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Investigations of touchscreen glasses from mobile phones for retrospective and accident dosimetry

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HIGHLIGHTS

- Touchscreen glasses are sensitive to ionizing radiation and show suitable dosimetric properties.
- Mechanically treated samples demonstrated a significant reduction of the intrinsic zero dose signal.
- An irradiation trial showed limitations of the used protocol for strongly bleached samples.

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ABSTRACT

Touchscreen glasses of mobile phones are sensitive to ionizing radiation and have the potential of usage as an emergency dosimeter for retrospective dosimetry for the purpose of triage after a radiological accident or attack. In this study the TL glow curves and dosimetric properties of touchscreen glasses were studied in detail, such as intrinsic background dose, dose response, reproducibility, optical stability and long-term stability of the TL signal.

Preliminary results are additionally presented to minimize the intrinsic background dose by mechanically removing the surface layer of the glass samples. Additionally chemical element analyses of the touchscreen glass samples were carried out to investigate the difference between glass samples which show a TL signal and samples which show neither an intrinsic zero dose signal nor a radiation induced TL signal.

An irradiation trial using glass samples stored in the dark demonstrated a successful dose recovery. However, when applying a realistic, external light exposure scenario, dose underestimation was observed, even though samples were pre-bleached prior to measurement. More investigations have to be carried out in the future to solve the challenge of the low optical stability of the TL signal, if touchscreen glasses are to be used as a reliable emergency dosimeter.

1. Introduction

The use of ionizing radiation sources for industrial, medical and research increases the possibility of accidental exposure of operators and civilians. Attention is also given to the possibility of intentional exposure due to a radiological attack with a high number of potentially exposed people. In the event of such an emergency, the dosimetric triage (using methods of biological and physical retrospective dosimetry) is extremely important to identify the people with high exposures and to distinguish them from the lower and non-exposed, including the so-called "worried-well", i.e. those who only need to be reassured.

Most of the methods of retrospective dosimetry are based on the measurement of the radiation damage induced in tissues, mainly blood cells but also teeth and nails (Williams et al., 2014; Trompier et al., 2014) or in personal items worn by the individual (Ainsbury et al., 2011). The possibility to use personal objects such as watches, electronic devices, ID cards, etc. as individual dosimeters has been

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successfully investigated (Bassinet et al., 2014a; Ekendahl and Judas, 2012; Ekendahl et al., 2015; Fiedler and Woda, 2011; Mrozik et al., 2014a, 2014b; Pascu et al., 2013; Pradhan et al., 2014; Sholom and McKeever, 2014; Trompier et al., 2011a, 2011b; Woda et al., 2009; Woda et al., 2012).

In particular, electronic components mounted on a circuit board, like resistors, inductors or resonators, and display screens of electronic devices appear particularly effective. Previous studies carried out on glass collected from display screens of mobile phones using thermoluminescence (TL) technique provided encouraging results. The investigated dosimetric properties allow using display glass for accident dosimetry (Bassinet et al., 2010; Discher and Woda, 2013, 2014; Discher et al., 2013). For instance a good reproducibility of the TL signal and linear response in the studied dose range between 0.1 and above 10 Gy were observed.

Additionally the photon energy dependence and angular response were experimentally investigated for different display glasses used in mobile phones (Bassinet et al., 2014b; Discher et al., 2014) and experimental results validated using radiation transport simulations (Discher et al., 2015).

However, limits related to the fast fading and the presence of an intrinsic background signal, which partially overlaps the radiation induced signal, have been reported (Bassinet et al., 2010; Discher and Woda, 2013, 2014; Discher et al., 2013). To correct for signal loss due to light exposure, Discher and Woda (2013) proposed a measurement protocol for dose evaluation, including a partial bleaching of the TL signal by exposure to 500 s of blue light from LEDs of the luminescence reader. Regarding the intrinsic background signal, its origin is not yet understood. The UV exposure at the production or manufacture stage has been suggested as one possible cause (Bassinet et al., 2010). In literature it is also reported that this signal is mainly present in the surface layer of the glass display and can be removed by either chemical (Discher et al., 2013) or mechanical treatments (Bassinet et al., 2014b).

The glass investigated so far was mainly obtained from liquid crystal displays (LCDs). In Fattibene et al. (2014) touchscreen glasses of mobile phones were investigated using electron paramagnetic resonance (EPR) and results of an inter-laboratory comparison are presented. The advantage using a touchscreen glass is that it can easily be replaced compared to other materials, like electronic components. The latter have to be extracted from the circuit board and consequently the mobile phone is irreparably damaged or destroyed.

In the present work touchscreen glasses of mobile phones were studied using the TL technique. In particular, TL glow curves were investigated and samples characterized according to their dosimetric properties, such as intrinsic background dose, dose response, reproducibility, optical stability and long-term stability of the TL signal.

2. Materials and methods

This study was carried out with touchscreen modules from five different iPhone 4 mobile phones produced by Apple Inc.. A touchscreen module on the mobile phone is an input device on top of the display screen to interact with the device by touching on the screen. Aliquots of glass samples were extracted from the touchscreen glass module with dimensions of approx. 5×5 mm^2, fitting into the measuring cup of the TL readers. Glass samples were thermally pre-treated in an oven for 10 min at 500 °C to investigate their dosimetric properties (dose response, reproducibility, optical stability and long-term stability of the TL signal). If necessary prior to the first measurement the paint on the surface of the glass was removed by scraping its surface with a metal blade or screwdriver and cleaning the sample with ethanol.

TL measurements were performed using an automated luminescence reader Risø TL-DA-15, equipped with a Thorn-EMI 9235Q bialkali photomultiplier. The TL signal was detected through a Hoya U-340 filter with a transmission window between 290–370 nm. All TL measurements were carried out in a nitrogen atmosphere with a heating rate of 2 °C/s to a maximum temperature of 450 °C and with a second TL measurement for thermal background subtraction.

Pre-bleaching of the samples was applied using the blue LEDs (470 ± 30 nm, approx. 36 mW/cm^2 at the sample position) of the Risø TL/OSL-DA-15 luminescence reader. Irradiations for TL measurements were done using the built-in beta source (Sr-90/Y-90) with a dose rate of approx. 27.6 mGy/s, calibrated for display glass using a Cs-137 source of the Secondary Standard Dosimetry Laboratory (SSDL) of the Helmholtz Zentrum München.

For a preliminary investigation both surfaces of the glass samples were mechanically treated with a grinding pencil to study the effect of this treatment on the intrinsic background TL signal. The measurements were carried out at the Istituto Superiore di Sanità (ISS) on a Risø TL/OSL-DA-20 (Hoya U-340 filter, detection window of 290–370 nm) and a Harshaw luminescence reader model 3500 (standard neutral filter, detection window of 350–700 nm). The measurement protocol does not include a pre-bleaching and the heating was set from 50 °C to a maximum temperature of 450 °C with a heating rate of 2 °C/s.

The material analysis measurements were carried out at the Department of Archaeology of Durham University. The chemical analyses of the touchscreen glass samples were performed on a Hitachi TM 3000 tabletop scanning electron microscope (SEM) employing an electron voltage of 15 kV (analysis mode). Elemental analysis was performed using a Swift ED 3000 attached to the SEM system, equipped with a silicon drift detector for the energy dispersive X-ray microanalysis. Each non-coated glass specimen was measured at least four times using the area analysis mode.

3. Results and discussion

3.1. TL glow curves after irradiation and optical stability

Touchscreen glass samples were irradiated with a dose of 1.1 Gy and were bleached using the blue LEDs of the luminescence reader before the TL measurement. The effect of bleaching the TL signal with different light exposure durations was examined with the same time delay of 500 s between end of irradiation and the TL readout (independent of the light exposure duration) to exclude the effect of signal fading. Optical stability and shape of the radiation induced TL glow curve were investigated on thermally annealed samples.

The radiation induced TL signal is a broad peak with a peak maximum between 190 and 220 °C for the unbleached measurement. It is similar in shape to the TL signal of display glass category A which was investigated in Discher and Woda (2013) and characterised as lime-aluminosilicate glasses by EPR measurements.

In Fig. 1 a the TL glow curves after irradiation and for different pre-bleaching times of sample #2 are shown. Similar results are obtained for all investigated samples #1 – #4. The light exposure duration was varied between 0 s (unbleached) and 500 s. Optical bleaching leads to a slightly stronger reduction in intensity in the lower temperature part compared to the higher part and to a shift in the peak temperature towards higher temperatures.

Fig. 1 b shows the optical stability of the TL signal normalized to the unbleached TL signal. The degree of bleaching strongly depends on the duration of the light exposure. For reasons to be explained further below the TL signal was integrated between 100 and 175 °C.

The optical stability of the TL signal of touchscreen glass is