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Thermally Stimulated Exoelectron Emission from LiF(Mg,Cu,Na,Si) Phosphor

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LiF(Mg,Cu,Na,Si)형광체의 열자극엑소전자방출

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Abstract

The TSEE characteristics of LiF(Mg,Cu,Na,Si)phosphor for gamma and beta rays are described. The TSEE glow curve of this phosphor showed 5 peaks in the range from 20°C to 400°C and its main peak appeared at 240°C. The sensitivity of the phospor for ^{60}Co gamma rays was about 450counts/mR. TSEE energy dependence for various beta radiation was nearly constant (±10%) in the mean beta particle energy range from 0.02MeV to 0.8MeV. The efficiency of TSEE of the phosphor for beta radiation was (2~15)x10^{-3}.

요 약

LiF(Mg,Cu,Na,Si)형광체의 γ선과 β선에 대한 TSEE 특성을 조사하였다. 이 형광체의 TSEE glow 곡선은 20°C에서 400°C 사이에서 5개의 피크를 나타내었으며 주피크는 240°C였다.^{60}Co γ선에 대한 형광체의 감도는 약 450 counts/mR 이었다. β선에 대한 TSEE 에너지의존성은 β입자의 평균에너지 0.02MeV에서 0.8MeV 사이에서 ±10%이었다. 그리고 이 형광체의 β선에대한 TSEE 효율은 (2~15)x10^{-3} 이었다.

Ⅰ. Introduction

Thermally stimulated exoelectron emission (TSEE) and thermoluminescence (TL) methods for beta dosimetry were reported by many workers[1-4]. Exoelectron emission is a surface layer effect. Exoelctrons escape from very thin sensitive layers (10^{-3} to 10^{-2}μm thick) similar in thickness to the range of electrons of energies less than 1eV. Therefore it is more advantageous for the dosimetry of weakly penetrating beta rays than other solid state bulk method like thermoluminescence. Beta particle radiation is strongly absorbed in the skin. Hence, the skin dose is of major concern in beta dosimetry. The International Commission on Radiological Protection(ICRP) recommends a tissue depth of 7mg·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 0.1mGy.

In the present work, we have studied TSEE characteristics of LiF(Mg,Cu,Na,Si) phosphor,

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including TSEE glow curves, sensitivity, energy dependence, TSEE efficiency and depth-dose distribution in the mean beta particle energy range from 0.02 to 0.8MeV.

Ⅱ. Experimental

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

The LiF(Mg,Cu,Na,Si) phosphor thus obtained was cold-pressed the shape of disc with a 7mm diameter and a thickness of 0.5mm and then sintered at 400°C for 30min. The LiF (Mg, Cu, Na, Si) discs were used as TSEE specimens.

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	0.2433	2.0
^{90}Sr	0.5460	0.8000	1.5
^{90}Y	2.2790		

The beta ray irraidiation was carried out 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.

Gamma irradiataion was carried out using a ^{60}Co under electronic equilibrium conditions. The gamma exposure was measured with ionization chamber(NE 2561,cavity size: 0.325cc). The injected number of incident beta particles were measured by a plastic scintillator of 5mm thickness and GM counter of $1.5{\times}10^{-2}Kg{\cdot}m^{-2}$ window thickness. The absorbed dose of beta rays was measured using an extrapolation chamber fabricated in our laboratory.[8]

The TSEE was detected using a monopoint type methane flow counter (DIGITEC Co., Western Germany[9]). An anode voltage was 3300V, and a charge-sensitive pre-amplifier was used to increase the sensitivity of the TSEE detection system.

Ⅲ. Results and discussion

1. The TSEE glow curve and sensitivity

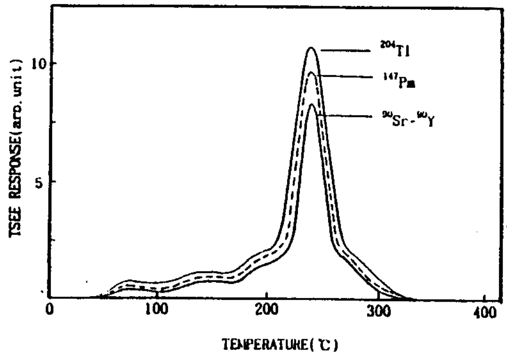

Fig. 1. The TSEE glow curves of LiF (Mg, Cu, Na, Si) phospor irradiated with beta ray of various energies.

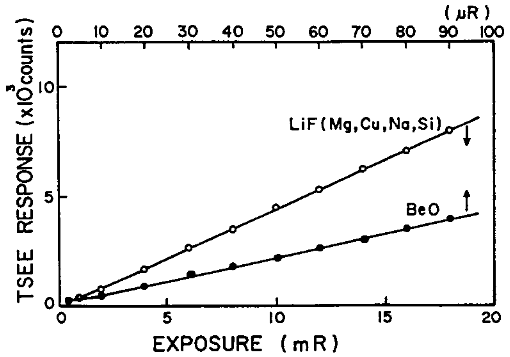

Fig. 2. The TSEE response versus gamma ray iraadiation.

Fig.1 shows the TSEE glow curves from the LiF(Mg,Cu,Na,Si) specimens surface irradiated using ^{147}Pm, ^{204}Tl and ^{90}Sr- ^{90}Y beta sources respectively. The linear heating rate was set at 1°C · s^{-1}. The TSEE glow curve of LiF(Mg,Cu,Na,Si) shows 5 peaks in the range from 20°C to 400°C. The main peak appears at 240°C and the other small peaks are at about 72, 144, 192 and 288°C The TSEE glow curve structure of the phospor was found to be similar to the TL glow curve.

Fig. 2 shows the TSEE responses of LiF(Mg,Cu,Ni,Si) and ceramic BeO(thermalox 995 from Brush Co,USA) for ^{60}Co gamma rays. The sensitivity of LiF(Mg,Cu,Na,Si) expressed in terms of the number of exoelectrons counted per unit exposure was about 450counts/mR, while for ceramic BeO it was about 4×10^4 counts/mR.

2. Beta energy dependence and TSEE efficiency

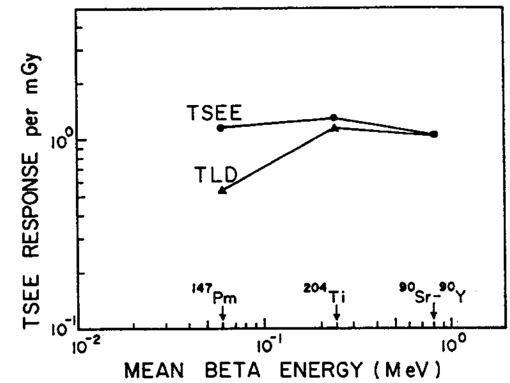

Fig. 3. The TSEE and TL energy dependence of LiF (Mg, Cu, Na, Si) as a function of mean beta energy.

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

Fig.4 shows the efficiency of the TSEE of LiF(Mg,Cu,Na,Si) phospor and ceramic BeO for beta radiation. Because TSEE will be emitted

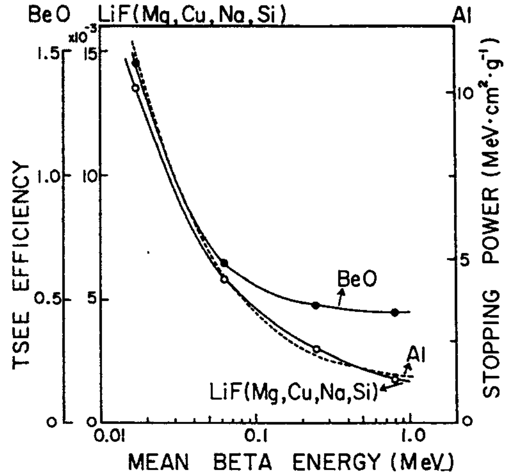

Fig. 4. The TSEE efficiencies of LiF (Mg, Cu, Na, Si) and BeO at various beta energies and the stopping power, dE/dX,of Al as a function of energy.

from the thin surface layer of several tens of nanometers,[10]the TSEE 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 the TSEE of LiF(Mg,Cu,Na,Si) phospor for beta radiation was in good agreement with stopping power data in aluminium. The efficiency of the TSEE of the phosphor for beta radiation was $(2 \sim 15) \times 10^{-3}$,and the efficiency of BeO was 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 of 0.07mm 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 $7mg{\cdot}cm^{-2}$ 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 with a $7mg{\cdot}cm^{-2}$ tissue-equivalent film.

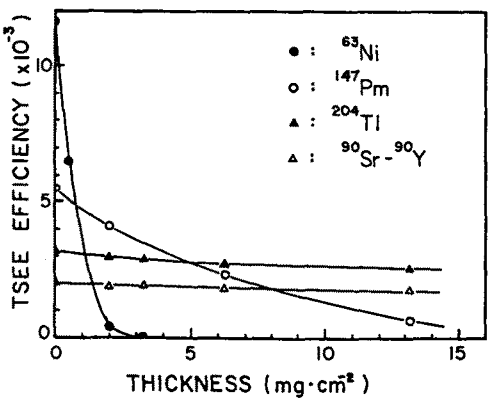

Fig. 5. Depth-dose curves in aluminium for beta rays of various energies.

Ⅳ.Conclusions

The TSEE glow curve of LiF(Mg,Cu,Na,Si) phospor showed 5 peaks in the range from 20°C to 400°C and its main peak appeared at 240°C. The sensitivity of the phospor for ^{60}Co gamma rays was about 450counts/mR. The beta energy dependence of the phospor for TSEE detection was observed to be flat within ±10%. The efficiency of TSEE of the phospor for beta radiation was in good agreement with stopping power data in aluminium. The efficiency of TSEE emission of this phospor for beta radiation was from $(2\sim15)x10^{-3}$.

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