Preparation of Radiation Detector and Radiation Dosimetry

— TSEE Characteristics of LiF(Mg,Cu,Na,Si) Phosphor —

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방사선 검출기의 제작과 방사선 선량측정

— LiF(Mg, Cu, Na, Si) 형광체의 TSEE 특성 —

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LiF(Mg, Cu, Na, Si) 형광체의 γ선과 β선에 대한 TSEE특성을 조사하였다. ^{60}Co γ선에 대한 감도는 약 450 ***counts/mR*** 이었고, 여러가지 β선에 대한 TSEE 에너지 의존성은 β입자의 평균에너지 0.02 ***MeV*** 에서 0.8 ***MeV*** 사이에서 ±10%이었다. 그리고 제작된 형광체 앞면에 $7mg \cdot cm^{-2}$의 인체 등가물질을 두면 입사 β입자의 에너지에 무관하게 피부 흡수 선량을 측정할수 있었다.

I. Introduction

Thermally stimulated exoelectron emission(TSEE) and thermoluminescence(TL) method for beta dosimetry was reported by many workers[1)~4)]. Beta particle radiation is strongly absorbed by the skin. Hence, the skin dose is of major concern in beta dosimetry. The International Commission on Radiological Protection(ICRP) recomends a tissue depth of $7mg \cdot cm^{-2}$ as a depth for skin dose assessment[5)].

We reported the preparation method[6)] and thermoluminescence dosimetric properties of LiF(Mg,Cu,Na,Si) phosphor[7)]. The sensitivity of the phosphor to gamma radiation was about 20 times higher than that of LiF TLD-700 powder(Teledyne Isotopes) and the minimum detection of doses was about 0.1*m*Gy with a heating rate of 4.3°*C/s*.

The present work has studied TSEE characteristics of LiF(Mg,Cu,Na,Si) phosphor, including TSEE glow curves, sensitivity, energy dependence, TSEE efficiency and depth-dose distribution in the mean beta particle energy range from 0.02 *MeV* to 0.8 *MeV*.

II. Experimental

A mixture of LiF and small amounts of $MgSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$ and $Na_2SiO_4 \cdot 9H_2O$ were mixed and dissolved in ion exchange water. The solution was heated on a magnetic stirrer at 80℃ for 30*min.* and was then dried in a oven at 150℃ for 15 hours. The mixture was sintered in a muffle furnace at 800°*C* for 30*min* in a nitrogen atmosphere. Then it was quickly cooled to room temperature in air atmosphere and was pulverized to the powder.

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The LiF(Mg,Cu,Na,Si) phosphor thus obtained was cold-pressed a disc with a 10*mm* diameter and a thickness of 0.5*mm* and then sintered at 400℃ for 30*min*. The LiF(Mg,Cu,Na,Si) discs were used as TSEE specimens.

Beta irradiations were made using ^{63}Ni, ^{147}Pm, ^{204}Tl and ^{90}Sr-^{90}Y beta ray sources. The characteristics of the beta ray sources are shown in Table 1.

Table 1. Beta ray energies and stopping powers

Source	Energy(*MeV*)		stopping power dE/dx in Al ($MeV \cdot cm^2g^{-1}$)
	Max.	Mean	
^{63}Ni	0.0659	0.0172	11.2
^{147}Pm	0.2246	0.0621	4.4
^{204}Tl	0.7634	0.0621	2.0
^{90}Sr	0.5460	0.800	1.5
^{90}Y	2.2790		

Gamma irradiation was made using a ^{60}Co under electronic equilibrium conditions. The gamma exposure was measured with ionisation chamber(NE 2561, cavity size: 0.325*cc*). The injected number of incident beta particles were measured by a plastic scintillator of 5mm thickness and GM counter of $1.5\times10^{-2}kg \cdot m^{-2}$ window thickness. The absorbed dose of beta rays was measured using an extrapolation ionisation chamber.

TSEE was detected using a monopoint type methane flow counter made by the DIGITEC Co. in Western Germany[8]. An anode voltage was 3300*V*, and a charge-sensitive pre-amplifier was used to increase the sensitivity of the TSEE detection system.

III. Results and discussion

1. TSEE glow curve and TSEE sensitivity

Fig.1 shows TSEE glow curves from the LiF(Mg,Cu,Na,Si) disc surface irradiated with beta sources: ^{147}Pm, ^{204}Tl and ^{90}Sr-^{90}Y. The linear heating rate was set at $1^{\circ}C \cdot s^{-1}$. The TSEE glow curve of LiF(Mg,Cu,Na,Si) shows 5 peaks in the range from 0 to 400°*C*. The main peaks appears at 200°*C* and the other small peaks are at about 40, 123, 158 and 244°*C*, while for the TLD the main peak at 230°*C* and the other small peaks at about 85, 128, 176 and 275°*C*[7].

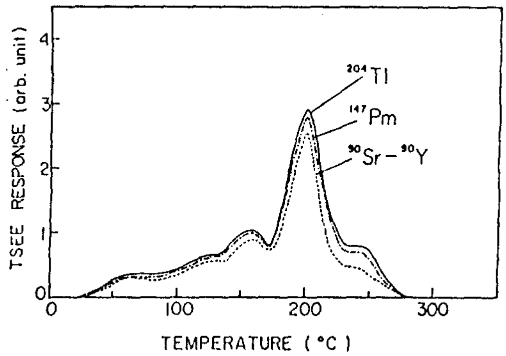

Fig. 1. TSEE glow curves of LiF(Mg,Cu,Na,Si).

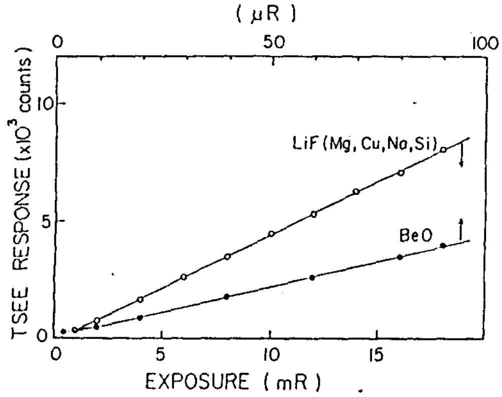

Fig. 2. TSEE responce versus exposure.

Fig.2 shows TSEE responses of LiF(Mg,Cu,Na, Si) and ceramic BeO(thermalox 995 from Brush Co, USA) for ^{60}Co gamma rays.

The sensitivity of LiF(Mg,Cu,Na,Si) expressed as the number of exoelectrons counted per unit exposure was about 450***counts***/*mR*, while for ceramic BeO it was about 4×10^4***counts***/*mR*.

2. Beta energy dependence and TSEE efficiency

Fig.3 shows TSEE and TL energy depenence of

LiF(Mg,Cu,Na,Si) as a function of mean beta energy. The mean beta energy response of LiF(Mg,Cu,Na,Si) was measured from 0.06*MeV* to 0.8*MeV* and normalized to ^{90}Sr-^{90}Y beta energy. As shown in Fig.3, the TSEE energy dependence was nearly constant($\pm 10\%$) in this region, whereas TL energy dependence showed decreasing sensitivity at lower energies. Therefore TLD elements can lead to significant errors in skin dose when exposed to low energy beta particles.

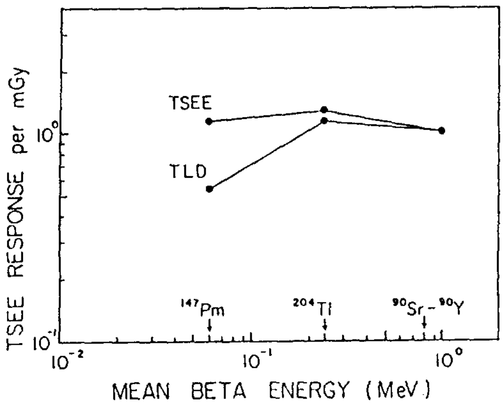

Fig. 3. TSEE and TL energy dependence of LiF(Mg,Cu,Na,Si) as a function of mean beta energy.

Fig.4 shows the efficiency of TSEE emission of LiF(Mg,Cu,Na,Si) and ceramic BeO for beta radiation. Because TSEE will be emitted from the thin surface layer of several tens of nanometers, the TSEE emission should be related to the stopping power dE/dx of mean beta radiation energy.

For comparision, the dE/dx data in aluminium have been chosen because the density of aluminium is nearly the same as that of LiF, and variation of stopping power in aluminium for mean beta energy was also plotted in Fig.4 on the same energy scale.

As we can see in Fig.4, the efficiency of TSEE emission of LiF(Mg,Cu,Na,Si) for beta radiation was in good agreement with stopping power data

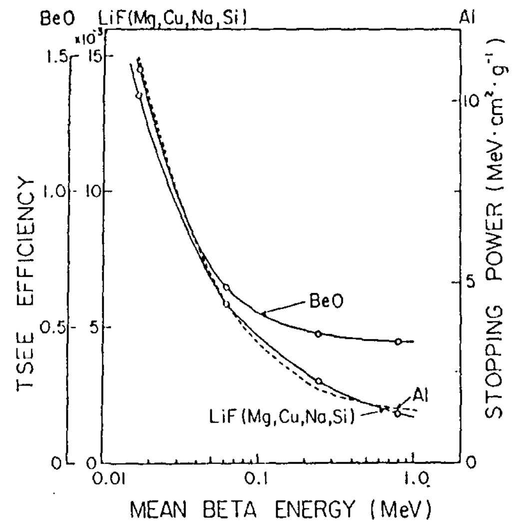

Fig. 4. TSEE efficiencies of LiF(Mg,Cu,Na,Si) and BeO at various beta energies and the stopping power, dE/dx, of Al as a function of energy.

in aluminium. The efficiency of TSEE emission of LiF(Mg,Cu,Na,Si) for beta radiation is 2×10^{-3} to 15×10^{-3}, and the efficiency of BeO is 0.45 to 1.5.

3. Depth-dose distribution

Fig.5 shows the depth-dose curve for beta rays in aluminium measured with LiF(Mg,Cu,Na,Si). Beta particles with energies greater than approximately 0.06*MeV* can penetrate to a depth

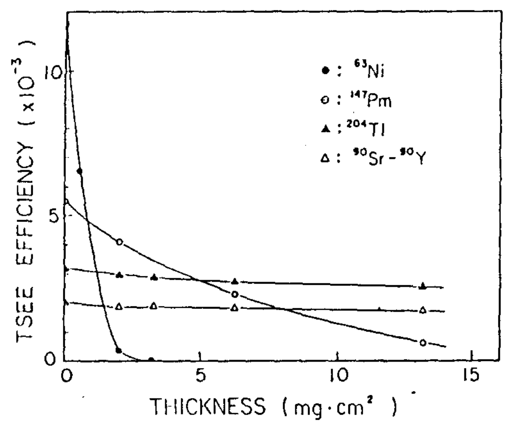

Fig. 5. Depth-dose curves in aluminium for beta rays of various energies.

of 0.07*mm* in soft tissue. As a shown in Fig.5, the beta particle from ^{63}Ni and those with lower energies do not contribute to the skin dose at 7mg · cm^{-2} depth. We can also measure beta doses nearly energy independently if a $7mg \cdot cm^{-2}$ thick window is applied. Skin absorbed doses from beta external sources can also be determined by this TSEE specimen without needing to know the beta particle energy, if the detector is covered by a $7mg \cdot cm^{-2}$ tissue-equivalent film.

IV. Conclusions

The TSEE glow curve of LiF(Mg,Cu,Na,Si) phosphor showed 5 peaks in the range from 0 to 400℃ and its main peak appeared at 200℃. The sensitivity of the phosphor for ^{60}Co gamma rays was about 450***counts***/*mR*. An accuracy of ±10% is obtained for the beta energy dependence. The efficiency of TSEE emission of LiF(Mg,Cu,Na,Si) phosphor for beta radiation was in good agreement with stopping power data in aluminium. The efficiency of TSEE emission of this phosphor for beta radiation was from 2×10^{-3} to 15×10^{-3}. The individual dose equivalent, superficial, Hs(0.07) can be measured by this specimen without needing to know the beta particle energy, if the phosphor is covered by a $7mg \cdot cm^{-2}$ tissue-equivalent film.

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