

Optimization of read-out sequences for optically stimulated luminescence (OSL) of household salt for retrospective dosimetry

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INTRODUCTION

Measuring the optically stimulated luminescence (OSL) of a crystalline material after it has been exposed to ionizing radiation is a way to estimate the absorbed dose to the material. The technique has been used for the last decades for dating geological and archaeological findings assuming a known dose rate. In the past few years, OSL has also been used to determine the absorbed doses in quartz and feldspar crystals of burnt building material such as bricks and tiles for retrospective dose assessments. NaCl is another crystalline material that has shown promising properties as a highly sensitive dosimeter for ionizing radiation. Household salt contained in light sealed packages have been found to have potential for retrospective dose assessments (Bernhardsson *et al.*, 2008). In contrast to quartz and feldspar crystals, household salt does not need any time-consuming chemical preparations before the OSL-signal can be measured.

To fully use the potential of household salt as a retrospective dosimeter using OSL, an optimization of the OSL read-out sequence is needed. This requires extensive measurements of the OSL-output per unit absorbed dose (referred to sometimes as the specific luminescence), as a function of stimulation power, powering mode (continuous wave (CW), pulsed or linearly modulated power stimulation), read-out temperature, etc.

MATERIALS AND METHODS

Salt

Of the household salts studied by Bernhardsson *et al.* (2008) "Falksalt fint bergssalt™" showed the highest sensitivity in terms of OSL output per unit absorbed dose and mass, the lowest background dose and thus also the lowest minimum detectable dose, MDD. The salt is aimed for cooking and household use and is a non-dissolved mine salt with no additives, thus consisting mainly of NaCl. It was considered the most logical choice to use this brand in the pursued studies to optimize the OSL-read-out sequence for household salt in general.

Irradiation

The salt was irradiated in an external 7 TBq ^{60}Co beam with a traceable calibration to a secondary standard laboratory (SSI, Sweden). The salt was kept in light-sealed cylindrical plastic boxes ($\text{Ø}=30$ mm, height=50 mm) that were placed in a hole ($\text{Ø}=33$ mm, depth=52 mm) of a rectangular PMMA phantom ($191\times 191\times 72$ mm³). The remaining space in the plastic box was filled with a PMMA cylinder. The samples were given an absorbed dose of 0.36 Gy by irradiating them at a distance of 0.5 m with a dose rate of 2 mGy s⁻¹. After the irradiation the salt

was stored in the light sealed boxes for 24 h before the read-out. The 24-hour time delay was used to reduce the influence of any possible fading during the first hours (Bailey *et al.*, 2000).

OSL-measurements

An automated TL/OSL reader (TL/OSL-DA-15; Risø National Laboratory, Roskilde, Denmark) equipped with a rotating wheel of 48 sample positions was used to measure the OSL-properties of the salt in this study. Each portion of irradiated salt was carefully mixed in a dark room, before aliquots of the salt were extracted and mounted on cups on the rotating wheel. Blue light emitting diodes, LEDs, with a peak emission at 470 nm and a constant stimulation power (continuous wave), were used to optically stimulate the salt. All the OSL-read-outs were preceded with a pre-heat at 220°C (220°C, 2°C s⁻¹, 10 s). The OSL measurements were performed at 100°C for 40 s at a stimulation intensity of about 20 mW cm⁻² (40% of the stimulation power). The measuring conditions were adopted from Bernhardsson *et al.* (2008).

LED power

The OSL-output as a function of LED-power was investigated for a number of different stimulation power densities; 1%, 5%, 10%, 25%, 40% and 80% of the maximum 50 mW cm⁻². Twelve aliquots of salt were used to obtain a mean value of the OSL-output for each stimulation power.

Grain size

To test the effect of the variation in the grain sizes that exist in several brands of salt, including the one studied here, studies were conducted by dividing the salt into groups. One group of salt samples was sieved after the ⁶⁰Co irradiation, using five test sieves (Retsch GmbH, Haan, Germany) with various mesh widths, to grain size fractions of 180-250, 250-300, 300-400 and 400-500 µm. The other group of salt was sieved before the ⁶⁰Co irradiation into four grain size fractions; 180-250, 250-300, 300-400 and 400-500 µm. Twelve aliquots of salt were used to obtain a mean value of the OSL-output for each grain size.

RESULTS AND CONCLUSIONS

The OSL-output per unit mass exhibits a slight maximum at about 40% LED-power density using CW-stimulation, corresponding to about 20 mW cm⁻² (Fig. 1). The figure shows that a higher power gives a higher OSL-output per given dose up to 40% after which a saturation and a slight decrease is observed.

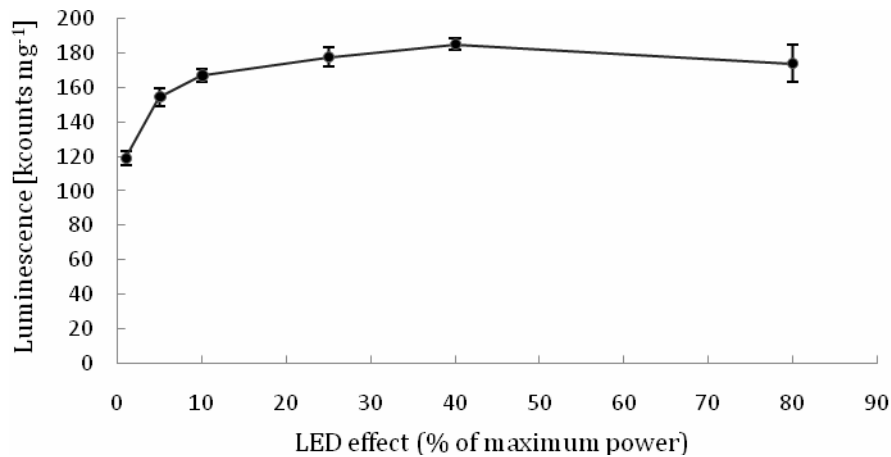


Figure 1. The OSL-output per unit mass at 360 mGy, as a function of CW stimulation power of the LEDs ($\lambda=470$ nm).

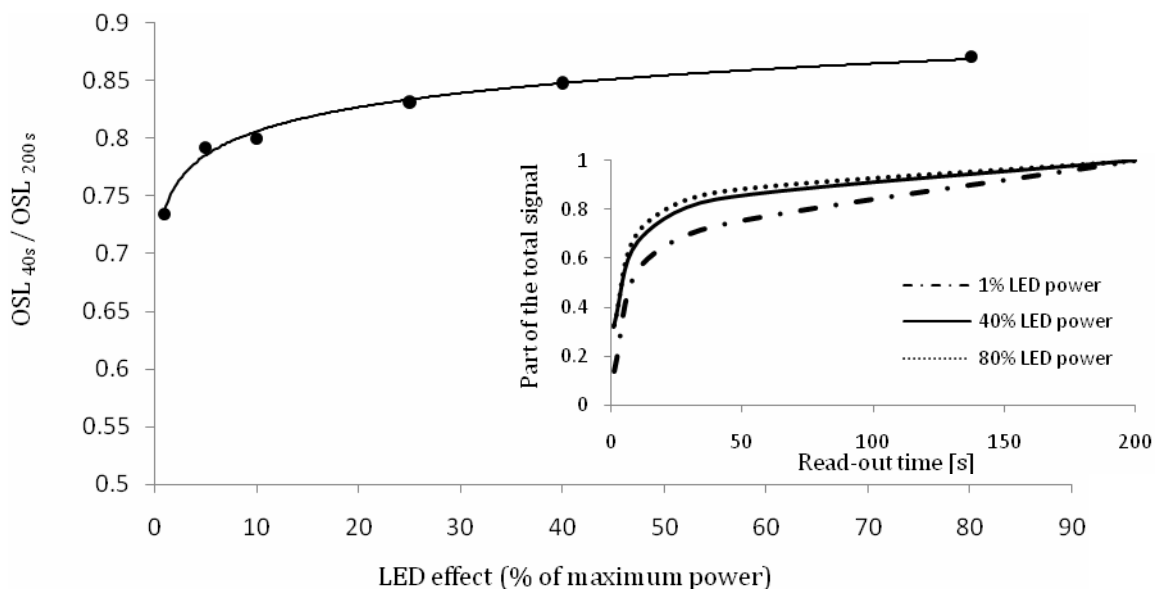


Figure 2. Accumulated signal after 40 s stimulation normalized to the corresponding signal after 200 s stimulation, as a function of CW-stimulation power of the LEDs ($\lambda=470$ nm).

The relation between the degree of depletion (in terms of accumulated OSL signal after 40 s normalised to the corresponding OSL signal after 200 s), and the CW-stimulation power of the LEDs is illustrated in fig. 2. The figure shows that the degree of depletion increases with higher LED power.

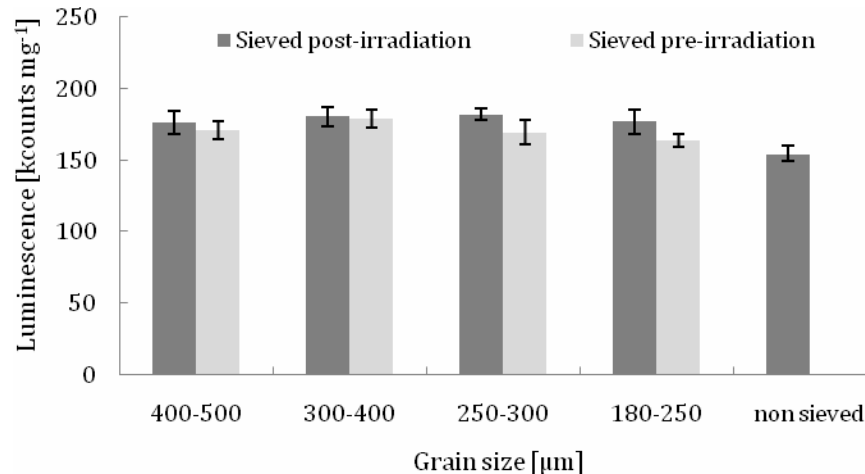


Figure 3. OSL-output per unit mass (± 1 standard error of the mean), at 360 mGy, for various grain size fractions with the salt sieved pre- and post-irradiation, and for non-sieved salt respectively.

Fig. 3 shows the relation between salt that was sieved before irradiation and salt that was sieved after irradiation compared to non-sieved salt. The salt that was sieved exhibits a slightly higher OSL-output than the non-sieved salt. No apparent difference in the OSL-output between the salt sieved before and after irradiation was observed.

Moderate LED-power of 40% is preferred to maximize OSL-output per unit absorbed dose when using CW-stimulation of blue light ($\lambda=470$ nm). Signal depletion is affected by the choice of stimulation power, but increases only slightly above 20 mW cm^{-2} . There is no significant influence of grain size between 100 and 500 μm .

ACKNOWLEDGEMENT

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REFERENCES

- Bernhardsson C., Christiansson M., Mattsson S., Rääf C.L., 2008 Household salt as a retrospective dosimeter using optically stimulated luminescence (OSL), submitted to Radiation and Environmental Biophysics, REBS230
- Bailey R.M., Adamiec G., Rhodes E.J., 2000 OSL properties of NaCl relative to dating and dosimetry, Radiation Measurements 32: 717-723