A light-emitting-diode based pulsing system for measurement of time-resolved luminescence

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Abstract

A new light-emitting-diode based pulsing system for measurement of time-resolved luminescence has been developed. The light-emitting-diodes are pulsed at various pulse-widths by a 555-timer operated as a monostable multivibrator. The light-emitting-diodes are arranged in a dural holder connected in parallel in sets of four, each containing four diodes in serial. The output pulse from the 555-timer is fed into an N7000 MOSFET to produce a pulse-current of 500 mA to drive the set of 16 light-emitting-diodes. This size of current is sufficient to drive the diodes with each driven at a pulse-current of 90 mA with a possible maximum of 110 mA per diode. A multichannel scaler is used to trigger the pulsing system and to record data at selectable dwell times. The system is capable of generating pulse-widths in the range of microseconds upwards. The new pulsing system was used to study the dependence of luminescence lifetimes on radiation dose and, on measurement temperature in quartz and α-Al_2O_3:C. In quartz, lifetimes measured between 5 and 200 Gy beta dose were constant at about 42.0 ± 1.3 µs. On the other hand, the lifetimes decreased with measurement temperature from 40.4 ± 0.9 µs at 20 ^{0}C to 14.8 ± 1.8 µs at 200 ^{0}C. In α-Al_2O_3:C, luminescence lifetimes decreased from 36.8 ± 0.1 ms at 20 ^{0}C to 28.0 ± 0.6 ms at 140 ^{0}C. The dependence of luminescence lifetimes on measurement temperature in quartz and α-Al_2O_3:C showed evidence of thermal quenching at high temperature. Thermal quenching is the decrease of luminescence due to increased non-radiative transitions at high temperature. The value of the activation energy for thermal quenching for quartz was evaluated as 0.67 ± 0.05 eV and as 1.02 ± 0.01 eV for α-Al_2O_3:C.

Keywords: **Luminescence lifetimes, pulsed-LEDs, Carbon-doped aluminium oxide, Quartz**

1 Introduction

Optically stimulated luminescence (OSL) is the light emitted at certain wavelengths from a previously irradiated material, mostly insulators and semiconductors, during exposure to light of a different wavelength. The absorption of energy from ionising radiation (e.g β-rays) by the material creates free electrons and holes some of which get trapped at point-defects within the material [1]. During exposure to stimulating light, electrons are released from trapping defects and recombine with charge carriers of opposite sign via the conduction band. If the recombination is radiative, optically stimulated luminescence is produced.

There are three basic modes for optical stimulation of luminescence. These are continuous-wave OSL (CW-OSL), linear-modulation OSL (LM-OSL), and time-resolved OSL (TR-OSL). In CW-OSL an irradiated sample is illuminated with light of constant intensity; in LM-OSL, the stimulation light power is increased linearly throughout the measurement periods whereas with TR-OSL a sample is pulsed-stimulated at a selected pulse-width. During stimulation of TR-OSL, the signal observed consists of photomultiplier noise, scattered stimulation light and the luminescence build-up whereas after stimulation i.e when the light is OFF, the luminescence is measured over photomultiplier only [2, 3]. Thus, TR-OSL separates in time the stimulation and emission of luminescence.

Measurement systems for TR-OSL based on laser and LED systems have been previously described [2, 3, 4, 5]. Sanderson and Clark [4] used 470 nm light from an N_2 dye laser to pulse OSL from alkali feldspar with a pulse width of the order of 10 ns. Markey et al [5] used TR-OSL to study features of luminescence from α-Al_2O_3 in which the light from an Ar-ion laser was used to stimulate luminescence. The use of light-emitting-diodes as a stimulating light source to obtain TR-OSL from quartz Chithambo and Galloway [2], who used a pulsed 525 nm green light-emitting-diode system to measure luminescence from feldspar and quartz.

TR-OSL measurements are carried-out using a brief light-pulse to stimulate luminescence. A

detector, for example, a photomultiplier tube detects the emitted luminescence. During stimulation, the luminescence increases over a background of photomultiplier noise and scattered stimulating light. After the light-pulse, the emitted luminescence is measured over photomultiplier noise. The detected luminescence from several scans are summed giving rise to a time-resolved luminescence spectrum.

The TR-OSL spectrum is generated by timing the duration between a START and a STOP signal. A multichannel scaler produces a START signal that triggers a pulsing system to turn ON LEDs for stimulation. The first luminescence-photon signal detected from a particular sample under stimulation provides a valid STOP signal. The multichannel scaler then records the luminescence-photon counting rate until a STOP signal arrives.

We report the design of a new light-emitting-diode based pulsing system for the measurement of time-resolved luminescence. The system has been developed to enable the automatic control of stimulation power and pulse-widths and to drive a high pulse-current of up to 90 mA per light-emitting-diode.

2   Design of the new pulsing system

This section describes the new pulsing system developed in this project. The system consists of pulsing circuitry capable of operating a stimulating light source.

2.1   Design considerations

Figure 1 shows a schematic diagram of the pulsing system. Figure 1(a) shows the schematic arrangement for detection and measurement of time-resolved luminescence spectra. Figure 1(b) is a schematic diagram of the circuitry used for pulsing. The detecting system shown in Figure 1(a) was reported previously by Galloway [7] and Chithambo [3]. The original design was reported by Chithambo and Galloway [2] and discussed by Chithambo [19]. The pulsing circuit shown in Figure 1(b) is new and is discussed in detail in this chapter.

Luminescence is stimulated by a set of 16 LEDs arranged in a dural holder. A Schott GG-420 long-pass filter was placed in front of each LED to prevent scattered stimulation light from reaching the photomultiplier tube. A Schott BG39 transmission filter, with a transmission peak at 340 nm was placed in front of the photomultiplier tube to transmit the emitted luminescence to the photomultiplier tube.

As shown in Figure 1, the emitted luminescence is detected by a photomultiplier tube (EMI 9635QA) and the signal fed into the combination of a timing filter amplifier (Ortec 474) and a constant-fraction discriminator (Ortec 584). The ORTEC Model 474 timing filter amplifier is designed to shape pulses and optimize the signal-to-noise ratio for timing measurements. These pulses from the photomultiplier tube are then furnished to an Ortec 584 constant-fraction discriminator where they are counted.

The multichannel scaler (Ortec MCS-plusTM) simultaneously triggers the pulsing circuitry and records the counting rate of events as a function of time as shown in Figure 1. In this context, an event is the detection of a photon. Once a scan is started, the multichannel scaler begins counting the luminescence photons emitted at a preset dwell-time in the first channel of its memory. The MCS then moves to the next channel of its memory to do same until all channels are covered. A display of the content of memory shows the counting rate of recorded data as a function of time.
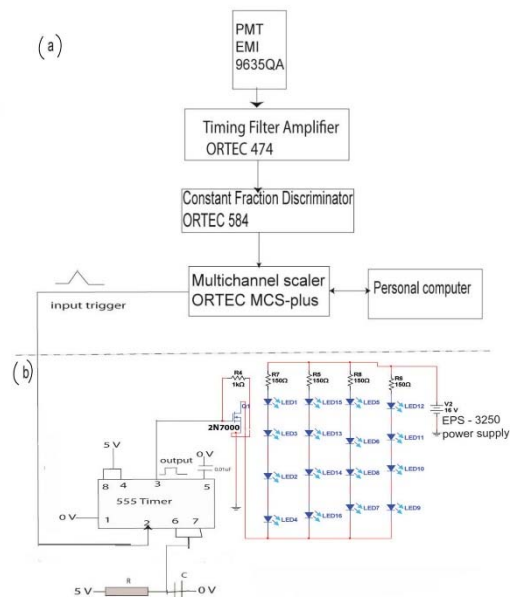

Figure 1: The pulsing system showing the arrangement for detecting and recording time-resolved luminescence spectra (a) and the pulsing circuitry used to pulse the light-emitting-diodes (b).

2.1.1   Pulsing circuitry

The pulsing circuit produces pulses of various durations using a 555-timer that was triggered externally by a multichannel scaler. The output pulse from the 555-timer is fed into a 2N7000 MOSFET transistor. The 2N7000 MOSFET was used to increase the pulse-current obtained from the 555-timer circuitry.

2.1.1.1   Operation of the pulsing circuitry

Figure 2 shows the circuitry of the pulsing system. In the circuitry, a monostable multivibrator based on the NE555N timer integrated circuit was used to produce pulses of various durations. Figure 2(a) shows the circuitry of an NE555N timer operated as a monostable multivibrator whereas Figure 2(b) shows the LED drive circuitry.

In Figure 2(a), the voltage of pin 2 is held above the trigger point (i.e > 1/3 of input voltage VCC) by the R1 pull-up resistor of value 10 k until a voltage pulse to trigger a timing cycle is applied from the multichannel scaler.

In quiescent condition, pin 7 of the NE555N timer is conducting and represents a short circuit across the timing capacitor C1. The level of the output (pin 3) is always low at this point. To obtain an output transition from LOW to HIGH, an external input trigger-pulse of amplitude greater than +2/3 VCC is applied to pin 2 of the NE555N timer from the multichannel scaler. As a result, the voltage of pin 2 drops below 1/3 VCC and forces the output of pin 3 to go HIGH to a value slightly above VCC. Since pin 7 is cut-off, capacitor C1 begins to charge exponentially and the voltage across it also increases exponentially from zero until it reaches 2/3 VCC through the resistor R2 with a time-constant equal to the product R2.C1. When the voltage of capacitor C1 becomes slightly greater than its threshold of +2/3 VCC, pin 6 goes HIGH, thereby causing capacitor C1 to discharge. Thus, the output of pin 3 of the timer goes LOW that is transits back from HIGH to LOW. The capacitor C1 discharges rapidly, and the output is held in its LOW state (Vout = LOW) until another trigger pulse is applied to pin 2 from the multichannel scaler. It should be noted that pin 4 is connected to VCC to prevent accidental reset while pin 5 is held to ground through a 0.01 µF capacitor C2 to help reduce background noise.

The output pulse-width of the pulsing circuitry is defined by the external resistor (R2)
and capacitor (C1). The pulse-width tw is given approximately by

$$tw = 1:1(R1)(C1). \qquad (1)$$

2.1.2   Drive circuitry for LEDs

Figure 2(b) shows the circuit used to operate the light-emitting-diodes. The output pulse obtained from the pulsing circuitry is fed into the gate pin of a 2N7000 MOSFET which then supplies sufficient pulse-current to the LEDs. The source pin of the 2N7000 is earthed while the drain pin is connected to the LEDs. The 2N7000 MOSFET is used as a switch to increase the pulse-current obtained from the NE555N timer circuitry.
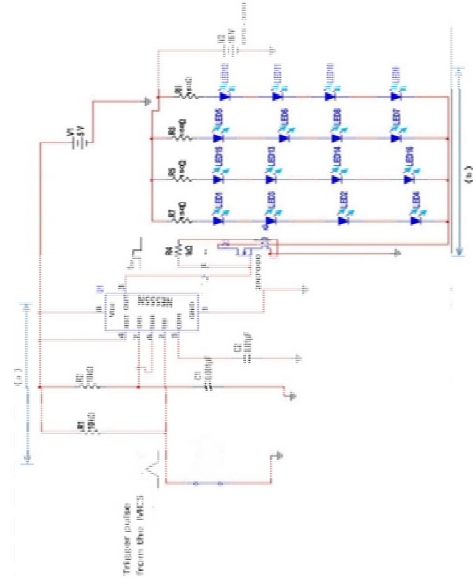

Figure 2: A circuitry showing an NE555N timer operated as a monostable multivibrator when triggered with a trigger pulse from a multichannel scaler (a) and the LED drive circuitry showing the connection of the sixteen blue light-emitting diodes to a 2N7000 MOSFET (b).
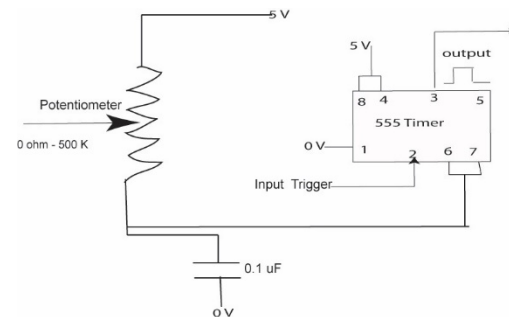

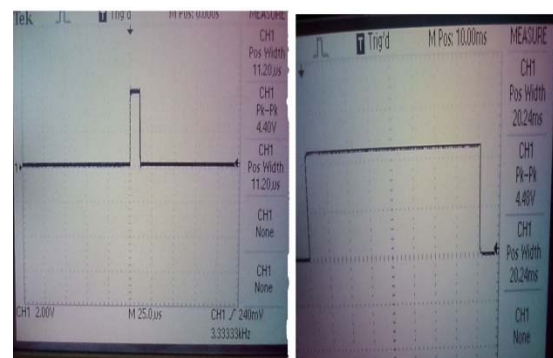Figure 3: A circuit showing the connection of the 555-timer to a potentiometer and a 0.1 µF fixed capacitor.

Figure 4: Examples of two pulses of different widths obtained automatically from the pulsing system. Part (a) shows an 11.2 µs pulse whereas part (b) shows a 24.24 ms pulse.

The 2N7000 can switch a maximum pulse-current of 500 mA, with a maximum ON-resistance of 5 ohm at 10 V Vgs. Sixteen LEDs are connected in parallel in sets of four, each set containing four LEDs in serial. Each LED is driven at 90 mA pulse-current with a possible maximum of 110 mA per LED. The intensity of the LED light can be controlled and regulated by an integrated adjustable power supply (shown as EPS-3250 in Figure 2) of constant current. To pulse the LEDS, the pulsing circuitry is triggered with a trigger pulse from a multichannel scaler.

2.1.3 Pulse-width control unit

Figure 3 shows the circuit used to vary the pulse-width. A potentiometer with resistance values ranging from 0 to 500 k connected to a 0.1 µF fixed capacitor was used to obtain pulses of various widths from the 555 timer. One of the two end-pins of the potentiometer is connected to a 5 V supply voltage whereas the center-pin is connected to one of the terminals of the fixed capacitor (the other terminal of the capacitor is connected to earth). This set-up was used to obtain various pulses of width between 4.7 µs to 489 ms. The output pulse obtained with the system becomes distorted when approaching the nanosecond range. Thus the output pulse-width is stable only from microseconds upwards. Figure 4 shows examples of pulses of different width obtained from the pulsing system. These output pulses were measured with a Tektronix oscilloscope.

2.1.5 Control of the light-emitting-diodes intensity

The intensity of the stimulation light is controlled and regulated by an integrated adjustable power supply (EPS-3250) of constant current. The power supply is capable of adjustable voltage from 0 to 20 V. Since the voltage from the EPS-3250 across the LEDs is forward-biased, the pulse-current from the 2N7000 ows through the LEDs in reverse-bias as shown in Figure 1(b). The intensity of the LEDs increases when the supply voltage is increased.

3   Applications

This section reports application of the pulsing system to study TR-OSL spectra from quartz and α-Al₂O₃:C. The measurements reported here were made using the new pulsing system described in the previous sections.

3.1   Time-resolved   optically   stimulated luminescence of quartz

Figure 5 shows an example of a TR-OSL spectrum obtained from a sample of quartz annealed at 500 ^{0}C and irradiated to 5 Gy. The luminescence was stimulated at a pulse-width of 11 µs. The open circles represent the TR-OSL spectrum while the solid squares show background counts. The inset

shows the portion of the TR-OSL spectrum after the light-pulse. All measurements were undertaken using the new pulsing system as described in section 2.1. Each measurement was repeated five times and the mean lifetime obtained. The portion of each TR-OSL spectrum after the light-pulse was fitted with the equation,

$$l(t) = A \exp(-t/T) + B, \qquad (2)$$

where A is a scaling parameter, $T = 1/\lambda$ is the luminescence lifetime, l(t) is the time-dependence of luminescence after the light-pulse, t is time and B a constant added to account for the background signal. The luminescence lifetime extracted from the fit is 40.2 ± 2.0 µs. This value is consistent with ones reported for quartz annealed at 500 ^{0}C. For example, Galloway [7] reported a lifetime of 39.9 ± 0.4 µs for a sample of quartz annealed at 500 ^{0}C, Chithambo and Galloway [2] reported a lifetime of 40.0 ± 0.3 µs for quartz annealed at 500 ^{0}C and Chithambo [6] reported a lifetime of 41.8 ± 0.3 µs for quartz annealed at 500 ^{0}C. The luminescence lifetime obtained using the new system is in good agreement with those reported in the literature as explained.
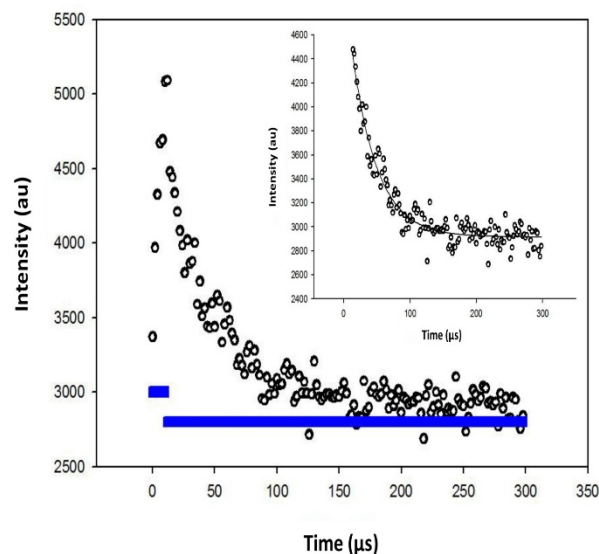

Figure 5: A TR-OSL spectrum from a sample of quartz annealed at 500 ^{0}C and irradiated to 5 Gy before 470 nm pulsed stimulation. Background counts (solid squares) are shown for comparison. The inset shows the luminescence after the light-pulse.

3.1.1 Dependence of luminescence lifetimes on dose

The aim of this experiment was to investigate the dependence of luminescence lifetimes on dose in quartz annealed at 500 ^{0}C. The sample was irradiated with beta doses between 5 and 200 Gy before 470 nm stimulation using an 11 µs pulse. Measurements were repeated five times and the

mean lifetime evaluated. Luminescence lifetimes were evaluated for each TR-OSL spectrum by fitting Equation 2 to the signal after the light-pulse.

Figure 6 shows the dependence of luminescence lifetimes on beta dose. For all doses used in this experiment, that is, between 5 and 200 Gy, the luminescence lifetimes obtained were unaffected by beta dose. The mean lifetimes were constant at about 42.0 ± 1.3 μs. Thus, the results show that luminescence lifetimes in quartz are independent of radiation dose for a sample annealed at 500 ^{0}C. This value is consisted with ones reported for quartz annealed at 500 ^{0}C. For example, Galloway [7] reported a lifetime of 41.5 ± 0.5 μs for quartz annealed at 500 ^{0}C and Chithambo [6] reported a lifetime of 41.8 ± 0.3 μs for quartz annealed at 500 ^{0}C.

The influence of irradiation on luminescence lifetimes can be described with reference to an energy band model proposed by Galloway [7]. The energy band model consist of a non-radiative recombination centre R and three radiative centres LH, LL and LS. In this model, annealing causes the transfer of holes from a non-radiative centre R to and between radiative centres LH, LL and LS with corresponding lifetimes LH and LL [7]. All luminescence centres contribute to the stimulated luminescence, but the value of the luminescence lifetime depends on the luminescence centre, that is dominant [7].

The luminescence lifetime is independent of dose, because most of the luminescence is emitted from LH centres which would not have been sufficiently emptied by annealing at 500 ^{0}C prior to irradiation [7, 8].
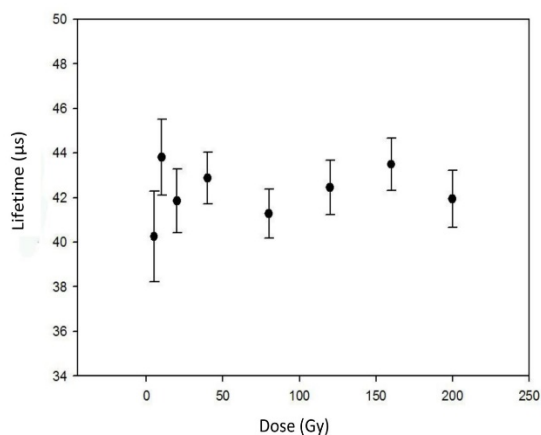

Figure 6: Dependence of luminescence lifetimes on beta dose in quartz annealed at 500 ^{0}C.

3.1.2 Dependence of luminescence lifetimes on measurement temperature

The effect of measurement temperature on luminescence lifetimes was investigated in quartz annealed at 500 ^{0}C. All measurements were made using 11 μs pulse, 90 mA pulse-current and a 300 μs dynamic range. Note that all data is described in degrees Celsius unless otherwise specified.

Figure 7 shows the dependence of luminescence lifetimes on measurement temperature from 20 to 200 ^{0}C represented in the figure as (a) and from 200 to 20 ^{0}C denoted as (b) in steps of 20 ^{0}C, respectively. Luminescence lifetimes obtained from 20 to 100 ^{0}C were constant at about 40.4 ± 0.9 μs. Thereafter, the values decreased to a minimum of 14.8 ± 1.8 μs at 200 ^{0}C. The decrease of the luminescence lifetimes with temperature is due to increased probability of non-radiative transitions at high temperature known as thermal quenching. Thermal quenching is the loss of luminescence efficiency with increasing temperature [1]. The change in luminescence lifetimes with increasing temperature as shown in Figure 7 is described by and was fitted with a thermal quenching equation of the form:

$$T = T_0 / 1 + C \exp(-\Delta E / kT), \qquad (3)$$

where T is the luminescence lifetime at any temperature T, T_0 the luminescence lifetime at 0 K, C a constant, ΔE the activation energy of thermal quenching and k Boltzmann's constant [14]. From the fit, $\Delta E = 0.67 \pm 0.05$ eV; $C = 2 \times 10^7$ for measurements from 20 to 200 ^{0}C and $\Delta E = 0.72 \pm 0.03$ eV; $C = 1 \times 10^8$ for measurements from 200 to 20 ^{0}C. The two experimental values of ΔE agree within experimental error as expected since they refer to the same process. These results are also consistent with values of ΔE reported for samples of quartz annealed at 500 ^{0}C as reported in the literature for example, 0.66 ± 0.04 eV by Chithambo and Galloway [9] and 0.77 ± 0.06 eV by Galloway [7]. Values of ΔE are compared in Table 1.

A useful model that described thermal quenching in quartz is given in the literature [10, 11]. The model consists of one radiative centre and one non-radiative centre within the recombination centre. The model allows for non-radiative transitions into the ground state with thermal activation energy of quenching, ΔE [10, 11]. In this model electrons from a trap are stimulated by optical or thermal stimulation into the conduction band, followed by an electronic transition from the conduction band into an excited state of the recombination centre. Subsequently electrons in this excited state undergo either a direct radiative transition into a

recombination centre, or a competing thermally assisted non-radiative process into the ground state of the recombination centre.
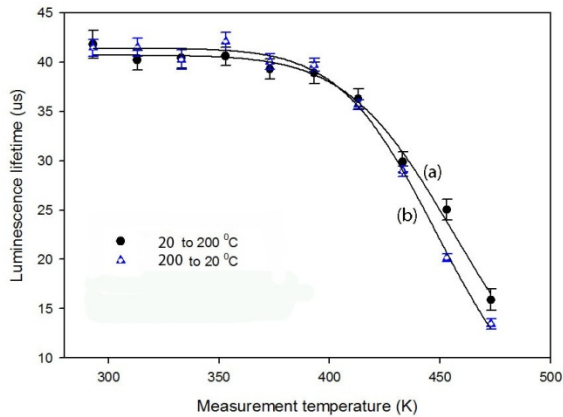

Figure 7: Dependence of luminescence lifetime on measurement temperature in quartz. The TR-OSL spectra were measured from 20 to 200 0C (a) and from 200 to 20 ^{0}C (b), in steps of 20 ^{0}C.

Table 1: A list of values for the activation energy of thermal quenching, ΔE, obtained in this work and some reported in the literature.

Measurement Temperature (^{0}C)	Radiation Dose (Gy)	ΔE (eV)	C
20 to 200	80	0.67 ± 0.05	2×10^7
200 to 20	80	0.72 ± 0.03	1×10^8
20 to 200	4.5	0.64 ± 0.03	3×10^7
20 to 200	15	0.69 ± 0.79	8×10^7
20 to 200	150	0.66 ± 0.04	4×10^7
200 to 20	15	0.67 ± 0.05	5×10^7
200 to 20	150	0.58 ± 0.06	5×10^7
20 to 200	343	0.83 ± 0.01	

3.2 Dependence of luminescence intensity on measurement temperature

The effect of measurement temperature on luminescence intensity was investigated in quartz annealed at 500 ^{0}C. The intensity was obtained by integrating a time-resolved luminescence spectrum corresponding to each measurement temperature between 20 and 200 ^{0}C.

Figure 8 shows the dependence of luminescence intensity on measurement temperature. The intensity decreases with measurement temperature from 20 to 200 ^{0}C. When measurements are made from 200 to 20 ^{0}C, the intensity increases as the temperature is decreased. The change in intensity with measurement temperature in both cases is similar. The change in intensity with measurement

temperature as shown is attributed to thermal quenching and is described as

$$I(T) = I_0 / 1 + C \exp(-\Delta E / KT), \qquad (4)$$

where I_0 denotes the initial value of luminescence intensity and the other parameters are as described previously [9, 12]. Thermal quenching is the increased probability of non-radiative transitions at high temperature. The data shown in Figure 8 was fitted with Equation 4. From the fit, $\Delta E = 0.61 \pm 0.08$ eV; $C = 7 \times 10^7$ for measurements from 20 to 200 ^{0}C and $\Delta E = 0.66 \pm 0.08$ eV; $C = 7 \times 10^7$ for measurements from 200 to 20 ^{0}C. These results obtained for ΔE are consistent with those reported in the literature [7, 9, 12]. For example, Galloway [7] reported 0.72 ± 0.08 eV for ΔE for a sample of quartz annealed at 500 ^{0}C without preheating. Chithambo and Galloway [9] reported 0.68 ± 0.11 eV for ΔE when the temperature increased from 20 to 200 ^{0}C and 0.57 ± 0.08 eV when the temperature was decreased from 200 to 20 ^{0}C for quartz.
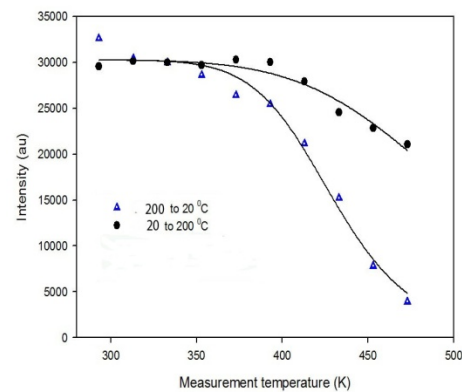

Figure 8: Dependence of luminescence intensity on measurement temperature in quartz annealed at 500 ^{0}C and irradiated to 80 Gy. Measurements were made from 20 to 200 ^{0}C and from 200 to 20 ^{0}C, in steps of 20 ^{0}C, respectively.

4 Time-resolved luminescence from α-Al₂O₃:C

This section describes the investigations on the dependence of luminescence lifetimes on measurement temperature in carbon-doped aluminium oxide, α-Al₂O₃:C, a highly sensitive luminescence dosimeter. The sample used was irradiated to 1.0 Gy before 470 nm pulsed stimulation. The luminescence was stimulated at a 17 ms pulse-width using 150 ms dynamic range. TR-OSL spectra were measured from 20 to 140 ^{0}C in steps of 20 ^{0}C.

Figure 9 shows an example of a TR-OSL spectrum obtained from α-Al₂O₃:C following beta irradiation to 1.0 Gy. Measurements were made at 40 and 140 ^{0}C. The solid squares in the figure show the

background counts. The inset shows the portion after the light-pulse. The portion after the light-pulse was analysed using Equation 2 to give the associated luminescence lifetime at a particular temperature. A luminescence lifetime of 35.5 ± 0.5 ms was obtained from the fit in Figure 9 (inset).
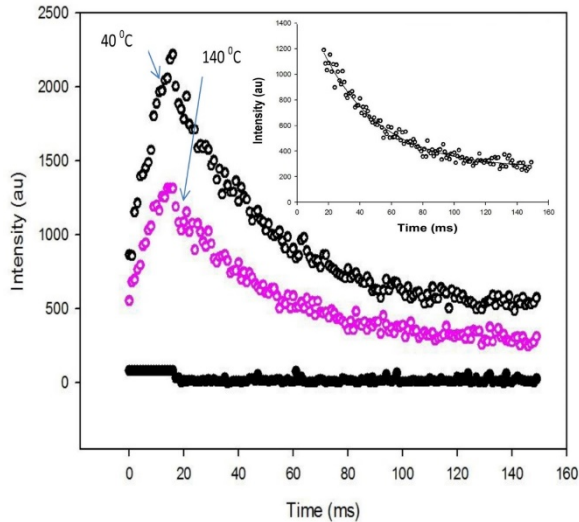

Figure 9: A TR-OSL spectrum from a sample of α-Al$_2$O$_3$:C following beta irradiation to 1 Gy. Measurements were made at 40 and 140 ^{0}C. Background counts (solid squares) are also shown. The inset shows the portion after the light-pulse.

Figure 10 shows the dependence of luminescence lifetimes on measurement temperature. The experiment was conducted at measurement temperatures from 20 to 140 ^{0}C in steps of 20 ^{0}C. Luminescence lifetimes from 20 to 60 ^{0}C were constant at about 36.8 ± 0.1 ms. Thereafter, the values decreased to a minimum of 28.0 ± 0.6 ms at 140 ^{0}C. This decrease in luminescence lifetime is evidence of thermal quenching. The luminescence lifetime decreases as a function of temperature as described before as

$$T = T_0 / 1 + C \exp(-\Delta E / KT), \qquad (5)$$

where all parameters are as described previously. The data in Figure 10 was fitted with Equation 5, and the values of ΔE and C obtained from the fit are 1.02 ± 0.01 eV and 9 x 10^{11} respectively. The value of ΔE is in good agreement with 1.08 ± 0.03 eV reported by Akselrod et al. [14], 1.075 ± 1.0 eV reported by Pagonis et al. [13], 0.96 ± 0.005 eV reported by Ogundare et al. [15] and 0.95 ± 0.04 eV by Chithambo et al. [16]. Thermal quenching is a process caused by loss of luminescence efficiency. Nikiforov et al. [17] developed a model that describes thermal quenching in α-Al$_2$O$_3$:C based on thermal and optical ionization of F-centres. However, in this paper, thermal quenching in α-Al$_2$O$_3$:C is described in terms of the model of

Pagonis et al. [18]. This model consists of an electron trap, two deep traps, and excited levels of the F-centre. The model allows non-radiative transition into the ground state with thermal activation energy of quenching, ΔE. Pagonis et al [18] described thermal quenching based on competition between radiative and non-radiative electronic transitions occurring within the recombination centre. The electrons from the trap are stimulated by optical or thermal stimulation into the conduction band. The electrons then transit from the conduction band into an excited state of the recombination centre. Subsequently electrons in this excited state undergo either a direct radiative transition into a recombination centre, or a competing thermally assisted non-radiative process into the ground state of the recombination centre. During this non-radiative transition into the ground state of the recombination centre, the absorbed energy is released as phonons.
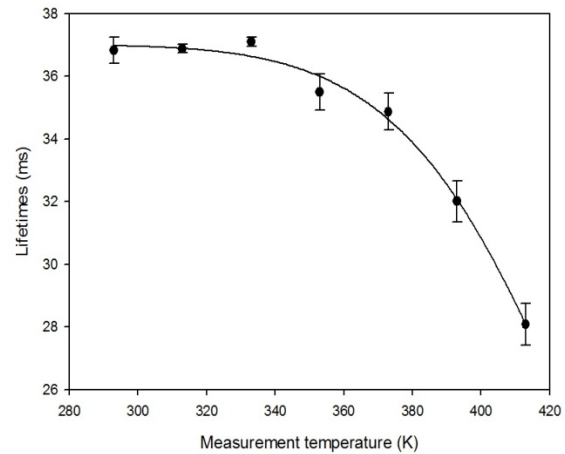

Figure 10: Dependence of luminescence lifetimes on measurement temperature in α-Al$_2$O$_3$:C following beta irradiation to 1 Gy. All measurements were made from 20 to 140 ^{0}C in steps of 20 ^{0}C.

5   Conclusion

A new light-emitting-diode based pulsing system for measurement of TR-OSL has been developed. The pulsing system is designed to generate pulses of various duration and, stimulation power. The light-emitting-diodes are pulsed at various durations by a 555-timer integrated circuit operated as a monostable multivibrator. The LEDs are connected in parallel in sets of four, each containing four LEDs in serial. The pulsing circuitry is made up of a 555-timer which produces pulses of different widths. The output-pulse obtained from the 555-timer is fed into the gate-pin of a 2N7000 MOSFET which then supplies sufficient pulse-current to the LEDs. In the pulsing circuitry, the source-pin of the 2N7000 is earthed while the drain-pin is connected to the LEDs. The

2N7000 MOSFET is used as a switch to increase the pulse-current obtained from the NE555N timer. The 2N7000 can switch a maximum pulse-current of 500 mA, with a maximum ON-resistance of 5 ohm at 10 V Vgs. A multichannel scaler was used to trigger the pulsing circuitry. The circuitry is capable of generating pulse-widths in the range of microseconds upwards. The stimulation power of the LEDs is controlled and regulated by an integrated adjustable power supply (EPS-3250) of constant current. The emitted luminescence is detected by a photomultiplier tube (EMI 9635QA).

TR-OSL spectra from quartz and α-Al_2O_3:C were measured to demonstrate the system performance. TR-OSL was measured at beta doses between 5 and 200 Gy from a sample of quartz to investigate the dependence of luminescence lifetimes on dose. The luminescence lifetimes obtained were independent of beta dose between 5 and 200 Gy. The luminescence lifetime is independent of dose because most of the luminescence is emitted from LH centres which would not have been sufficiently emptied by annealing at 500 ^{0}C prior to irradiation [7]. In addition, TR-OSL was measured at various temperatures from 20 to 200 ^{0}C and from 200 to 20 ^{0}C in steps of 20 ^{0}C, respectively for a sample of quartz annealed at 500 ^{0}C. The luminescence lifetime showed evidence of thermal quenching as the measurement temperature increased. The activation energy of thermal quenching ΔE obtained for the quartz sample was 0.67 ± 0.05 eV for measurements from 20 to 200 ^{0}C. When the temperature was decreased from 200 to 20 ^{0}C, the value of ΔE obtained was 0.72 ± 0.03 eV. These values of ΔE are in good agreement with each other and with others reported in the literature. The dependence of luminescence lifetimes on measurement temperature were studied in α-Al_2O_3:C. TR-OSL was measured at various temperatures from 20 to 140 ^{0}C in steps of 20 ^{0}C. The luminescence lifetimes showed evidence of thermal quenching as the measurement temperature increased. The activation energy of thermal quenching ΔE obtained for α-Al_2O_3:C was 1.02 ± 0.01 eV. The value of ΔE is in good agreement with those reported in the literature. Hence, a new light-emitting-diode based pulsing system for measurement of TR-OSL has been developed. The performance of the new pulsing system from TR-OSL measurements on quartz and α-Al_2O_3:C agree with values of lifetime studied with other systems in the literature.

Acknowledgement

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