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The Effect of the Build-up Wall at the TLD Calibration Using Co-60

N. Nariyama

*Nuclear Technology Division, Ship Research Institute,
Mitaka, Tokyo 181-0004, Japan*

Abstract

Absorbed dose in thermoluminescent dosimeter (TLD) material at the calibration using Co-60 gamma rays depends on the TLD thickness and the wall material used for electric equilibrium condition. The relation was examined for LiF, BeO and CaF_2 TLDs sandwiched with PMMA, Teflon and Pyrex glass walls using a Monte Carlo transport code and compared with cavity ionization theory calculations. For the mismatched combination of LiF, BeO/Pyrex glass and CaF_2/PMMA, it was found that the energy deposition did not change monotonously with TLD thickness from small cavity to large cavity value: a depression observed around 1-mm thickness for LiF/Pyrex glass and a peak around 0.6-mm thickness for CaF_2/PMMA. The phenomena were explained by using different exponential attenuation coefficients β and β' for the weighting functions of cavity theory. Moreover, use of large cavity values was found to lead possibly to 3-5% errors in the calibration of thin TLDs.

1 Introduction

Recently, increase of synchrotron radiation and ion beam facilities make the LET effect of radiation dosimeters an interesting and important subject because the radiation considerably differs from that of nuclear industry facilities and ordinary medical machines in regard to energy, strength and beam quality. For the LET effect, thermoluminescent dosimeters (TLDs) have been extensively examined [1] because TLDs are used for personal dosimetry and many kinds of materials are available.

For the use, TLDs are calibrated using Co-60 or Cs-137 in general. In the calibration, dose in the TL material does not have to be estimated: only the relation between TL signal and dose equivalent is important. The LET effect, however, is the phenomenon the TL material itself shows. To investigate the effect quantitatively, estimation of the absorbed dose in the TL material is indispensable.

At the calibration, TL material is sandwiched with wall materials such as Teflon to attain electric equilibrium condition. The absorbed dose in the TL material is obtained as follows[2]:

$$D_{TLD} = f(\mu_{en}/\rho)_{wall}/(\mu_{en}/\rho)_{air}D_{air} \tag{1}$$

where f is the response, which is obtained based on Burlin's cavity ionization theory [3], $(\mu_{en}/\rho)_{wall}$ and $(\mu_{en}/\rho)_{air}$ are the mass energy absorption coefficients of the wall material and air, and D_{air} is the absorbed dose in the air. If the influence of the wall is neglected, which is a simpler method for rough approximation, the dose in the TL material is obtained only by multiplying the air absorbed dose by the ratio of the mass energy absorption coefficients of the TLD material and air.

Cavity ionization theory for TLDs has been extensively investigated using Monte Carlo transport codes [4]-[6], in which energy deposition distribution in the TLDs and electron spectra were calculated. Practically, the sandwich materials often used are tissue-equivalent materials such as Teflon or PMMA. Moreover, Pyrex glass is employed as powder capsule because of the good heat resistance. It is important to estimate the difference of f values for the materials as a function of TLD thickness.

In this study, to estimate the difference of the wall material effect at the calibration, energy deposition in LiF, BeO and CaF_2 TLDs sandwiched with Teflon, PMMA and Pyrex glass were calculated for Co-60 gamma rays as a function of TLD thickness with a Monte Carlo transport code. The result was compared with that of cavity ionization theory.

2 Monte Carlo Calculation

A Monte Carlo transport code used was TIGER of ITS package [7]. The geometry available is one-dimensional slab. Cut-off energy used was 1 keV for photons and electrons. The TLD thickness was varied from 0.1 mm to 10 mm. The thickness of the wall was determined so as to establish electric equilibrium condition, that is, 3 to 4 mm. The statistical errors were all below 1%.

3 Results and Discussion

Figure 1 shows the energy deposition of LiF between Teflon walls as a function of TLD thickness. The values change smoothly from small cavity to large cavity value. On the other hand, Fig. 2 represents the result of Pyrex glass. The value decreases from small cavity value and increase at 1-mm thickness. When using large cavity value for 0.1-mm thickness, 3% error will appear.

The reason of the depression observed at 1-mm thickness was attributable to the different rates of electron attenuation from the wall and electron buildup in the TLD. Cavity theory calculation was then made using larger β value than β' value in the weighting functions d and d' as suggested by Attix[8]:

$$d = \frac{\int_0^g e^{-\beta x} dx}{\int_0^g dx} \tag{2}$$

and

$$d' = \frac{\int_0^g (1 - e^{-\beta' x}) dx}{\int_0^g dx} \tag{3}$$

in the equation

$$f = d f_s + d' f_l \tag{4}$$

where f_s and f_l are small and large cavity values, respectively, and g is a mean chord of length in the cavity. The result is shown in Fig. 3, in which the similar shape having a depression to that in Fig. 2 was obtained. The depression was also found in the experimental deta of LiF/aluminum[9].

The result of BeO between PMMA is indicated in Fig. 4. Monotonous change was observed. On the other hand, the result of Pyrex glass is shown in Fig. 5, in which a depression larger than that in Fig. 2 was seen because the effective atomic number of BeO is smaller than that of LiF.

Figure 6 shows the energy deposition of CaF_2 between PMMA walls. Contrary to Fig. 2, a peak was observed: the values rise until 1-mm thickness and decrease. This time by using smaller β value than β' value, cavity theory calculation was made. Figure 7 shows the result. The similar shape including a peak was observed in Fig. 6. If the large cavity value is used for the 0.4-mm thickness, 5% error will be introduced.

4 Conclusion

The calculation of energy deposition in LiF, BeO and CaF_2 as a function of TLD thickness showed a depression and a peak for LiF, BeO/Pyrex glass and CaF_2/PMMA, respectively. The behavior was reproduced by cavity theory calculation. Practically, if the large cavity value is used, 3-5% errors will appear for the mismatched combination. The errors are influential when a high accuracy is required.

References

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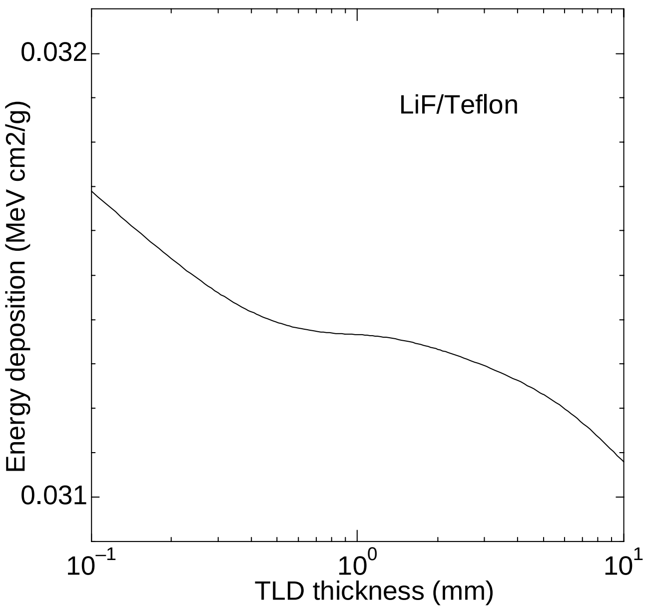

Figure 1: Energy deposition of LiF between Teflon walls as a function of TLD thickness

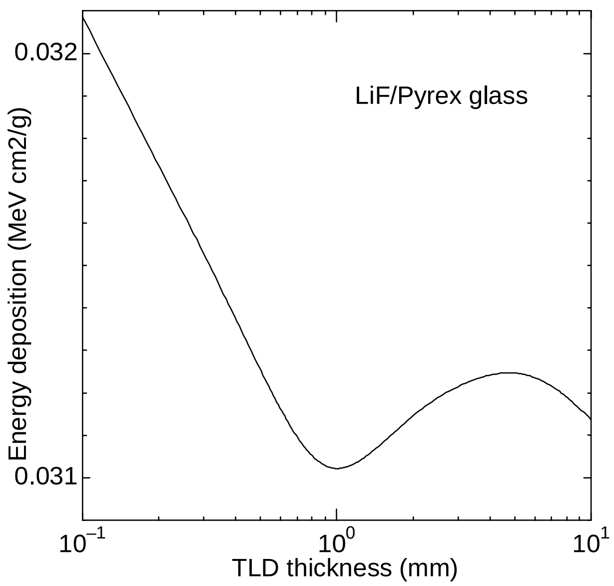

Figure 2: Energy deposition of LiF between pyrex glass walls as a function of TLD thickness

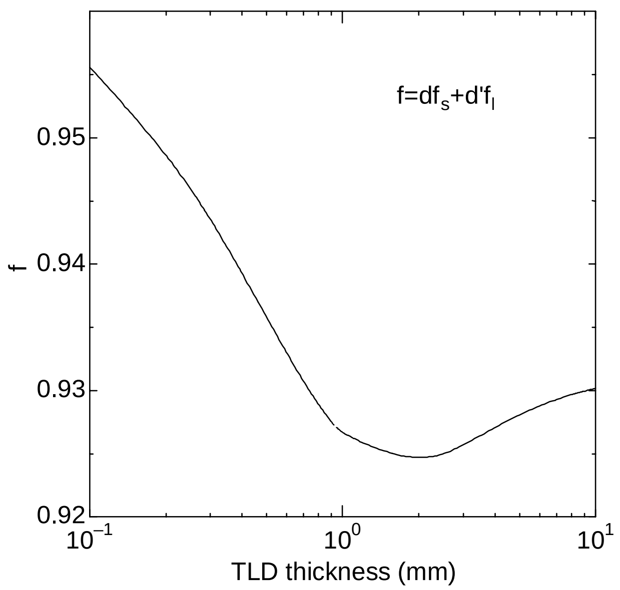

Figure 3: f value calculation of LiF with cavity ionization theory as a function of TLD thickness

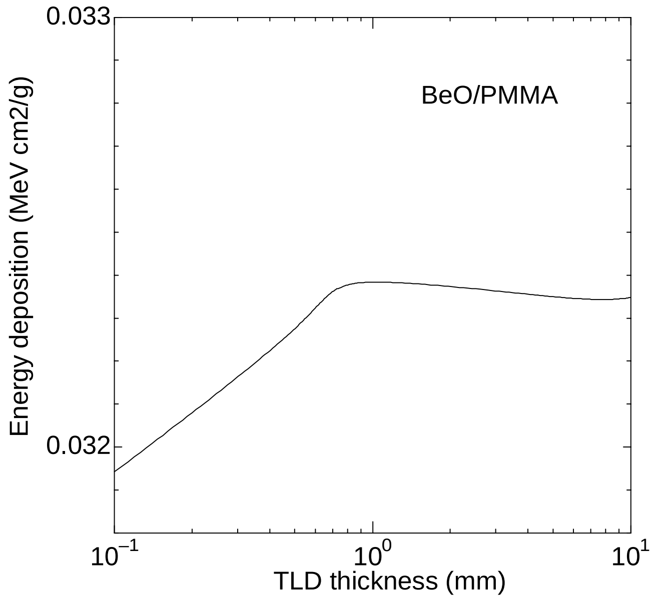

Figure 4: Energy deposition of BeO between PMMA walls as a function of TLD thickness

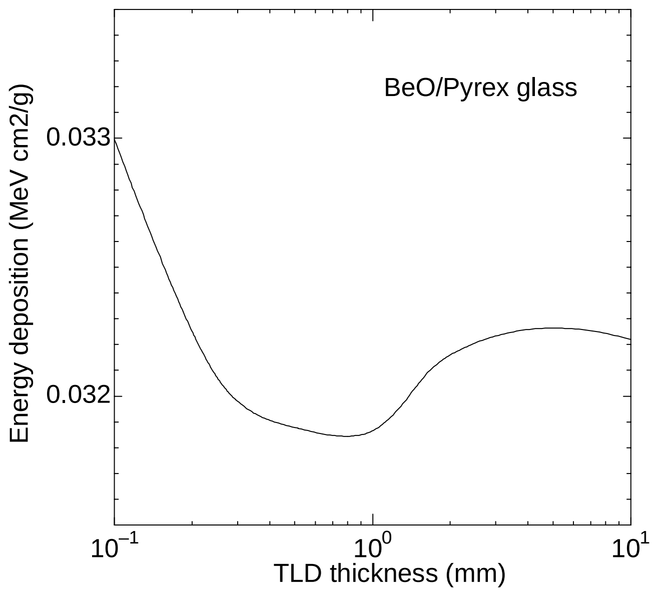

Figure 5: Energy deposition of BeO between Pyrex glass walls as a function of TLD thickness

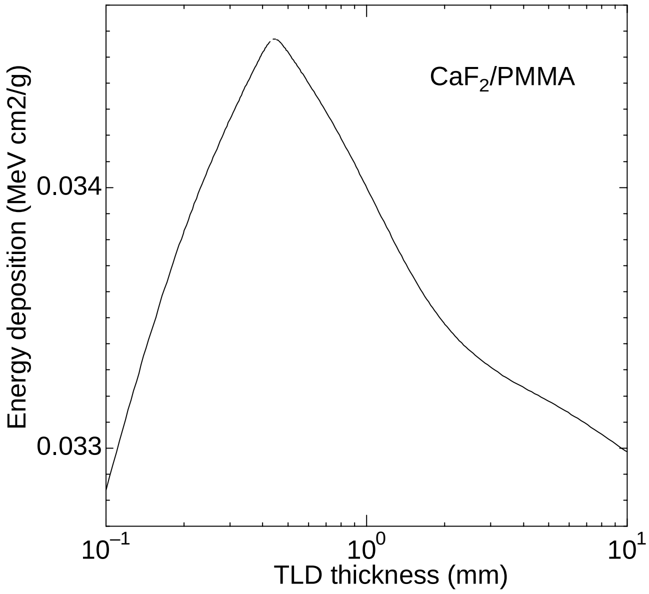

Figure 6: Energy deposition of CaF_2 between PMMA walls as a function of TLD thickness

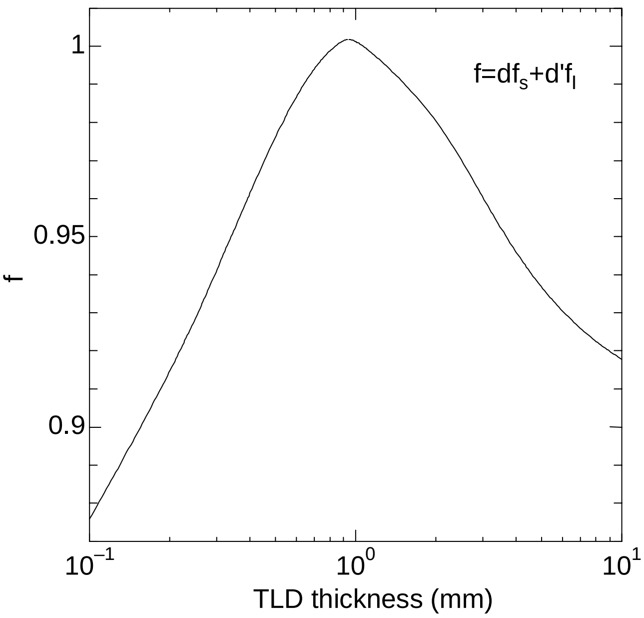

Figure 7: f value calculation of CaF_2 with cavity ionization theory as a function of TLD thickness