Dose reconstruction using LCD glass of category B in recent mobile phone (*Smart Phone*)

Min Chae Kim[a,b], Hyoungtaek Kim[a], Seung Kyu Lee[a], Insu Chang[a], Sangwon Park[a,c], Jungil Lee[a*], Jang-Lyul Kim[a], Chan Hyeong Kim[b]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 34057, Republic of Korea*
[b]*Department of Nuclear Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, 04763, Korea*
[c]*UST(University of Science and Technology) ,217,Gajeong-ro, Yuseong-gu, Daejeon, 34113, Republic of Korea*
**Corresponding author: jilee@kaeri.re.kr*

1. Introduction

When unexpected radiation accidents occur, such as malevolent terror in public places using radiation sources or large-scale nuclear accidents, securing the dose information of the exposed person is very important for the triage and fast medical treatments. Retrospective dosimetry, such as thermoluminescence and optically stimulated luminescence (TL/OSL) method, is a technology that provides dose information using surrounding materials in the absence of personal dosimeter, enabling rapid dose reconstruction in emergency situations. Until now the emergency dosimetry using TL/OSL method was mainly based on the use of resistors of mobile phones. As the latest process technology develops, however, the number of resistors in mobile phones is actually reduced, resulting in limitations in the use of resistors on retrospective dosimetry. Although dosimetric properties of display glasses were shown promising results for retrospective dosimetry, the detection limit of display glasses is relatively high compared to other electronic components of the mobile phone. Using a display glass of the mobile phone is only applicable to accident doses above 130 mGy in the TL/OSL method [2] compared to 100 mGy of resistors [4]. On the other hand, display glasses of a mobile phone has two advantages compared to the other electronic components. First, the size of glasses in latest mobile phones has a tendency to grow in contrast to resistors. Second, the collected mobile phones can be reused through a glass replacement since only the glass is used for dose analysis. In case of expensive smartphones, the burden of the economic cost due to the disassembly of the phone is relatively low.

In the previous study on display glasses (liquid crystal display, LCD) of mobile phones, the glasses were divided into four categories according to the radiation induced shape of the TL glow curve: Category A (lime-aluminosilicate glasses) , category B and C (boron-silicate glasses) and category D (soda-lime glasses) [1] which are shown in Fig. 1. Currently, retrospective dosimetry using the display glasses is mainly focused on category A due to favorable properties like long-term stability and detection limit [1]. However, it turned out that the LCD glass of the iPhone 6™, one of the most popular phones, belongs to the category B through several experiments in this study. Moreover, the number of resistors (type 0402) located on the circuit board in the iPhone 6 were confirmed to be less than 4 which limits the dose reconstruction using resistors. Therefore, it is highly required to evaluate the dosimetric properties of glasses of category B especially in a recent mobile phone like iPhone 6.

In the previous study, the dosimetric characteristics of category B glass was measured using Risø TL/OSL reader with a Hoya U-340 filter which has blue detection windows between 280 and 380 nm [3]. In case of the TL signals of iPhone 6 glasses, it revealed that no meaningful signal was observed with the U-340 filter which means lower sensitivities of the glasses than that of the previous studies. In addition, the difference in intensity between longer wavelengths and shorter wavelengths was also found in the TL spectra of iPhone 6 glasses. Therefore, dose recovery protocol on category B glasses was conducted without U-340 filter in this study.

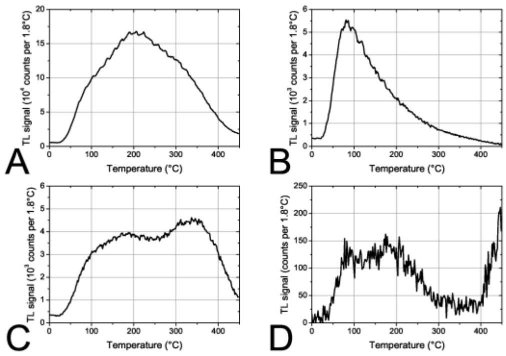

Fig 1. Different TL glow curves of display glasses divided into four categories A, B, C and D [1].

2. Materials and Methods

To prepare the glass samples, after separating the display glass part from the mobile phone, it was divided to two parts of the glasses (front glass and bottom glass). The material used in the experiment is the bottom substrate glass where the thin-film transistor (TFT) structure is defined. The glass was cleaned with ethanol and acetone for 15 min to remove glues on the surface. The influence of the intrinsic background signal caused by these TFT patterns is quite high. To reduce this intrinsic background signal, the glass samples was etched with hydrofluoric acid (HF). The samples were cut into 5 x 5 mm and placed on the sample disc.

The measurements were recorded up to 450 ˚C using a Risø TL/OSL reader Model DA-20, and the signal integration interval was set from 100 to 250 ˚C. Some parts of the TL signals of the glasses are very unstable because it is inherently influenced by natural light or its own backlight. To simulate the similar light condition, the signal readings were always performed after an optical bleach for 500 s using the built in blue LEDs (470 nm) of the reader. Consequently hard to bleaching components which are remained and stable signal after bleach was only used for the measurement. The U-340 filter was used during the bleach because the filter is combined with the LED module and the filter was removed when measuring the TL signal for each measurement. Background subtraction was applied to offset the black body radiation at high temperature region.

3. Results and Discussion

The TL glow curve of iPhone 6 glass was represented in Fig. 2. The curve shows a maximum peak around 100 ˚C and decreases with increasing temperature. The result is confirmed that the iPhone 6 glasses are in agreement with the category B in Fig. 1 B.

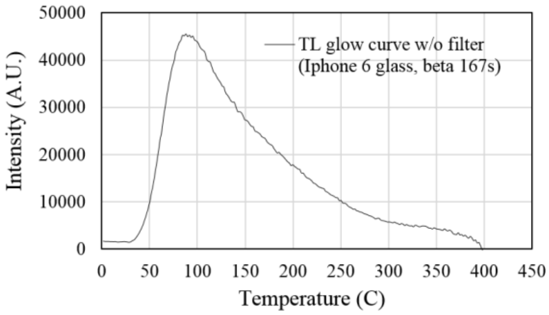

Fig 2. The TL glow curve of a beta irradiated (167 s) iPhone 6 glass measured without U-340 filter.

To confirm that the category of iPhone 6 glasses is B, the TL spectra were acquired from 280 to 750 nm. The emission spectra of the iPhone 6 glasses about 1 – 20 kGy of Co-60 gamma ray is presented in Fig. 3.

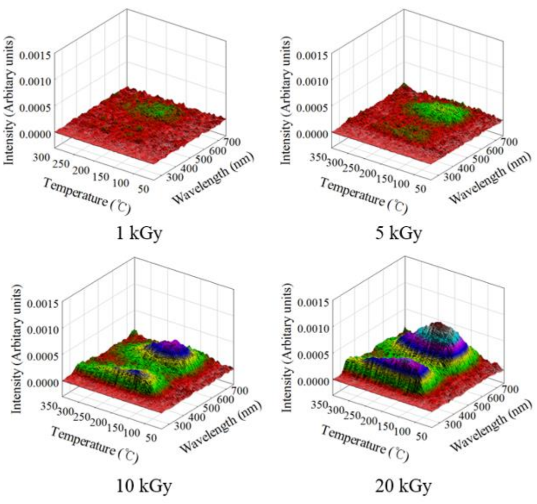

Fig 3. The TL emission spectra of iPhone 6 glass

At 1 kGy, almost negligible signals were observed due to the lower sensitivity of the glasses. At 20 kGy, two peaks of around 300 and 600 nm were obtained. The result is consistent with the spectra acquired in previous study [3].

Long term stability of the TL signals of iPhone 6 glasses is shown in Fig. 4. The signal was measured by delaying from the initial measurement to the measurement after 30 days and the signals were normalized to the initial value. The results show a similar tendency to the category B glasses of the previous study. The fading characteristics of the iPhone 6 glasses are quite poor since the signal after one month is only around 20% compared to the category A around 50% of the initial signal. The reason for the signal shift slightly high compared to the previous results is that the initial signal was less estimated due to the time spent by filter removal.

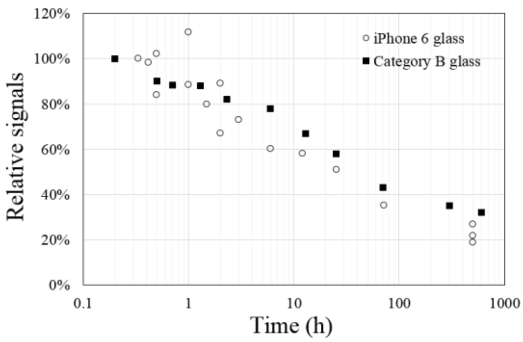

Fig 4. Long term stability of the TL signals of iPhone 6 glasses compared to the previous results of category B [3]

4. Conclusion

It was confirmed that the LCD glass in iPhone 6 were category B through characterization of the TL glow curve structure, 3D TL emission spectra and fading pattern. Dose response of the glass sample was linear up to several Gy. Measuring the TL signals of the glass without the U-340 band-pass filter was required due to the low radiation sensitivity. It could be concluded that the category B glass can be applicable to dose reconstruction in case of radiological accident.

REFERENCES

[1] M. Discher, and C. Woda, Thermoluminescence of glass display from mobile phones for retrospective and accident dosimetry, Rad. Meas., 53-54, pp. 12-21, 2013
[2] M. Discher, C. Woda, and I. Fiedler, Improvement of dose determination using glass display of mobile phones for accident dosimetry, Rad. Meas., pp. 1-4, 2013
[3] M. Discher, and C. Woda, Theremoluminescence emission spectrometry of glass display in mobile phones and resulting evaluation of the dosimetric properties of a specific type of display glass, Rad. Meas., pp. 1-5, 2014
[4] J. S. Eakins et al, The PHE fortuitous dosimetry capability based on optically stimulated luminescence of mobile phones, Rad. Pro. Dos., Vol. 170, No. 1-4, pp.412-415, 2016