Radiation Measurements 56 (2013) 240–243

Contents lists available at SciVerse ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Improvement of dose determination using glass display of mobile phones for accident dosimetry

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HIGHLIGHTS

- ► Glass displays from mobile phones have good potential for emergency dosimetry.
- ► The background signal can be reduced by etching glass samples with hydrofluoric acid.
- ► The minimum detectable dose can be lowered to approximately 80 mGy.

ARTICLE INFO

Article history:
Received 15 October 2012
Received in revised form
20 December 2012
Accepted 15 January 2013

Keywords:
Retrospective dosimetry
Accident dosimetry
Glass display
Mobile phone
Emergency dosimeter
Thermoluminescence (TL)

ABSTRACT

Previous studies have demonstrated that mobile phones can be used as suitable emergency dosimeters in case of an accidental radiation overexposure. Glass samples extracted from displays of mobile phones are sensitive to ionizing radiation and can be measured using the thermoluminescence (TL) method. A non-radiation induced background signal (so-called zero dose signal) was observed which overlaps with the radiation induced signal and consequently limits the minimum detectable dose. Investigations of several glasses from different displays showed that it is possible to reduce the zero dose signal up to 90% by etching the glass surface with concentrated hydrofluoric acid. With this approach a reduction of the detection limit of a factor of four, corresponding to approximately 80 mGy, was achieved. Dosimetric properties of etched samples are presented and developed protocols validated by dose recovery tests under realistic conditions. With the improvements in sample preparation the proposed method of dose determination is a competitive alternative to OSL/TL measurements of electronic components and chip cards and provides a useful option for retrospective accident dosimetry.

1. Introduction

In case of radiation exposure by a radiological incident a technique is needed to determine the absorbed dose of individuals for triage purposes, if no personal dosimeters are available. Previous studies have demonstrated that certain electronic parts of a mobile phone are suitable as accident dosimeters (Ekendahl and Judas (2012); Fiedler and Woda (2011); Inrig et al. (2008)). Next to electronic components on the circuit board, glass from mobile phone displays has also been shown to be potentially useful as a dosimetric material using thermoluminescence (TL) (Bassinet et al. (2010)). In the majority of cases a mobile phone is carried close to the body by a large part of the general population so it can be used as fortuitous dosimeter.

In a recent work, the dosimetric properties of glass displays were investigated in detail with regard to signal stability, signal bleaching and dose response. A suitable protocol was developed for the use under realistic conditions (Discher and Woda, in press). One of the challenges is that for TL measurements of an irradiated glass sample an overlap of the radiation induced signal with a non-radiation induced background signal (so-called zero dose signal) is observed. The latter is irreversibly deleted after the first TL measurement or after heating the sample in an oven. Despite optimizing the temperature integration interval of the TL glow curve, the zero dose signal contributes significantly to the detection limit of around 340 mGy, while on thermally annealed glass samples detection limits of approx. 10 mGy are achievable.

Generally, backside glasses of displays showed lower background doses than frontside glasses, making the former the material of choice for dose assessment. The aim of this work was to minimize the non-radiation induced background signal by removal of the glass surface layer through etching. The minimum detectable dose (MDD) on the chemically pretreated glass samples is assessed

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http://dx.doi.org/10.1016/j.radmeas.2013.01.027

and the applicability of previously developed protocols validated by dose recovery tests under realistic conditions.

2. Materials and methods

Extracted glass samples of different mobile phone displays were investigated (different brands, models and production years). The dimensions of the samples were approx. 5 × 5 mm^2, fitting into the measuring cup of the TL reader. Concentrated hydrofluoric acid (HF, 40%) was used to etch the glass surface for different periods of time. After etching the samples were cleaned thoroughly with distilled water and ethanol.

TL measurements were carried out with the automated luminescence reader Risø TL/OSL-DA-15 (Risø Danmarks Tekniske Universitet (2008)). For laboratory irradiations a built-in beta source (Sr-90/Y-90) was used, with an absorbed dose rate of ≈41.9 mGy/s, determined for quartz grains in the grain size fraction of 140–200 μm. As shown in Moffatt et al. (2012), these values should be readily applicable to glass samples as well. The luminescence reader is equipped with blue LEDs (470 ± 30 nm, approx. 36 mW/cm^2 at the sample position), which were used in the present study mainly to bleach the samples prior to TL measurement. The luminescence signal was detected with a bialkali photomultiplier tube (Thorn-EMI 9235) through a Hoya U-340 filter (transmission window of 290–370 nm). All TL measurements were carried out with a heating rate of 2 °C/s with thermal background subtraction. To simulate the bleaching of the TL signal by the background light LEDs of a mobile phone display after irradiation, a still functioning display unit was used where the display glasses had been removed.

3. Results and discussion

3.1. Etching of glass samples

The effect of etching glass samples with concentrated HF was investigated. An etching time of 4 min is sufficient to remove the TFT structure. This structure exists only on the surface of a backside glass of a display. After the HF treatment the glass samples appeared transparent (see Fig. 1).

3.2. Reducing the zero dose signal by etching

Every glass sample shows a natural, non-radiation induced TL signal, which is termed zero dose signal. It is erased by the first TL readout or after heating the sample in an oven (Discher and Woda, in press).

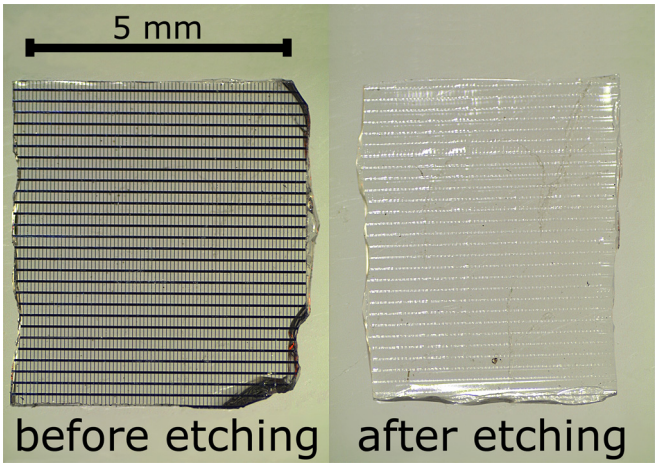

Fig. 1. Enlarged image of a glass sample (backside glass with TFT structure) before and after etching with HF for 4 min. The etched sample appears totally transparent.

3.2.1. Variation of the etching times

The influence of the etching time was investigated with several samples cut from the same extracted glass plate. By increasing the etching time a mass loss and a strong decrease of the zero dose signal was observed (see Fig. 2). To compensate the mass loss during etching, measured TL glow curves were normalized to the sample mass. The result demonstrates that the zero dose signal originates from the surface layer of the glass. The radiation induced signal, on the other hand, originates from the bulk material (not shown).

In the inset of Fig. 2 the signal decrease (integration interval 0–450 °C) was calculated relatively to the unetched TL signal for different etching times. In addition a linear correlation is observed between the mass loss, calculated relatively to the unetched sample and the etching time ($R^2 = 0.997$). The majority of loss of zero dose signal occurs within the first four minutes of etching. For longer etching times the additional gain in signal reduction is small and is outweighed by the increasing loss in sample mass, which will result in less radiation sensitivity. Considering the additional aspect that shorter sample preparation times will enable higher throughput in a mass casualty scenario, the etching time was fixed to 4 min as the optimum compromise between background reduction, sensitivity and sample preparation time.

3.2.2. Zero dose signal vs. radiation induced signal

With a set of 28 etched and unetched samples the reduction of the zero dose signal was investigated with the standardized etching time of 4 min. For each sample the zero dose signal was recorded and after an irradiation of 1 Gy a TL calibration measurement followed (see Fig. 3). To compare the zero dose signals of the different samples, each glow curve was normalized to the respective 1 Gy glow curve. The intensity of the zero dose signal decreased significantly with etching. The degree of reduction in the integration interval (100–250 °C) is not the same for all investigated samples and will be investigated in detail further below. The reduction of the zero dose signal potentially enables shifting of the integration interval towards higher temperatures, where fading is significantly reduced (Discher and Woda, in press).

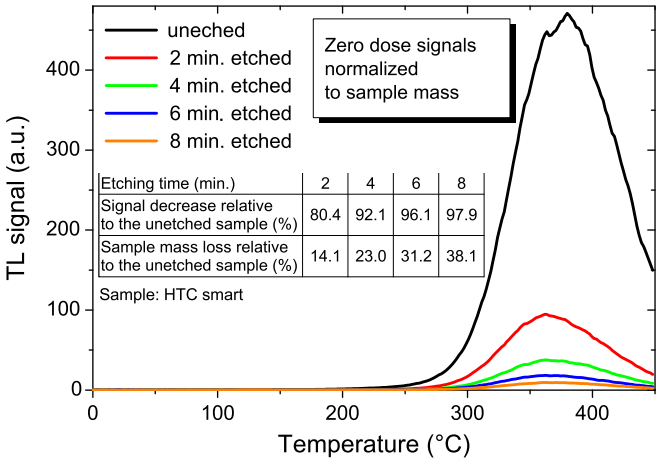

Fig. 2. Variation of etching time. The samples were extracted from the same display glass plate and the etching time with HF was varied. The TL intensity of the TL glow peak is normalized to mass, because of the mass loss due to etching. The table inset shows the signal and mass decrease relative to the unetched sample depending on etching time.