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ENERGY RESPONSE OF LiF AND Mg_2SiO_4 TLDs TO 10–150 KeV MONOENERGETIC PHOTONS

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Energy response of LiF:Mg,Ti, LiF:Mg,Cu,P and Mg_2SiO_4:Tb thermoluminescence dosemeters (TLDs) was measured in the range 10–150 keV for monoenergetic photons at SPring-8 of an 8-GeV synchrotron radiation facility. The photon beam was monitored by a parallel-plate free-air ionisation chamber calibrated with an uncertainty of 3%. Owing to the small dimension of the beam, a rotating holder was designed in order to irradiate TLDs uniformly. The measured responses of LiF to energy were approximately in agreement with the calculated dose absorption dependence in the soft tissue. However, two types of LiF TLDs presented the different luminescent responses to the photon energy. The response of LiF:Mg,Ti had a smooth curve, and that of LiF:Mg,Cu,P presented a local maximum at 30 keV and a local minimum at 100 keV. The Mg_2SiO_4:Tb response was nearly bone equivalent. Linearity of dose responses was also confirmed up to 2 Gy on each TL material.

INTRODUCTION

The LiF based thermoluminescence dosemeters (TLDs) are widely used because they satisfy the soft tissue equivalence. The response of magnesium orthosilicate (Mg_2SiO_4) TLDs is accepted as the suitable response for bone tissue.

Energy responses of the TLDs to low-energy photons have been measured using conventional X-ray generator[(1)], but the energy spectra were inevitably broad. Recently, the number of synchrotron radiation facilities has been increasing and monoenergetic photons are becoming available in the low-energy region; responses of some kinds of TLDs have been measured in this energy region[(2–6)]. At SPring-8, a third-generation 8-GeV synchrotron radiation facility, intensity of the synchrotron orbital radiation is monitored by the newly developed parallel-plate free-air ion chamber which is characterised up to 150 keV[(7)].

In this study, the energy responses and dosimetric properties of LiF and Mg_2SiO_4 TLDs to 10–150 keV monoenergetic photons were measured at the SPring-8 facility.

MATERIALS AND METHODS

The experiments were carried out at a bending magnet beamline BL38B1 of SPring-8. Figure 1 shows an overview of the experimental set-up. This beamline provides monoenergetic photon beams from 10 to 150 keV through a silicon double-crystal monochromator.

A HP-Ge detector was used to check the incident photon energies and remove the high harmonic components caused by Bragg diffraction. The intensity of photon beam was monitored with a parallel-plate free-air ionisation chamber (85-mm plate separation): the response uncertainty was confirmed to be bounded within 3% by comparison with a calibrated Si-PIN photodiode. The beam size and the photon intensity were typically 6 mm^2 and 10^8–10^9 photons s^{-1}. A Cu foil was removed during the irradiation.

Two types of LiF TLDs and a Mg_2SiO_4 TLD were prepared: a LiF:Mg,Cu,P (GR-200, Sange) (3-mm square, 0.4-mm thickness), a LiF:Mg,Ti (TLD-100, Harshaw) (3.2-mm square, 0.38-mm thickness), and a Mg_2SiO_4:Tb (MSO-5D, Kyokko) (5 mm diameter, 0.5-mm thickness). The adopted annealing procedures were as follows: 10 min at 240°C for GR-200, 1h at 400°C followed by 2 h at 100°C for TLD-100 and 10 min at 500°C for MSO-5D. The TLDs were sandwiched between 2-mm-thick Teflon plates and calibrated with ^{60}Co gamma rays.

The beam size was comparable with the TLDs size, and the intensity distribution was inhomogeneous in the beam. In order to irradiate the TLDs uniformly in the free-air, the TLDs were mounted on the hollow acrylic wheel rotating perpendicularly to the beam axis. The irradiated doses were calculated using the photon intensity and the irradiated area[(8)]; it was 5×10^{-5}–2 Gy in these experiments.

The TL intensity was measured with a TLD reader (3500, Harshaw) at a heating rate of 10°C s^{-1}. The TL signal was integrated from 135 to 240°C including 3 s holding at 240°C for GR-200, from 50 to 300°C for TLD-100 and from 50 to 350°C for MSO-5D.

RESULTS AND DISCUSSION

It was confirmed that the TLDs had linear dose responses up to 2 Gy in the domain 50–150 keV (Figure 2).

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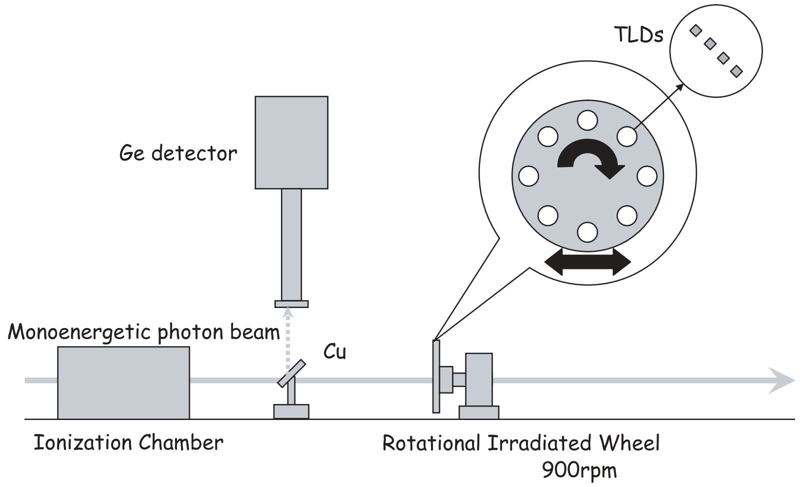

Figure 1. Experimental set-up.

The energy responses of LiF and Mg_2SiO_4 TLDs are shown in Figures 3 and 4, respectively. They were compared with calculated response of soft tissue and bone normalised by the response to 1250 keV photon. The value of calculated response *D* was defined as follow;

$$D = \frac{(\mu_{en}/\rho)_{material}}{(\mu_{en}/\rho)_{air}}$$

where $(\mu_{en}/\rho)_{material}$ is the mass energy absorption coefficient of target material and $(\mu_{en}/\rho)_{air}$ is that of air at each point of photon energy[9].

The measured energy responses of LiF TLDs, GR-200 and TLD-100 were close to the calculated response of soft tissue. However, the tendency of the measured response of GR-200 and TLD-100 was different.

The response of GR-200 was smaller than the calculated one of LiF:Mg,Cu,P. Additionally, it had the local maximum and minimum around 30 and 100 keV, and decreased below 30 keV. This behaviour agreed with literature data[5]. On the other hand, the measured response of TLD-100 was higher than the calculated tissue response by up to 34%. Besides, compared with the calculated

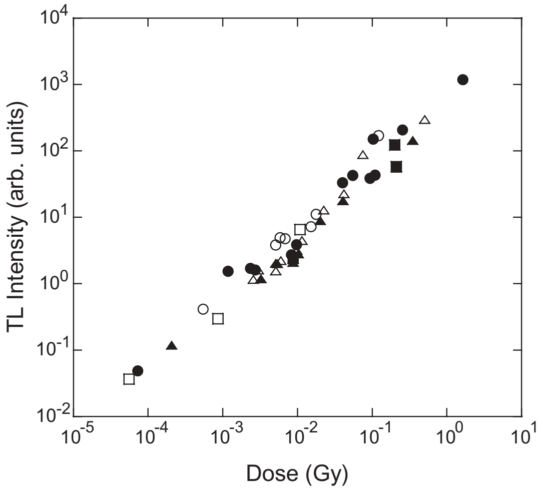

Figure 2. Dose response of Mg_2SiO_4. Open circles, 50 keV; closed circles, 60 keV; open triangles, 80 keV; closed triangles, 100 keV; open squares, 150 keV; and closed squares, 1.25 MeV.

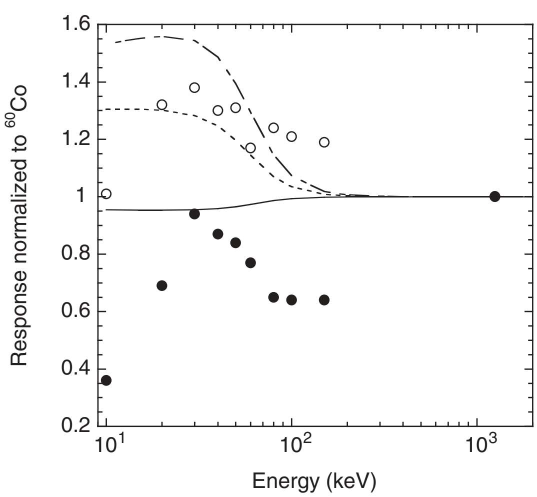

Figure 3. Energy response of TLDs. Open circles, TLD-100; closed circles, GR-200; dashed line, LiF:Mg,Ti; dash-dashed line; LiF:Mg,Cu,P; and solid line, soft tissue.

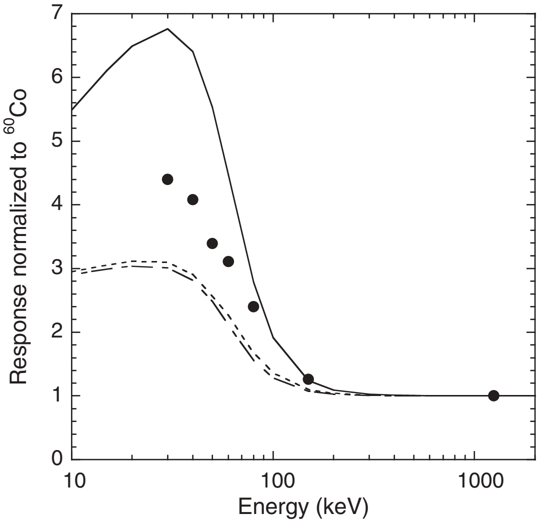

Figure 4. Energy response of Mg_2SiO_4 TLD. Dash-dashed line, Mg_2SiO_4; solid line, bone; dashed line, Mg_2SiO_4: Tb(0.001 g atom mol^{-1}); and closed circles, MSO-5D.

LiF:Mg,Ti response, the measured values were 18% larger.

The two types of TLDs should have the same energy dependence of absorbed dose, because their compositions almost agree. However, the TL energy response of each TLD shows different dependency. Thus the different luminescent efficiency can be thought as one of the reasons why the TLDs of LiF have the different energy response. The luminescent mechanism of both types of TLDs should be investigated in more detail.

The measured response of MSO-5D was higher than the calculated value of Mg_2SiO_4:Tb and lower than that of the bone. Such a discrepancy between measured and calculated values has also been observed at 15–40 keV[6]. The calculated value of energy response became larger, when the dopant ratio of Tb was increased in Mg_2SiO_4:Tb. The calculated response presented in Figure 4 is in the case of the nominal dopant ratio of 0.001 g atom mol^{-1}. However, it was assumed that Tb dopant was contained more in MSO-5D for the above reason.

CONCLUSION

The responses of TLDs of LiF:Mg,Cu,P (GR-200), LiF:Mg,Ti (TLD-100) and Mg_2SiO_4:Tb (MSO-5D) to dose and photon energy have been measured with 10–150 keV monoenergetic synchrotron photons at the SPring-8 facility. Linearity of dose responses was confirmed up to 2 Gy on each type of TLD between 50 and 150 keV. The TLDs of LiF and Mg_2SiO_4 had the energy responses nearly equal to soft tissue and human bone, respectively. However, TLDs of LiF:Mg,Cu,P and LiF:Mg,Ti exhibited different energy responses to each other, which seems to come from the luminescent efficiency. Therefore, more detailed study on the luminescence mechanism of TLD will be required.

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