DETERMINATION OF X-RAY EFFECTIVE ENERGY USING CaF_2:Mn AND LiF:Mg,Ti THERMOLUMINISCENT DOSIMETERS

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1. Introduction

The response to γ or X - irradiation of a dosimeter depends, among other things, on the incident photon energy. Using two dosimeters with different energy dependencies, gives the possibility to determine the "effective energy" of the incident radiation. This method, called the "Tandem Method", consists of using the ratio of the energy dependencies of the two dosimeters' response from energy calibration curves to determine the effective energy of the radiation beam [1]. Several types of thermoluminescent dosimeters (TLD) were investigated in order to determine the best pair: CaF_2:Dy (TLD-200), CaF_2:Mn (TLD-400) and $CaSO_4$:Dy (D-$CaSO_4$:Dy-0.4), one by one in pair with LiF:Mg,Ti (TLD-100) [1]; $CaSO_4$:Dy ($CaSO_4$:Dy/PTFE, Vinten) in pair with LiF:Mg,Ti (LiF-7, Vinten) [2]. Also, CaF_2:Mn detectors together with Fricke dosimeter were used for the estimation of photon energy spectra of ^{60}Co gamma photons degraded in water [3].

The aim of the present work was to investigate the possibility of determination of X-ray effective energy using the CaF_2:Mn detectors produced by the Jožef Stefan Institute in pair with LiF:Mg,Ti (TLD-700) detectors.

2. Experimental procedure

The characteristics of the used TLDs and the evaluation parameters are presented in Table 1. After irradiation, before reading in the TLD reader, a 100°C post-irradiation external annealing for 20 min, followed by the internal (100°C for 6 s in the reader) preheat treatment was applied. All readings were made with a TOLEDO 654 (Vinten) reader.

TL detectors were irradiated in polymethyl methacrylate (PMMA) holders (with 3 mm wall thickness) containing nests for detectors. In every irradiation run, 10 detectors of each type were irradiated at the same time.

Table 1. Characteristics of TL detectors and evaluation parameters

	TLD-700	CaF_2
Material	^{7}LiF	CaF_2
Doping	Mg,Ti	Mn
Manufacturer	Harshaw*	IJS**
Form	chip	disc
Size (mm)	3.2 x 3.2 x 0.9	4.6 (dia.) x 0.7
Pre-irradiation annealing		
Temp. (°C)	400 + 100	400 + 100
Time (h)	1+2	1+2
Reading		
Temp. max. (°C)	270	270
Time (s)	35	32

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The individual calibration factors for all TLDs used were obtained by irradiations with calibration device containing ^{137}Cs source previously calibrated in terms of exposure [4]. Absorbed dose in air was calculated using the conversion factor 8.69 mGy = 1 R. For the calculation of dose absorbed in the TL material placed in a PMMA holder, general form of the cavity theory was used, and the method following our previous work [5] was applied. Conversion factors, f, for the calculation of the dose absorbed in TL materials from the dose absorbed in air were 0.958 for CaF_2 and 0.920 for LiF, respectively. The irradiations were performed at the distance of 1m from the source; the dose rate was 0.66 mGy/h (in air).

The energy dependence of the responses of CaF_2 and LiF TLDs was determined for X-ray beams with effective energies between 33 and 116 keV, generated by a Pantac HF 160C Series-2 Constant Potential X-Ray Unit (150 kV) with narrow spectra and heavy filtration (used in radiation protection). The specified effective energies were obtained by varying the operating potential and added filtration. The characteristics of the obtained X-ray spectra are presented in Table 2.

Reference dosimetry was performed with the secondary standard ionisation chamber LS-01 (active volume 1 dm^3) produced by Austrian Research Centre Seibersdorf. The dose was specified in terms of exposure and the dose absorbed in air was calculated as was described earlier. The irradiations were performed at the distance of 1m from the tube. Dose rates were about 50 mGy/h (in air). For the calculation of dose absorbed in TLDs, calibration factors obtained for ^{137}Cs were used. In this range of effective energies there is no need to apply the cavity theory since the dosimeters are mainly "photon detectors", and the dose absorbed in them from electrons generated in the wall, can be neglected.

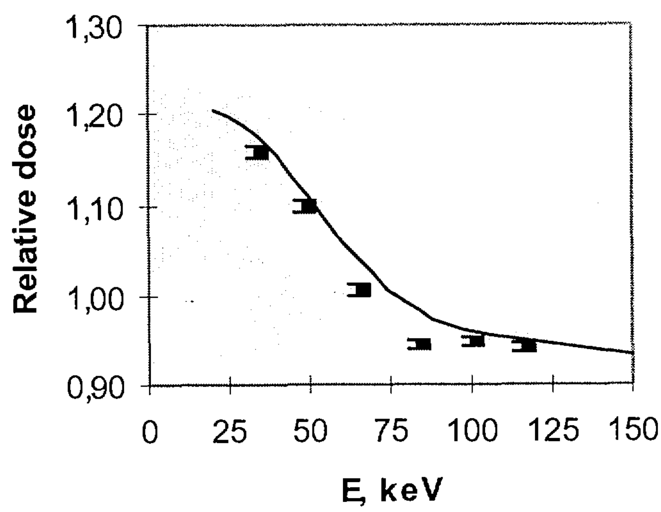
Table 2. Characteristics of the X-ray spectra

Quality	Gen. Pot.	Added filtration (mm)			Effective energy
Q	(kV/mA)	Al	Cu	Sn	(keV)
Q1	40/10	1	0.30		33
Q2	60/6	1	0.59		48
Q3	80/10	1	1.85		65
Q4	100/22	1	5.30		83
Q5	120/20	1	5.00	1.0	100
Q6	150/3	1		2.5	116

3. Results and discussion

The results are presented in Figures 1, 2 and 3. In Figures 1 and 2 the ratios of photon mass energy-absorption coefficients of LiF (CaF_2) and air [6] (curves), are compared with the experimental ratios of doses measured in LiF (CaF_2) and air (points with error bars), as function of energy. In Figure 3 the ratios of photon mass energy-absorption coefficients of CaF_2 and LiF [6] (curve), were compared with the experimental ratios of doses measured in CaF_2 and LiF (points with error bars), as function of energy. The experimental uncertainties expressed as standard errors of the mean ranging from 0.4-0.9% for LiF to 4.2-6.3% for CaF_2, are shown. The results for LiF in Figure 1 show that the experimental points are in the average 2% lower than the theoretical curve. This is probably due to the uncertainty of calibration and/or to the influence of PMMA walls in changing spectra and attenuation for low energy photons. No systematic error is obvious for CaF_2 (Figure 2), and for the ratios of doses measured with LiF and CaF_2 in Figure 3, despite the fact that uncertainties of CaF_2 dose measurements are too high for this type of detectors. The uncertainties of the effective en-

Figure 1. The ratios of photon mass energy-absorption coefficients of LiF and air (curve), compared with the experimental ratios of doses measured in LiF and air (points with error bars), as a function of energy



ergy determination are about ±5-10keV, depending on the position on the calibration curve.

The results show that, with some improvements of the measurement technique, a more careful (i.e. better selection of CaF_2 detectors and the examination of the PMMA wall effect), it is possible the use this pair of TLDs for the determination of the effective energy of X-ray beams in the energy range used. Also, from the curves in Figures 1 and 2, it is possible to determine the dose absorbed in air and pertaining exposure.

Figure 2. The ratios of photon mass energy-absorption coefficients of CaF_2 and air (curve), compared with the experimental ratios of doses measured in CaF_2 and air (points with error bars), as a function of energy

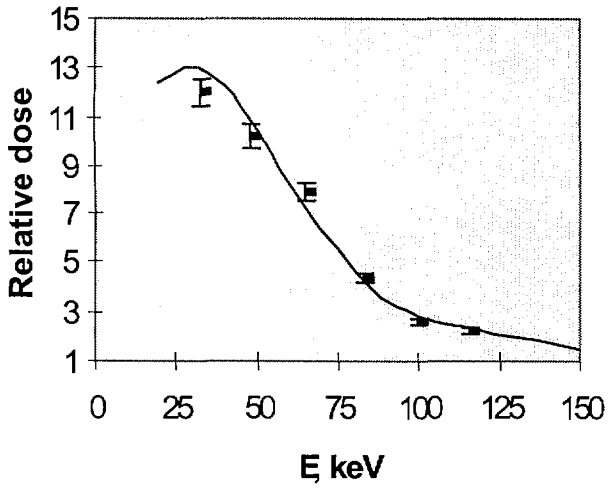
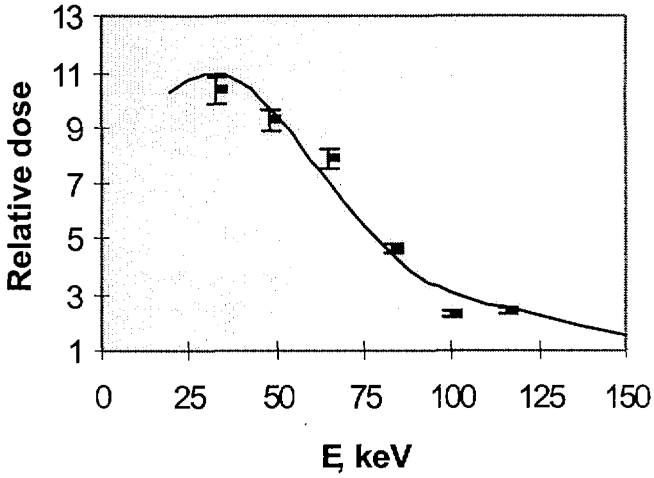


Figure 3. The ratios of photon mass energy-absorption coefficients of CaF_2 and LiF (curve), compared with the experimental ratios of doses measured in CaF_2 and LiF (points with error bars), as a function of energy



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5. References

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