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Dosimetric Characteristics of LiF:Mg,Cu,Na,Si Phosphor

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Abstract

Newly developed LiF:Mg,Cu,Na,Si phosphor is prepared at Korea Atomic Energy Research Institute (KAERI) and its dosimetric characteristics is studied. LiF based thermoluminescent (TL) material is a n early tissue equivalent material which is widely used to personal and environmental dosimetry. A numb er of LiF materials involving different dopants have been developed during past several decades

In the present study, we have investigated the TL characteristics of LiF:Mg,Cu,Na,Si phosphor as a new TL material. The phosphor was prepared with the concentrations of dopants: Mg, 0.6 mol%, Cu, 0. 8 mol% and NaSi, 1.8 mol%, respectively according to the preceding research results. Irradiation of thi s phosphor was carried out using X-ray beams and ^{137}Cs gamma source. The TL glow curves were me asured with a manual type TLD reader (System 310, Teledyne) at a constant flux and a heating rate of 5 K.s^{-1}.

The dosimetric properties of LiF:Mg,Cu,Na,Si phosphor examined in this study were included TL se nsitivity, photon dose response, energy response, detection threshold and fading characteristics. The main dosimetric peak of the phosphor appeared at 493 K for a constant heating rate of 5 K.s^{-1}, and its TL sensitivity was about two times higher than that of LiF:Mg,Cu.P. Photon dose response was linear up to the 20 Gy and the detection threshold was estimated 2.8 μGy. Photon energy response was within 2 0% than that of ^{137}Cs. When phosphor was stored at a room temperature, the intensity after 6 months s howed a bit of increase. At 343 K, the TL intensity gradually decreased to 80% of the initial intensity for 6 months.

INTRODUCTION

LiF TL material is a nearly tissue equivalent material which is widely used to personal and environ mental dosimetry. A number of LiF materials involving different dopants have been developed during p ast several decades. The sensitivity of LiF:Mg,Cu,P is approximately 30 times higher than that of LiF: Mg,Ti, so LiF:Mg,Cu,P is regarded as a very useful material in most of dosimetric applications.

A new TL material LiF:Mg,Cu,Na,Si phosphor is prepared at Korea Atomic Energy Research Institut e (KAERI). LiF:Mg,Cu,Na,Si [(1,2)] has a similar glow curve shape as LiF:Mg,Cu,P (GR-200P, Beijing) [(3)], but it is shown that both side peaks of the main peak have lower heights than those of GR-200P. The relative TL sensitivity of LiF:Mg,Cu,Na,Si phosphor is higher by about 2 times than that of GR-200P. Hence it can be used for the measurement of low doses effectively, but the glow curve struc ture and the dosimetric characteristics are not well known yet.

In this paper, we have studied the TL dosimetric properties of LiF:Mg,Cu,Na,Si phosphor. Relative TL sensitivity is compared with other commercial LiF phosphors. Photon dose response, detection thresh old and fading characteristics have been investigated.

MATERIALS AND METHODS

The fabricating procedure for LiF:Mg,Cu,Na,Si phosphor was shown in Figure 1. A host material LiF was thoroughly mixed with dopants of the following compounds; $MgSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$ and $NaSiO_3 \cdot 9H_2O$ in distilled water. The solution was mixed on a magnetic stirrer and dried in an oven at 353 K, the wet mixture was sintered in a muffle furnace at 1073 K for 30 minutes under a controlled nitrogen atmosphere. The sintered material in the crucible was quickly quenched to the room temperature and then pulverized in a mortar by hand to give a grain size about 200 mesh.

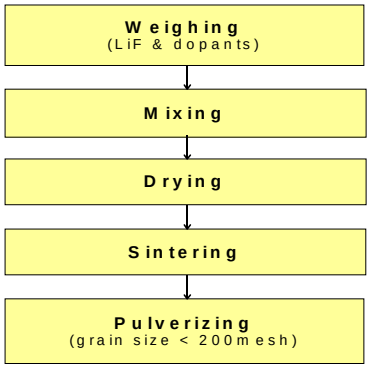

Figure. 1. Fabricating procedure for LiF:Mg,Cu,Na,Si phosphor.

The photon irradiation for phosphors was carried out using ^{137}Cs source and X-ray beams at the Korea Atomic Energy Research Institute (KAERI). The exposure rates and the effective energies of X-ray beams are shown in Table 1, and the irradiation dose is 10 mGy at all energies. The energy response was measured from 20 keV to 66 keV and normalized for the ^{137}Cs radiation.

The usefulness of dosimeter was examined with a result of linearity and the low dose detection limit. Dose response was investigated using 3.7, 185 and 3700 GBq ^{137}Cs gamma source in the range of 10^{-6} Gy – 20 Gy. Data was accumulated for 10^{-6}, 10^{-5}, 10^{-4}, 10^{-2},10^{-2}, 10^{-1}, 1, 10 and 20 Gy. All samples were placed on the 30cm PMMA phantom during the irradiation and were readout 8 times for each data point. Measurements were taken 24 hours after irradiation to eliminate the influence of low temperature TL glow peaks.

The glow curves of the samples were measured using commercial TLD reader (System 310, Teledyne Brown Engineering) controlled by personal computer. The weight of phosphor was 10 mg each measurements. Measurements were carried out with linear heating rate 5 $K.s^{-1}$ in a nitrogen flow. TL intensity evaluated by the area of glow curve between 373 K and 553 K.

Table 2. Effective energies used in photon source for energy depende

Radiation quality	Effective energy (keV)	Exposure rate (mR/min)
M30	20	1310
M60	34.2	1230
M100	54.2	1210
M150	76.7	1440
H150	118.0	60
^{137}Cs	662	416

RESULTS AND DISCUSSION

TL sensitivity

Figure 2, shows the TL glow curve of LiF:Mg,Cu,Na,Si phosphor compared with LiF:Mg,Cu,P (MCP-N, GR-200P). We can see that the each shoulder glow peaks of LiF:Mg,Cu,Na,Si is lower than those of LiF:Mg,Cu,P. MCP-N and GR-200P were annealed at 240°C for 10 minutes and LiF:Mg,Cu,Na,Si was used virgin phosphor. In the shapes of glow curve, we can show that both side peaks of main peak of LiF:Mg,Cu,Na,Si have lower intensities than the others. The TL sensitivities of MCP-N and GR-200 have nearly the same value. It is shown that the TL sensitivity of LiF:Mg,Cu,Na,Si is about two times higher than that of LiF:Mg,Cu,P. The main peak temperature of the LiF:Mg,Cu,Na,Si occurs in a bit higher temperature than that of LiF:Mg,Cu,P.

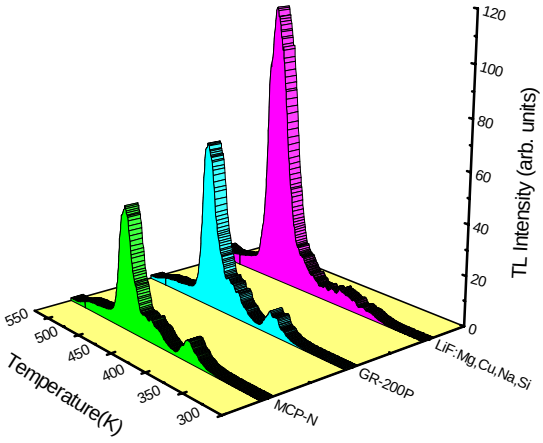

Figure 2. Typical TL glow curves of phosphors for constant heating rate of 5 $K.s^{-1}$. (a) MCP-N (LiF:Mg,Cu,P: Poland) (b) GR-200P (LiF:Mg,Cu,P: China) and (c) LiF:Mg,Cu,Na,Si. Irradiation dose was 10 mGy by ^{137}Cs source.

Dose response

Figure 3 shows the dose response for LiF:Mg,Cu,Na,Si phosphor irradiated with ^{137}Cs. The solid line is linear fitting of linear range. Linearity of LiF:Mg,Cu,Na,Si phosphor is shown from 10^{-4} Gy and the upper limit of linearity was not determined in this experiment. There is a large deviation from linearity in low dose region, it is due to the contribution of the photomultiplier dark current.

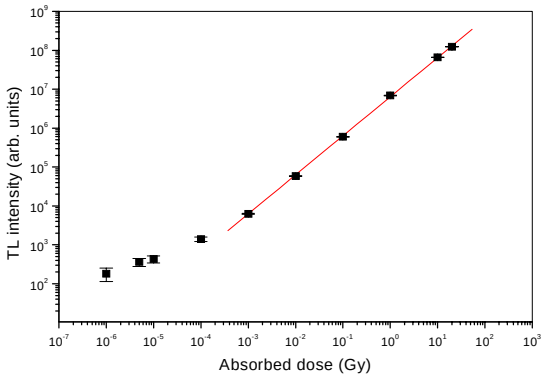

Figure 3. Dose response as a function of absorbed dose for LiF:Mg,Cu,Na,Si phosphor .

Detection threshold

The dose at the lower limit of detection was determined experimentally as the three times the stand ard deviation of the zero-dose reading for unexposed dosemeters [4]. The detection threshold of LiF:Mg, Cu,Na,Si phosphor was estimated to be 2.8 μGy. To apply another method for determine the minimum measurable dose (MMD) of the phosphor, the relative standard deviation, σ_D/D, was plotted as a functio n of dose as shown in Figure 4. The relative standard deviations are high for low doses caused by the dark current of the system but decrease with increasing dose level and result in a constant value for higher doses. Adapting a criterion of $1\sigma = \pm 20\%$ [5], the MMD is 2 μGy. The MMD and the detection threshold have almost same value.

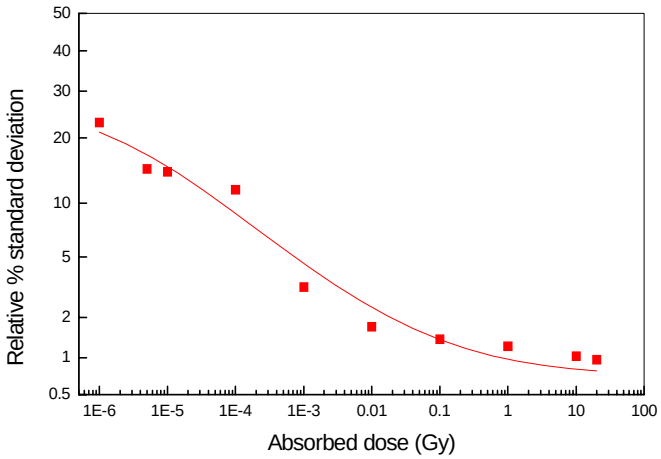

Figure 4. Relative standard deviation as a function of absorbed dos e for LiF:Mg,Cu,Na,Si phosphor . Lines are for the eyes.

Photon energy dependence

The photon energy response of LiF:Mg,Cu,Na,Si is shown in Figure 5. The experimental conditions of photon energies are shown in Table 1. The relative TL responses are normalized to that of ^{137}Cs res ponse. The energy response value for 34 keV is 20% higher than that of ^{137}Cs.

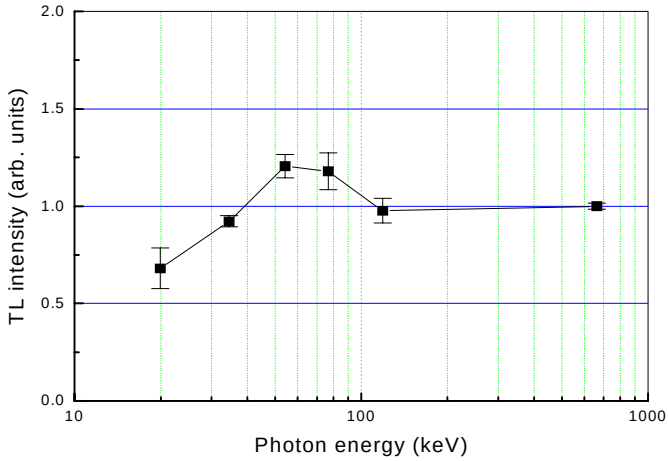

Figure 5. Photon energy dependence of LiF:Mg,Cu,Na,Si phosphor.

Fading

The fading experiment was carried out over a period of 6 months after irradiation. The phosphors o f 10g were irradiated by ^{137}Cs (10 mGy), and then divided two groups. One group was stored at a nat ural room temperature and the other was stored in the oven at 343 K. The TL response were normaliz ed to the TL response obtained at 2 hour elapsed time after irradiation. As shown in Figure 6, when p hosphor was stored at a room temperature, the intensity after 6 months showed a bit of increase. At 3 43 K, the TL intensity gradually decreased to 80% of the initial intensity for 6 months.

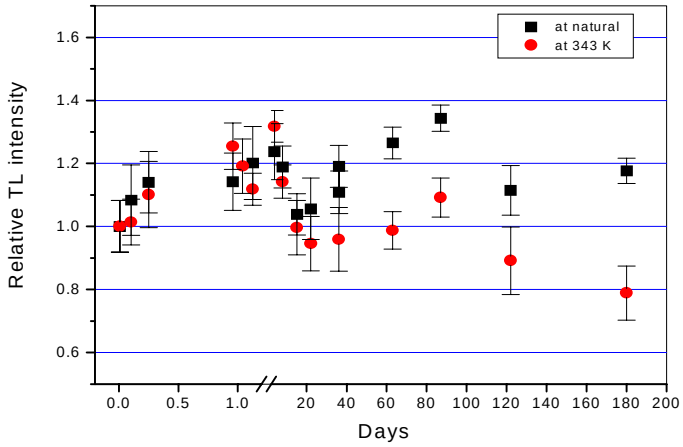

Figure 6. Fading characteristics of LiF:Mg,Cu,Na,Si phosphor at the r oom temperature(■) and at the 343 K (●).

CONCLUSIONS

The dosimetric properties of LiF:Mg,Cu,Na,Si phosphor examined in this study were included TL se nsitivity, photon dose response, energy response, detection threshold and fading characteristics. The main dosimetric peak of the phosphor appeared at 493 K for a constant heating rate of 5 $K.s^{-1}$, and its TL sensitivity was about two times higher than that of LiF:Mg,Cu.P. Photon dose response was linear up to the 20 Gy and the detection threshold was estimated 2.8 μ Gy. Photon energy response was within 20% than that of ^{137}Cs. When phosphor was stored at a room temperature, the intensity after 6 months showed a bit of increase. At 343 K, the TL intensity gradually decreased to 80% of the initial intensi ty for 6 months. These results present that LiF:Mg,Cu,Na,Si phosphor may be applied in personal and environmental dosimetry.

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