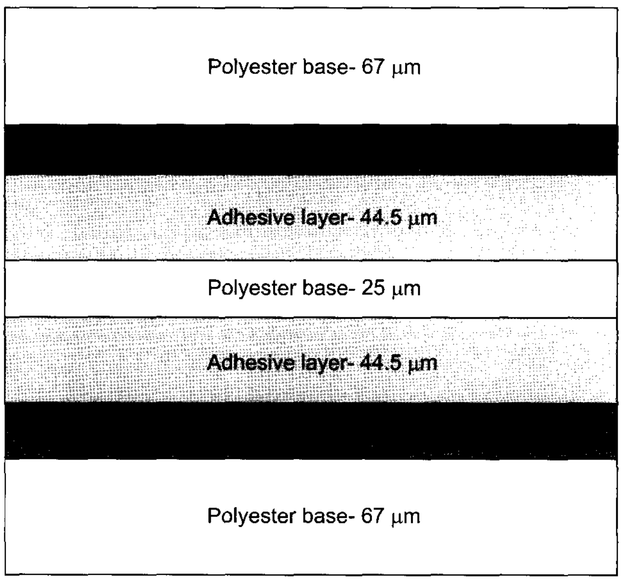

Fig. 2. A schematic diagram of the GafChromic film; MD-55-2provided by nuclear associates, USA.

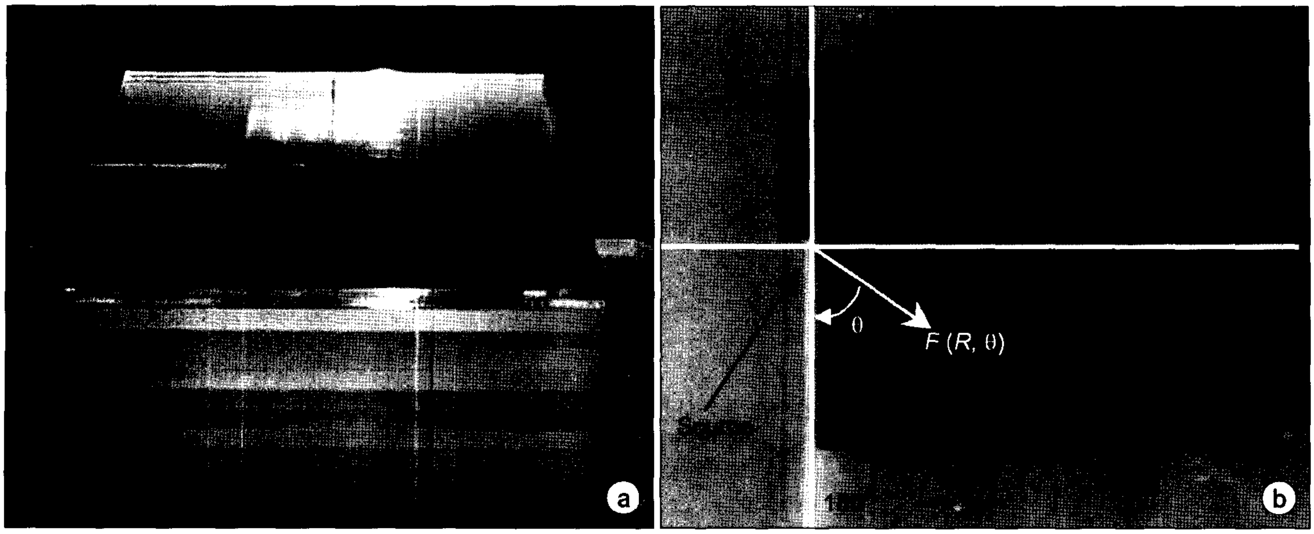

Fig. 3. A schematic diagram of the experimental arrangements (a) for the measurement film exposure by the Ir-192 HDR source, and (b) for -measurement of the source anisotropy.

wavelength of 632.8 nm (Lumiscan 75 laser digitizer, Lumisys Inc, USA)

4. Experimental setup

As described in Fig. 3, the measurements in this work were performed in a custom designed acrylic phantom. Two acrylic phantoms (30×30×0.5 cm, respectively) are contacted and a hole in which source is input was drilled in the middle of the boundary between the two phantoms. The catheter (2 mm in outer diameter) was inserted in the hole and the film was placed between the two phantoms. To provide full backscatter conditions, this phantom was sandwiched between other acrylic phantoms (30×30×30 cm). The source position was chosen so that the source was centered at the origin of the coordinate system. This position was verified radiographically. A Kodak X-OMAT V film was placed in close contact with the catheter and was exposed to the source in its actual dwell position. The source was removed and a dummy source was inserted into the catheter, and a second exposure was obtained with x-ray from a mobile machine. The developed films show the source position and the dummy source position, from which the origin of the coordinate system was found. The above method was used for various dwell positions spaced at 1 mm interval and the position which places the source closest to the origin was found. In this way, the center of source is determined with an accuracy of less than 1 mm.

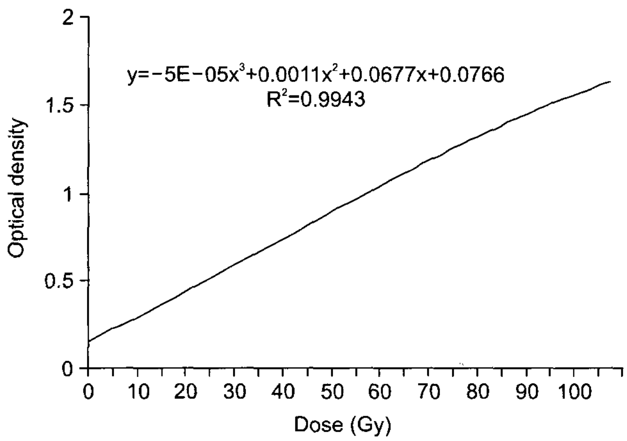

Fig. 4. The fitted calculation curve (Optical density vs. radiation dose) for GafChromic film MD-552.

5. The double irradiation method

The method used here was double irradiation. In the double-exposure technique a matrix of correction factors is obtained from the relative film response exposed to a uniform irradiation field. The size of this correction matrix depends on the size of the aperture of the densitometer, desired spatial resolution, and mode of the scanning system. In practice, a layer of film was four-fiducial marked (up, down, right, left)

Table 1. Comparison of anisotropy function, F (r, θ), by GAF film and Monte Carlo calculation*

polar angle (°)	r=2.5 mm			r=5 mm		
	Gafcromic film	Monte carlo	Difference(%)	Gafcromic film	Mognte carlo	Difference (%)
0						
25				0.814	0.881	−7.6
30				0.856	0.910	−5.9
35				0.898	0.933	−3.7
40	0.757			0.936		
45	0.840	0.951	−11.7	0.940	0.965	−2.6
50	0.939	0.982	−4.4	0.977	0.972	0.5
55	0.980			0.982		
60	0.989	0.991	−0.2	0.986	0.988	−0.2
65	0.991			0.995		
70	0.996			0.995		
75	0.987	0.995	−0.8	0.995	0.996	−0.1
80	1.010			0.995		
85	1.011			0.998		
90	1.000	1.000	0.0	1.000	1.000	0.0
95	0.994			1.000		
100	0.978			0.997		
105	0.994	0.993	0.1	0.974	0.996	−2.2
110	1.004			0.974		
115	0.991			0.968		
120	1.009	0.991	1.8	0.955	0.989	−3.5
125	0.991			0.968		
130	0.953	0.979	−2.7	0.953	0.972	−2.0
135	0.882	0.972	−9.3	0.979	0.966	1.3
140	0.784	0.951	−17.6	0.939	0.933	0.6
145	0.686			0.923		
150				0.918	0.908	1.1
155				0.864	0.877	−1.5
160				0.832	0.837	−0.6
180						

and then exposed to a uniform dose of D_1 (50 Gy) using a 4-MV photon beam (Siemens Mevatron 6,700) at the depth of 5 cm and in the field size of 15×15 cm. The mean optical density of the film, $<OD_1(i, j)>$, in the area of interest can be determined 48hour after the film is exposed. The film was then exposed to an unknown dose of D_2 (around 45 Gy) in the desired irradiation field. Next, irradiation were carried out with high dose rate brachytherapy source (Nucletron, micro-Selectron).

The film is scanned again after the film is exposed, and the two images are corrected using the four- fiducial mark. The optical density, $OD_1(i, j)$, from the first exposure and the second exposure, $OD_2(i, j)$, can be used to obtain a corrected net optical density, $OD_{net}(i, j)$, using the following relations

$$OD_{net}(i,j) = \frac{OD_2(i,j) - OD_1(i,j)}{f(i,j)}, \qquad (1)$$

$$\text{where } f(i,j) = \frac{OD_1(i,j) - OD_0(i,j)}{< OD_1(i,j) - OD_0(i,j)}$$

RESULTS

1. Film calibration

The calculation result are shown in Fig. 4. The curve has been fitted to third-degree polynomial for converting measured optical density dose. The curve shows a good linearity from 5 Gy to 90 Gy.

2. Anisotropy

The anisotropy measurements were carried out using

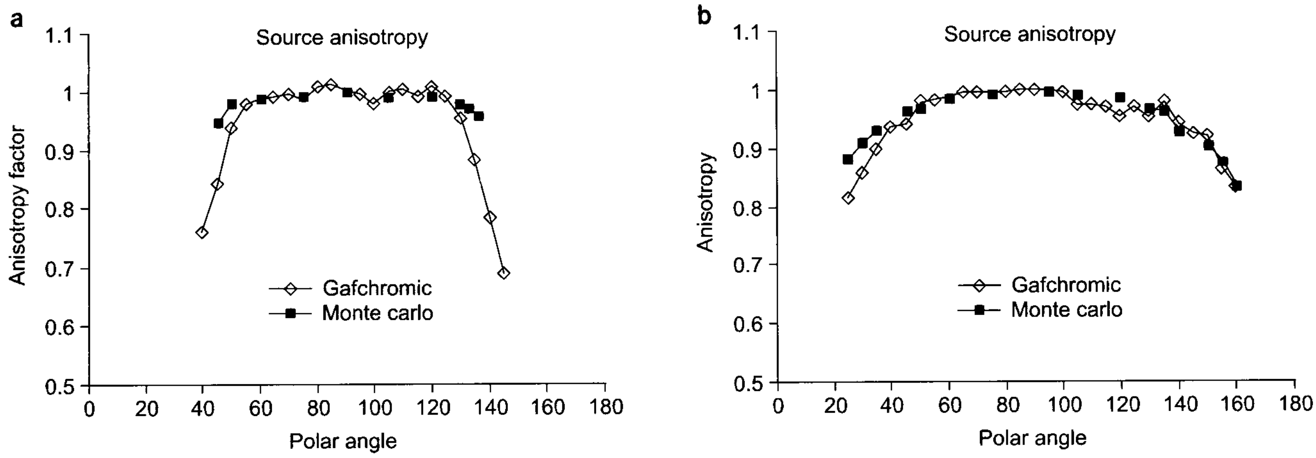

Fig. 5. Anisotropy functions, F(r, θ), as a function of polar angle, θ, relative to the long axis of the source, at radial distances (a) r=2.5, and (b) r=5 mm from the ^{192}Ir microSelectron HDR. The solid square and open diamond represents the Monte Calro calculation of J. F. Williamson and measurement of GafChromic film, respectively.

GafChromic film. A doubledexposure technique was used to evaluate GafChromic film MD-55-2 (model No.37-401) using a Lumiscan 75 system Spectrophotometer with 632.8 nm wavelength.

An anisotropy was measured at a radial distance of 2.5 mm and 5 mm with GafCromic film in acrylic phantom. The measurement of the anisotropy at radial distance r=2.5 mm and 5 mm and at polar angle $\theta=25^{\circ}-160^{\circ}$ relative to the long axis of source, are presented in Table 1 and In Fig. 5. The results agree within 4.4% with MC calculation of J. F. Williamson and Z. Li[3] at polar angle $\theta=50^{\circ}-130^{\circ}$ and radial distance r=2.5 mm, while deviation of 17.6% are observed at angles near 140° and agree within 3.7% at the polar angle 35°-160° and r=5 mm , while deviations of 7.6% are observed at angle near 30°.

CONCLUSIONS

Despite all inherent practical difficulties, which include misalignment of the source, film cutting effects, and source positioning, the results of our relative dosimetric measurements performed in a few mm distance from the source showed a good agreement with Monte Carlo calculation by J. F. Williamson (the polar angle $\theta=50^{\circ}-130^{\circ}$ at the radial distance r=2.5 mm and the polar angle $35^{\circ}-160^{\circ}$ at the radial distance r=5 mm).

A GafCromic film can be used as a more efficient detector for measuring the anisotropy of an HDR ^{192}Ir source at close distance than any other detectors.

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아크릴 팬톰에서 GafChromic 필름을 이용한 고선량률 근접 치료용 Ir-192 선원의 근접 거리에서 비등방성 측정

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GafChromic 필름은 높은 분해능과 낮은 민감도 그리고 조직 등가 물질에 유사하게 구성되어 있다. 본 연구의 목적은 GafChromic 필름을 이용하여 고선량률 근접치료에 사용하는 Ir-192선원 근접 거리에서의 비등방성을 측정하는 것이다. GafChromic 필름은 0 Gy 105 Gy까지 4 MV 선형가속기를 이용하여 흑화도를 구하였다. 비등방성 값은 아크릴 팬톰에서 GafChromic 필름을 이용하여 측정하였고, 측정된 값은 J. F. Williamson이 몬테칼로 계산한 값과 비교하였다. 비교 결과 거리(r) 2.5 mm, 각도 50～130도까지 영역에서 4.4% 이내로 일치하였고 반면 140도 부근에서 17.6% 차이가 나는 것을 알 수 있었고, 한편 거리(r) 5 mm, 각도 35～160도까지 3.7% 이내로 일치하였고, 30도 부근에서는 7.6% 정도 차이가 나는 것을 알 수 있었다. GafChromic 필름은 고선량률 근접치료 Ir-192선원의 근접 거리에서 비등방성 측정 시 기존에 사용되고 있는 측정 장비보다 매우 유용한 것으로 생각된다.

중심단어: Gafchromic 필름, 비등방성, Ir-192 선원.