ENERGY DEPENDENCE AND FILTER COMPENSATION OF SELF-FABRICATED TLD-$CaSO_4$:Dy/TEFLON DISCS FOR BETA-GAMMA PERSONNEL DOSIMETER

Chuan-Fu Wu and Shian-Jang Su
Institute of Nuclear Energy Research
P.O.Box 3-10, Lung-Tan, Tao-Yuan
Taiwan 325, R.O.C.

Thermoluminescent dosimeter-$CaSO_4$/Teflon discs were prepared by the authors. Series of experiments were applied to investigate the photon energy dependence of these TLD discs. Calculations of Bassi et. al.[1] had shown that the photon energy dependence of high effective atomic number (Z_{eff}) TL materials such as CaF_2, $CaSO_4$:Dy, etc. could be reduced by embedding them into lower Z_{eff} materials such as teflon and silicone rubber. Pradhan et.al.[2] had pointed out that the photon energy dependence is independent of the proportion of TL phosphor embedded. Our results are in good agreement with the statements of Pradhan et.al. The reasons are discussed thoroughly. The effects of various filters on photon energy dependence of TLD discs were also studied and a choice of filter combination for personnel β-γ dosimeter was suggested.

MATERIALS AND EXPERIMENTS

Self-fabricated $CaSO_4$:Dy powder (0.11 mol% Dy) was prepared following the method derived from Yamashita et.al.[3] Two ranges of grain size from 0 to 74μ and 74 to 177μ were divided by sieving them through sieves with equivalent mesh numbers 200 and 80 respectively. A mixture of phosphor and teflon (Du Pont 800J, grain size 330) was pressed under 7000 psi into small discs. After being properly sinterred, TLD discs (0.4mm thick and 9mm diameter) of different weight percentages (15%, 25%, and 30%) of $CaSO_4$:Dy were thus produced[4,5]. The weight of each disc was 70mg and the density was 2.75 g/cm^3 approximately.

Irradiations were carried out by using a ^{60}Co source, a ^{137}Cs source, and an X-ray machine which provided 42, 64, 86, and 110 keV X-rays. A batch of 10 TLD discs kept adjacent to each other and sandwiched between two sheets of 1.5mm plastic was attached to a phantom and exposed to 2.58×10^{-3} C/kg (10R) each time. These TLD discs were immediately read out in TLD reader and the data were averaged to minimize the statistical errors. TLD discs were annealed at 290°C for an hour before reused.

Square plastic and metal plates including aluminum, copper, cadmium, and stannum of 2 cm^2 area and various thickness were used in the experiments for filter compensation. Whenever Cu, Cd, and Sn were used, a sheet of 0.4mm Al was added before them to cut off beta particles from reaching these high Z materials and thereby eliminating the production of bremsstrahlung radiations.

RESULTS AND DISCUSSION

Bassi's calculations[1] based on 1). considering the mixture as a homogeneous compound, 2). assuming the electronic equilibrium,

3). not taking the self-absorption and the effect of grain size into account, and 4). assuming the light yield per rad independent of the LET. They claimed that the energy dependence of TLD discs could be obviously reduced by decreasing the weight percentage of TL phosphor. In this study (curves 1,2 and 3 in Fig.1) we found that the energy dependence of $CaSO_4$:Dy/teflon discs is almost independent of the proportion of $CaSO_4$:Dy.

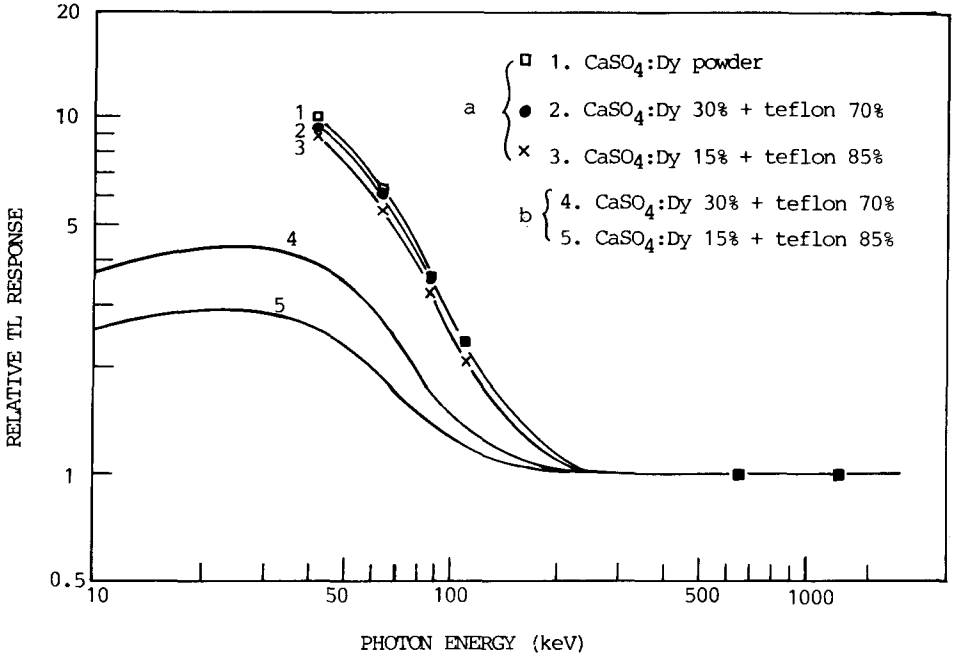

Fig.1. Experimental and calculated photon energy dependence of TLD-$CaSO_4$:Dy/teflon discs.
(a. results of present work. b. calculations of Bassi et al.[2])

The calculations took only the "mass energy absorption coefficients" into account. Therefore the values obtianed could merely represent the "relative mass energy absorbed by TLD discs" but not the "relative TL response of TLD discs".

The energy of secondary electrons (including Auger electrons) originated in both $CaSO_4$:Dy and teflon when exposed to low energy photons (<60 keV) is less than 60 keV. According to the "Katz and Penford Formula"[6],

$$R(mg/cm^2)=412\cdot E_{max}^{1.265-0.0954\ \ln E_{max}}, \quad 0.01<E_{max}<2.5MeV \quad ...(a)$$

the ranges of these secondary electrons in TLD discs are smaller than 20μ. Most of the photon energy transferred to both $CaSO_4$:Dy

and teflon particles is completely absorbed by themselves respectively when the grain size of $CaSO_4$:Dy is larger than 40μ. The energy absorbed in teflon gives no significant contribution to the TL response. Only the energy absorbed in TL phosphor is responsible for TL response. This is the reason why the relative photon energy dependence of TLD discs does not change obviously while the proportion of TL phosphor varies. The matrix of teflon particles may act only as an attenuator to low energy photon and therefore reduce the TL response per unit weight of TL phosphor.

When the grain size of $CaSO_4$:Dy in TLD disc is smaller than 40μ the secondary electrons originated in TL grains may escape and deposit their residual energy to the surrounding teflon particles. The probability of energy transfer from TL phosphor to teflon increases as the grain size or proportion of $CaSO_4$:Dy decreases. Therefore the photon energy dependence of TLD discs can be significantly reduced by using small-grain-sized $CaSO_4$:Dy particles. It had been stated[7] that not only the handling procedures of such fine particles are difficult but also the sensitivity may decrease to a factor of 8. Hence the attempt to produce energy independent TLD discs by using small-grain-sized TL phosphor is not practical.

The problem of energy dependence of TLD discs can be solved by applying several kinds of filters. Fig.2 shows how the filters affect the TL response of 25% $CaSO_4$:Dy/teflon discs. Curves 5 and 6 in Fig.2 show that an energy independent response beyond 70 keV can be achieved by using a filter combination of 1.0mm Sn + 0.4mm Al or 0.85mm Cd + 0.4mm Al. The decrease in the response under these combined filters below 70 keV and the increase in the response of bare or 1.0mm Al + 1.5mm plastic filtered TLD discs appear to be complementing each other. It had been found that the energy independent response (I) can be evaluated by the following equation[7],

$$I = 0.9A + 0.1B \qquad \text{(b)}$$

Where A is the reading of 1.0mm Sn + 0.4mm Al or 0.85mm Cd + 0.4mm Al filtered TLD discs, and B is the reading of bare or 1.0mm Al + 1.5mm plastic filtered TLD discs. The data of our experiments are listed in Table 1. Maximum error of the dose estimated by this method is 10%.

Table 1. Calculated Energy Independence of $CaSO_4$:Dy/ Teflon Discs Using Two Sets of Filters.

FILTERS \ RELATIVE RESPONSE \ E_{eff} (keV)	42	64	86	110	662	1250
A: 1.0mm Sn + 0.4mm Al	0.19	0.67	0.81	0.95	1.00	1.00
B: 1.0mm Al + 1.5mm Plastic	8.33	4.95	3.26	2.36	1.02	1.00
I = 0.9A + 0.1B	1.00	1.10	1.06	1.09	1.01	1.00

It is suitable to use three TLD discs with bare (B_o), 1.00mm Al + 1.5mm plastic (B), and 1.00mm Sn + 0.4mm Al (A) filters in a badge for a personnel β-γ dosimeter. The difference between the readings of B_o and B gives the information of effect of beta in β-γ mixed fields. The readings of A and B can be used to determine γ(or x) dose by applying eq.(b). The "effective energy" of the photons can be determined by the ratios of these two sets of readings.

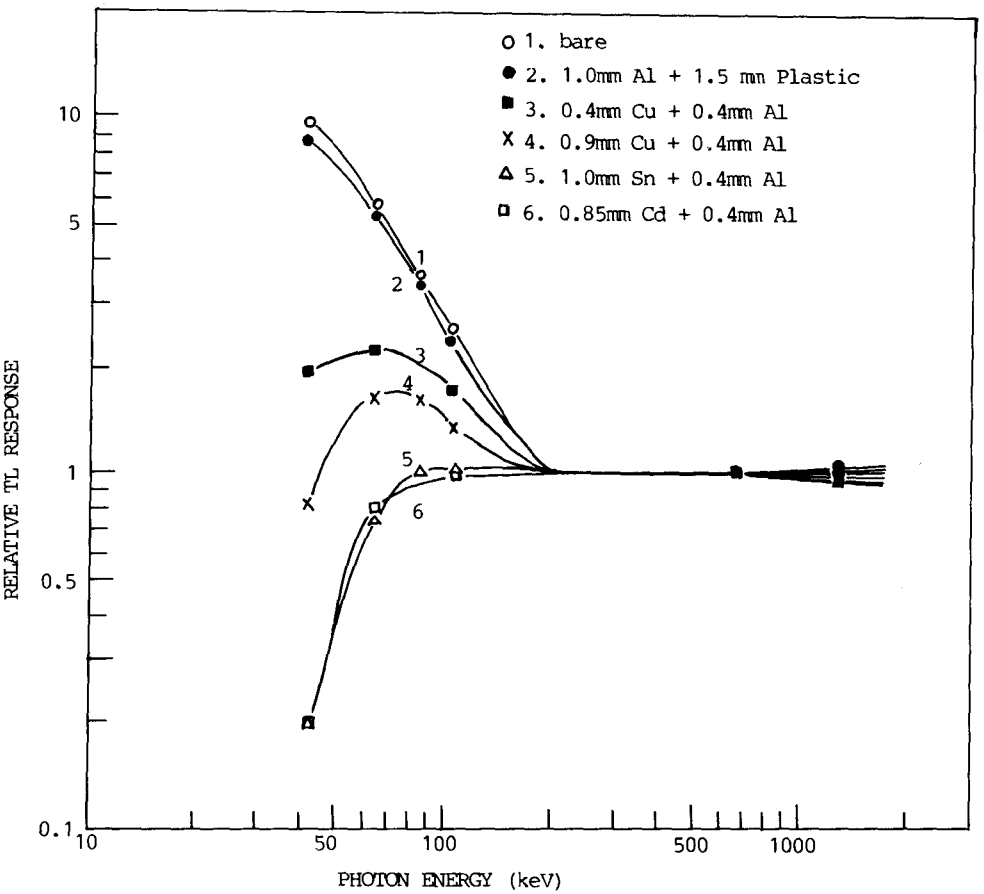

Fig.2. Effects of different filter combinations on the photon-energy-dependent TL response of 25% TLD-$CaSO_4$:Dy/teflon discs.

REFERENCES

1. P. Bassi and G. Busuoli, Intern. J. Appl. Radiation Isotopes, 27, 291 (1976).
2. A.S. Pradhan, R.K. Kher, A. Dere and R.C. Bhatt, Intern. J. Appl. Radiation Isotopes, 29, 243 (1978).
3. T. Yamashita, N. Nada, H. Onishi and S. Kitamura, in Proc. 2nd Int. Conf. on Luminescence Dosimetry, Gatlinburg (1968).
4. C.S. Wuu, C.F. Wu and S.J. Su, Nucl. Sci. J., 19, 108 (1982).
5. C.F. Wu, C.S. Wuu and S.J. Su, Hoken Butsuri, 18, 129 (1983).
6. L. Katz and A.S. Penford, Rev. Mod. Phys., 24, 28 (1952).
7. A.S. Pradhan and R.C. Bhatt, Nucl. Instr. and Meth., 16, 233 (1979).