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# Study on Characteristics of Photo Transferred Thermoluminescence Effect on LiF:Mg,Cu,Si

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## 1. Introduction

Thermoluminescence dosimeter (TLD) is a detector that represents personal dosimeter in many years. Recently, dose re-evaluation in personal dosimetry is gradually required because it makes the measurement system more reliable as offering a chance to repeat the measurement. Compared with OSLD (Optical stimulated luminescence dosimeter), dose re-evaluation using TLD was considered impossible due to erase process of trap charge during high temperature measurement. However, the residual charges in the deep trap are still remained after TL reading, these charges are recycled by phototransferred thermal luminescence (PTTL) method. PTTL is a phenomenon of charge transfer from a deep trap to a shallow trap by irradiating the pre-measured TLD with UV [1]. In general, TL materials such as LiF:Mg,Cu,P and LiF:Mg,Ti reported fairly successful dose re-assessment with PTTL [2-4]. However, in the case of LiF:Mg,Cu,Si, PTTL characteristics have not been sufficiently studied. LiF:Mg,Cu,Si developed by the Korea Atomic Energy Research Institute (KAERI) showed higher signal(55 times) than LiF:Mg,Ti and lower residual signal(0.025%) than LiF:Mg,Cu,P [5]. Unfortunately, from these properties, a lower PTTL signal is expected, as the result implies that the charge density in the deep trap is lower. Therefore, careful procedures need to be considered to optimize the signal. In this study, the results of PTTL properties of LiF:Mg,Cu,Si were presented to provide a simple and reliable method for re-evaluation, compatible with routine personal dosimetry service. The parameters of UV irradiation were optimized with respect to wavelength, exposure time and maximum temperature of TL reading. Various heat treatments after each PTTL measurement were performed to remove residual PTTL signals that affect the subsequent PTTL measurement. Using this protocol, linear dose response curves were successfully recorded .

## 2. Materials and Methods

LiF:Mg,Cu,Si TLD was manufactured as pellets with a diameter of 4.5 mm and a thickness of 0.8 mm [5]. Both sides of the pellet were polished to confirm close contact on the hot plate during readout. Two stage thermal annealing at 300 ℃ for 10 minutes followed by 260 ℃ for 10 minutes was performed using an oven [6] to obtain thermal stability of TLDs. A $^{90}Sr/^{90}Y$ beta ray irradiator was used to give a reference dose of 28.5 mGy. TL and PTTL signals were acquired by a Harshaw 4500 reader. The measurement temperature was started from 50 to 260 ℃ with a heating rate of 5 ℃/s and the final temperature was lasted for 20 seconds. The signal integration interval was from 190 to 260 ℃. The sample was irradiated with UV using UV lamp (UVP UVLMS-38 EL 8W) capable of selecting 3 wavelengths. Despite the fact that wavelengths of 254, 302, 365 nm are supported, only 254 nm was mainly used for the best signal. Pellets were placed along the center of the UV lamp by using a fixed sample plate at a distance of 1.5 cm from the surface of the lamp in order to make uniform and strong ultraviolet radiation incident. UV Lighting was done in the dark at room temperature for 90 minutes. All experiments were done under red light condition to avoid the additional UV irradiation contained in the fluorescent lamp.

Prior to the measurement, all TLDs were prepared after two-stage thermal annealing. Due to the large signal variation of the sample, the same TLD was used for one experiment and different sets of pellets were provided for each experiment. The order of the experiments is as follows. First, the sample was irradiated with beta rays, and immediately thereafter the TL signal was measured. Secondly, the sample was exposed for a predetermined time by UV, and the PTTL signal was also immediately measured to ignore the fading effect. Third, since a significant residual UV induction signal was observed after PTTL measurement, PTTL reset by heat treatment to reuse the same sample was applied. Finally, the first step was repeated with the same sample. Heat treatment was carried out using RadPro TLD Cube. The distance of this UV lighting was the same as PTTL setting.

## 3. Results and Discussion

In Fig. 1, PTTL by UV irradiation time is shown. In this experiment, signals after UV irradiation for 30 to 150 minutes were recorded. The intensity linearly increases with irradiation time and the saturation from 90 minutes are observed. The saturated signals are about 20 and 10% higher than that of 30 and 60 minute exposures, respectively. Due to no increase in intensity over 90 min is observed, 90 minutes is the more suitable with considering the convenience of the experiment.

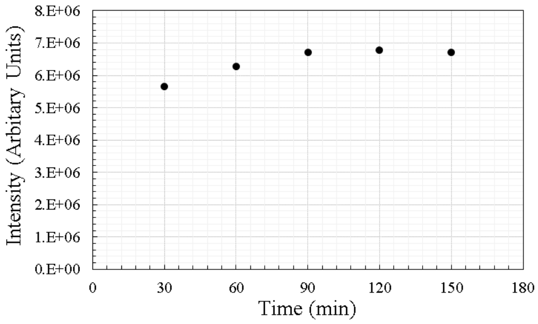


Fig 1. PTTL according to the UV illumination time from 30 to 150 min.

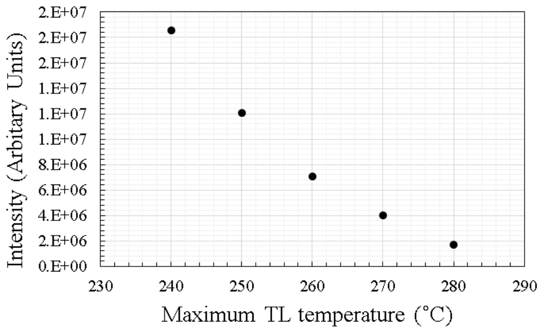


Fig 2. PTTL according to the maximum temperature of the previous TL measurement from 240 to 280 ˚C.

The PTTL signal is sensitive to the maximum temperature of TL measurement. The PTTL signal after TL measurement from 240 to 280 ℃ was presented in Fig. 2. All TL measurements were done with a heating rate of 5 ℃/s and each final temperature was lasted for 20 seconds. The PTTL signal decreases as increasing the maximum temperature of TL, as deep traps are easily emptied by high temperature. The PTTL signal tends to linearly decrease from the 240 to 260 ℃, but for the 270 and 280 ℃ decreasing rate is reduced due to sensitivity changes. For each of 240 and 250 ℃, signals as high as 2.5 and 1.7 times, respectively, were obtained. The optimum TL reading temperature is confirmed at 240 ° C from the result. Nonetheless, 260 ℃ TL reading has already been used for routine personal dosimetry service, so the TL measurement at 260 ℃ was used as default.

The dose response of PTTL in the range of 1.14 to 51.3 mGy was measured in Fig. 3. The results exhibit fairly linear characteristics within the given dose range. The zero dose and minimum detectable dose (MDD) were also verified. The zero dose is 1.36 ± 0.51 mGy and the MDD (3 sigma) is 1.53 mGy. These values are quite effective for dose re-estimation, which is mainly used for highly exposed persons.

In fact, the routine personal dosimetry service measures TL every quarter. Therefore, it is difficult to take into the PTTL reset, but accumulation of the signal by quarterly recorded dose become a problem. Furthermore, because the PTTL signal decreases with the number of TL measurements, the decrease in cumulative PTTL signal should also be considered. A normalized PTTL signal according to the number of serial TL measurements is presented in Fig. 4. The data shows the exponential decay with the TL measurement. Consequently, since the PTTL signal is maintained more than 10% after 5 TL measurements, the correction should be made especially for the highly exposed TLD.

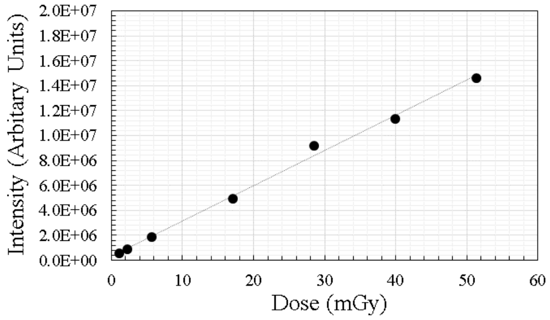


Fig 3. Dose response of the PTTL in a range of 1.14 to 51.3 mGy

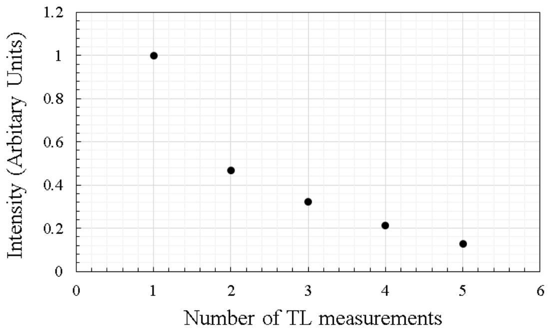


Fig 4. Normalized PTTL signals according to the number of serial TL measurements

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