The Effects of Metal Plate loaded on TLD chip in 6 MV Photon and 6 MeV Electron Beams

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There is necessity for making a smaller and more sensitive detector in small field sizes. This report assesses the suitability of metal-loaded thermoluminescent dosimeters for this purpose. Measurements were performed in the 6 MV photon and 6 MeV electron beams of a medical linear accelerator with LiF thermoluminescence dosimeters (TLD-100) embedded in solid water phantom. TLD-100 chips(surface area 3.2 × 3.2 ㎟) loaded with a metal plate(Tin or gold respectively) were used to enhance dose readings to TLD-100. Surface dose was measured for field size 10 × 10 ㎠ and 100 ㎝ SSD. Measurements have been made of the enhanced signal intensity and good linearity for absorbed dose with each metal. Using a 1 ㎜ each metal on TLD-100 in the beam increased the surface dose to 14% and 56% respectively for 6MV photon. In the case of 6 MeV electron, gold plate enhanced the TL response to 13%, but there is no difference for tin plate. The specific dose response of TLD-100 with thin metal plate increases with electron concentration of metal film, this is most likely due to increased electron scattered from the additional material with electron density higher than TLD-100. This emphasizes the role of TL dosimeters with metal as amplified dosimeters for therapeutic high energy x-ray beams. Due to the enhanced dose reading of TLD-100 with metal plate, it could be possible to develop smaller TL dosimeter with high sensitivity.

Introduction

The dose at the surface relative to the dose at maximum buildup (relative surface dose, RSD) depends on a large number of factors, including energy, field size, obliquity, and distance from any trays of filters in the beam. Measurements of RSD are generally done using thin-windowed ionization chambers. Although these chambers are suitable for measurements in cuboidal phantoms, they are generally too large for measurements on patients or on humanoid phantoms.[1]

Due to their small physical size, TL dosimeters are usually treated as point detectors. However, in locations where strong dose gradients are encountered, the physical dimensions of the TL dosimeters cannot be neglected. In stereotactic radiosurgery, we need a small fields in which collimators are as small as 4 ㎜ of diameter including those with small irregular fields. generally, TLD-100 chips (3.2× 3.2× x 0.9 ㎣) are not available to evaluate the data on radiosurgery in phantom for these special small fields. There is necessity for making a detector which is not only smaller in size but also has more response for absorbed dose in small field sizes.

One of the fundamental principles in this study is based on the importance of the Compton scattering that depends on both the photon quantum energy and the atomic number Z of the absorbing medium.[2] The physical density of LiF is 2.675 times the physical density of water. Taking into account the electron densities of water (3.343×10^{26} kg^{-1}) and LiF(2.786×10^{26} kg^{-1}), this results in about 2.2 times more electrons per unit volume (=electron concentration) in LiF than in water.[3] In the range of therapeutic megavoltage x-rays where the Compton effect dominates, this leads also to about 2.2 times higher attenuation per unit linear thickness for LiF than for water. When a thin metal is loaded on TLD-100 chip, one can also expect that the number of scattered electrons through the surface of TLD-100 would increase because of the higher number of electron concentration in metal. The flux of high-speed electron by Compton scattering process deposit energy within TLD-100 while it is irradiated by high energy beams. The deposit energy in TLD-100 can be released as a TL readout.[4] This sorts of electrons coming from metal plate on the TLD-100 chip might enhance the signal intensity. In this case, the metal plate on the surface of the TLD-100 chip acts as an absorber and intensifier. Therefore, it would be supposed that loaded metal could influence TL dosimeters response.

It was the aim of the present study to investigate how thin metal plate on TLD chip affect their dose reading. Also, the dependence of the TL signal on different beams and different metal plates, was studied.

Materials and methods

1. TL dosimeters

In this study TLD-100 chips (Solon/Harshaw, USA) and two kind of metal plates (tin or gold) were used respectively. TLD-100 was simply loaded by a certain metal plate (0.1 ㎜) using vacuum tweezer. TL dosimeter without any metal

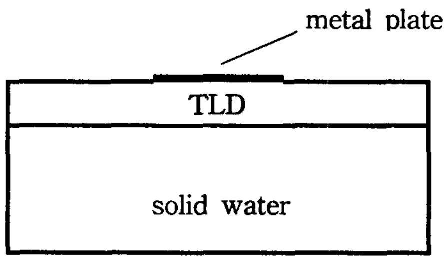

Fig. 1. The schematic of TLD-100 chip loaded with metal plate on a solid water phantom.

plate (abbreviated as nc = nude chips) and TL dosimeter loaded with a certain metal plate (abbreviated as mc = TLD chip with a certain metal plate, tc = TLD chip with tin plate, gc =TLD chip with gold plate) were investigated. Using vacuum tweezer, TL dosimeters were embedded in the hole of solid water phantom, which just accommodate one chip. Figure 1 shows this geometry.

2. Irradiation of the TL dosimeters

All radiation was delivered by Simens Mevartron. Exposure of nc and mc chips were made in the 6 MV photon or 6 MeV electron beams on the surface of a 20 ㎝ thick polystyrene plate (Victoreen, SCRAD Calibration Phantom) as phantom material at a field size of 10 × 10 ㎠ and 100 ㎝ SSD. The nc and mc dosimeters were arranged as seen in Fig. 1 and exposed at surface in the hole of solid water phantom.

3. Readout of TL dosimeters

The TL dosimeters were read in a TLD reader (Harshaw TLD reader 5500, photomultiplier voltage 800 V) in a two-step readout cycle after annealing at 100℃ for 10 mins (PTWO annealing oven) as prereading process. The readout cycle consisted of a linear heating rate of 15℃/s (50-300℃), followed by an isothermal plateau for 20

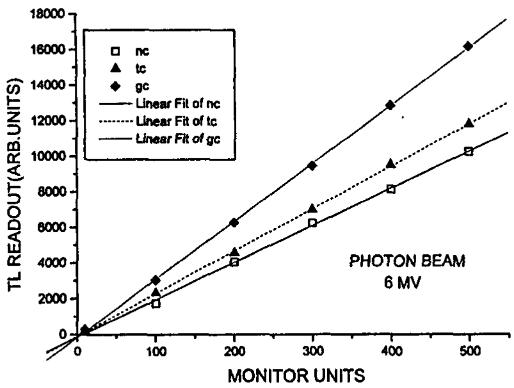

Fig. 2. The linearity of mc and nc chips as a function of monitor units for the 6MV photon beam.

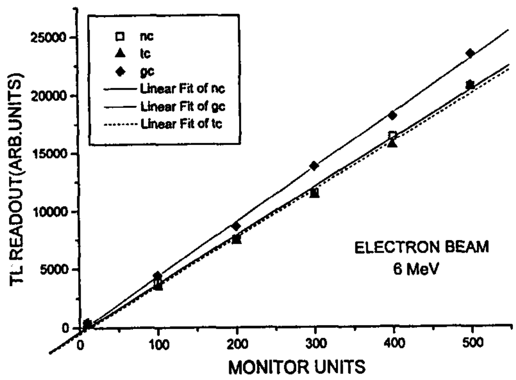

Fig. 3. The linearity of mc and nc chips as a function of monitor units for 6MeV electron beam.

sec. The integral over all channels (channel width 0.1 s) in the second step was used as the TLD reading. It was recorded as charge collected by the photomultiplier in nanocoulomb (nC). A personal computer on line, allowed the glow-curve analysis. All chips were annealed (1 h 400℃ followed by 2 h 100 ℃) in a dedicated TLD annealing oven after each readout.[5]

Experimental and calibrating measurements are made using a total of 30 chips, where each chip was individually calibrated for dose response. Each chip was characterized by its number in the set and a sensitivity value that relates the individual dose response of the chip to the mean dose response. For each set of readings in this studies, five TLDs were used per measurement. The variability of the reading between different chips of the same set was calculated as standard deviations. With this system the variability was on the average ±4% (2 s.d.).

Results and Discussion

1. Dose response of TLD with metal plate

The TL dosimeter being flush with the solid water surface were exposed from 10MU to 500MU in a 10 x 10 ㎠ field with 6 MV x-rays. Figure 2 shows surface dose response measured by nc and mc receiving high doses in single field. All results are the average of 5 measurements. The variation of the dose readings is comparable to the measurement precision of ±4% (2 s.d.). Results of measurements are plotted against absorbed dose as MU, and a linear representation is also plotted. The general shape of these curves are linear up to about 500 monitor units. The mc dosimeter has good linearity. The resulting comparison shows that the surface dose reading of mc dosimeter is typically higher than nc reading by up to 56 % of nc. In this case, the metal plate acts as an intensifier of signal intensities, this is primarily due to the different scattering condition in the TL dosimeter. It can be attributed to the increasing scattered electrons from the overlying metal plate with a high number of electrons per unit volume as compared to the air. As was it expected, the different signal intensity between the mc and nc chips was mainly the Compton effect resulting from the interaction of the high energy photon beam with a high atomic number material such as the metal plate. The measured dose response is highest in gc dosimeter. However, this may also be due to in part the buildup effect of mc for open fields. Actually 0.1㎜ gold plate is equivalent to 1.4㎜ tissue which makes buildup effect of an approximately 3% increase in the percent depth dose from the surface to 1.4 ㎜ depth for a 6 MV photon beam.

Fig 3 shows the dose response of nc and mc chips which were exposed with 6MeV electron beam in the same condition as 6 MV photon beam. As we can see in Figure 3, for 6 Mev electron beam, there is only a small difference in the signal gaps in the TL readout between gc and nc chips. The gc only enhanced the TL response to 13% and there is no difference for tc dosimeter, since the electron beams do not have the probability of Compton scattering process with metal plate. The sensitivity of mc chips is much more susceptible to high energy photon beams than electron beam because of Compton effect. All mc TL dosimeters have the properties of higher response and better linearity than nc TL dosimeter in 6 MV photon beam. If they are calibrated by exposing the dosimeter to a known amount of radiation, mc can be suitable for the measurement of a point dose on the surface or a point dose in the phantom because of its enhanced response.

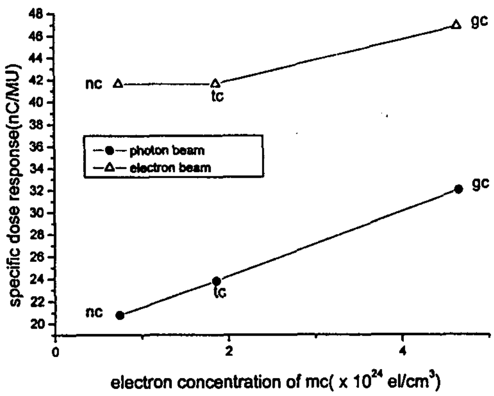

Fig. 4. Specific dose response of mc and nc chips as a function of the electron concentration in 6 MV photon beam or 6 MeV electron beam.

2. Specific dose response of TL dosimeters

The absolute reading of TL dosimeter is given as the charge collected in the photomultiplier during readout in nC as displayed in Figure 2 and 3. As the measured dose increases differently with the properties of the metal plate used, one can expect that the absolute dose response (measured in a nC/MU) should increase with the amount of electron concentration or atomic number of metal plate used in particular dosimeters. This can be seen in Figure 4 where the specific dose response is plotted against the electron concentration of the thee different TL dosimeters shown in Table 1. The specific dose response varies between the different types of TL dosimeter in different beams. For electron beam, the specific dose response doesn't seem to be related with electron concentration directly. But for 6 MV photon beam the increase in signal with electron concentration of metal plate is exactly linear in 6 MV photon. It is lowest for the nc chip and the highest for the gc chip as to their electron concentrations. The results shown in figure 4 emphasize the role of Compton effect on metal plate in this range of photon beam energy.

Table 1. Chracteristics of TL dosimeter with metal plate.

	nc	tc	gc
Loaded metal on TLD-100	None	Tin	Gold
Thickness of metal (㎜)	None	0.1	0.1
Area (㎟) of chip	3.1 x 3.1	3.1 x 3.1	3.1 x3.1
Equivalent thickness of metal to tissue (㎜)	None	0.53	1.4
Electron concentration of metal ($x10^{24}$ el/㎤)	0.74	1.86	4.66
Specific dose response in photon beam	20.8	23.8	32.5
Specific dose response in electron beam	41.6	41.1	46.8

Conclusion

Making or handling mc chips is very simple and this process can be applied to all kinds of TLD chips. It was shown that TLD chips loaded with metal plate was significantly enhanced in their dose responses and good linearity especially in 6MV photon beam. Experimently, the specific response of gc dosimeter was highest than that of tc chips.

The mc TL dosimeters are sturdy and reusable, and provide convenient in vivo measurements of skin doses. The measurement system described compliments the normal TLD service, and no extra annealing facility is required.[6] The mc TLD would provide the closest measurement depth in megavoltage x-ray beams. In view of the results so far achieved, mc chips have a useful role to perform in the measurement of skin dose (entrance and exit dose) or dose in solid water phantom in megavoltage radiotherapy and for preparatory experiment of a small detector used in stereotactic radiosurgery.

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6 MV 광자선과 6 MeV 전자선 하에서 TLD 기판 위에 얹힌 금속 박막의 효과

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본 실험은 의료용 가속기로부터 나오는 6MV 광자선과 6 MeV 전자선을 고체 팬텀위의 LiF 열형광 선량계(TLD-100)에 쪼여서 수행하였다. TLD-100의 방사선 반응감도를 증가시키기 위해 TLD-100 기판(표면적3.2 x 3.2 ㎟) 위에 같은 면적의 금속박막(주석 혹은 금)을 얹어서 실험하였다. SSD 100㎝ , 방사선장의 크기 10 x 10 ㎠의 조건 하에서 표면 흡수선량을 측정하였다.

측정결과 각 금속들로 인하여 TLD-100의 신호강도가 증강된 것이 관측되었다. 그리고 표면 흡수선량이 방사선량에 따라서 매우 선형적인 값을 가지는 것으로 나타났다. 6 MV 광자선의 경우 1 ㎜의 금속박막을 TLD-100에 얹은 결과 표면 흡수선량이 각 각 14%, 56% 증가되었다. 6 MeV의 전자선의 경우에는 금박막은 TL 반응감도가 13% 증가되었으나 주석의 경우에는 전혀 변화가 없었다.

금속박막을 얹은 TLD-100의 방사선량 반응감도는 금속박막의 전자 입자밀도에 따라 증가하는 것으로 관측되었다. 이것은 TLD-100보다 큰 전자밀도를 가진 부가물질(금속박막)로부터 TLD-100으로 산란전자가 유입되는 데 기인하는 것으로 보인다. 이 결과로부터 금속박막을 얹은 TL 선량계가 치료광자선용 증폭 선량계로서의 역할을 할 수 있을 것임을 시사한다. 즉 금속박막으로 인해서 TLD-100의 방사선량 반응감도가 증가되었으므로 높은 감도의 보다 작은 TL 선량계의 개발이 가능하게 되었다.