

Chapter 3

Experimental set-up and Method

3.1 Introduction

Two groups of TL materials have been studied in this project. The first group is a commercial TLD, and the second group is lanthanide oxide (Ln_2O_3) powder doped with rare earth (RE) elements.

The first step of this study was about the formation of the chips by mixing with Teflon as a resin material. The chips were then exposed to UV light and sunlight to check their sensitivity. Then, the thermal and light stability were tested, and finally the reproducibility was tested for the most sensitive one to UVR. The study was accomplished with the estimation of TL parameters, calibration of UV meter and measurement of solar UV radiation using UV meter. The study is summarized in the flow chart of figure (3.1).

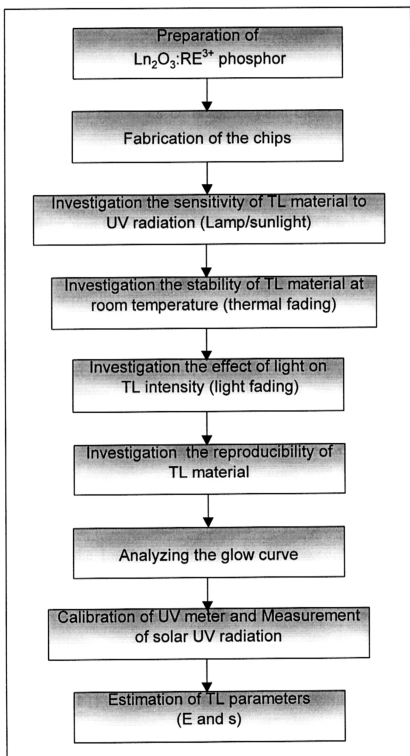


Figure (3.1): flow chart plan of the study

3.2 Preparation of the powder

The procedure for the preparation of the $\text{Ln}_2\text{O}_3:\text{RE}^{3+}$ powder phosphors is summarized schematically in figure (3.2).

The host oxide powder (Y_2O_3 , La_2O_3 or Gd_2O_3) and the activator powder (Er_2O_3 , Eu_2O_3 , Pr_6O_{11} , Tb_4O_7 or Tm_2O_3) in the required atomic percentage were first mixed in a mortar. The concentration of the dopant or activator in the host powder was 5%. This mixed powder was then dissolved in a hot dilute HCl solution. This solution was then poured into ammonium oxalate solution to obtain oxalates of $\text{Ln}(\text{Ln}(\text{CO}))$ and $\text{RE}(\text{RE}(\text{CO}))$ as precipitates.

Ammonium oxalate solution was prepared by dissolving $(\text{NH})\text{CO}\cdot\text{HO}$ powder in H_2O . The Oxalate precipitates are dried overnight on a hot plate at a temperature of about 80°C . The dried precipitates are then placed in an alumina crucible and fired at 1200°C for 1 hour in air (Yeh 1996), see figure (3.3) for the temperature stability of the crystalline for these phosphors. After firing, the sample was pulverized in a mortar. The powder obtained was then the $\text{Ln}_2\text{O}_3:\text{RE}^{3+}$ phosphor.

The preparation of the $\text{Ln}_2\text{O}_3:\text{RE}^3$ phosphor is done according to the procedure suggested by Alias 1994.

3.2.1 Fabrication of the TLD chips

Tetrafluoroethylene (PTFE or Teflon) is used as a resin material for two reasons:

1. It has high softening point that is 327°C .
2. It is used as a resin material to form TLD-100 in the rod shape and in the formation of TLD-900 in solid form (Vij 1993).

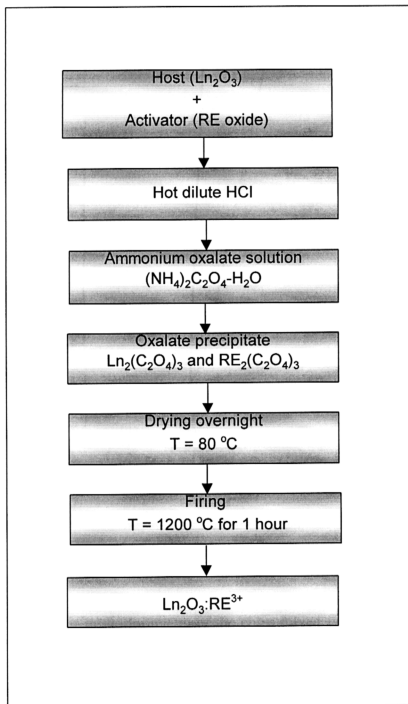


Figure (3.2): Flow chart diagrams for preparation of $\text{Ln}_2\text{O}_3:\text{RE}^{3+}$ phosphor

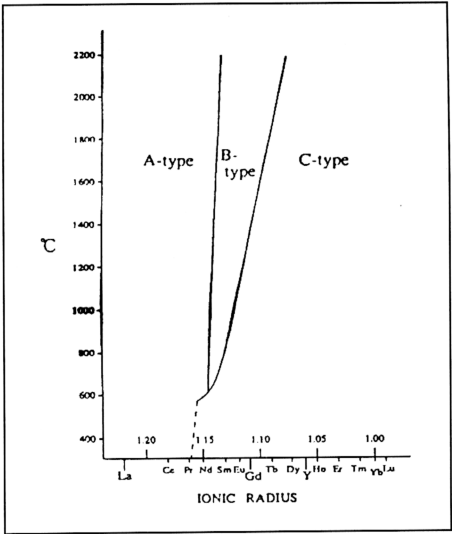


Figure (3.3): Temperature stability of the rare earth oxide (Warsaw 1961)

The three main steps in the formation of the chips mixed with Teflon is shown as follow (Azorin 1989, Bjarngard 1967):

1. Mixing with teflon

Teflon and the powder were weighed separately using an electronic balance. The mixing ratio of powder to Teflon is 1:2. We found that this ratio is the most suitable to prevent the chips from being broken during handling and measurement.

2. Making a pellet

About 300 mg of the mixture was filled inside the mould of 1.4 cm in diameter (pellet maker). The applied pressure was ~25 Mpa, which was moderate compare with 98 Mpa in formation of TLD-900 discs (Azorin 1989 and Campos 1986), and with 1 Mpa in formation of TLD-100 bars (Bjarngard 1967).

The disc with a diameter of 1.4 cm was then cut manually by a knife to get 9 chips of about 3 mm in the sides and 1 mm in the thickness.

3. Sintering process

For hardening, the obtained chips was placed over copper plate and kept inside the furnace for one hour at 300 °C as suggested by Vij 1993.

The dimension of the obtained chips is shown in Table (3.1). Its dimensions are designed as similar to that of commercial TLD for comparison.

Phosphor	Dimension (mm)	Weight (mg)	Phosphor	Dimension (mm)	Weight (mg)
Gd ₂ O ₃ :Tb ³⁺	3.0 × 3.1 × 0.90*	19.20	La ₂ O ₃ :Er ³⁺	3.1 × 3.2 × 0.90*	20.50
Gd ₂ O ₃ :Tm ³⁺	3.0 × 3.2 × 0.85*	18.04	La ₂ O ₃ :Eu ³⁺	3.0 × 3.2 × 0.92*	20.80
Gd ₂ O ₃ :Pr ³⁺	3.1 × 3.2 × 0.90*	20.60	Y ₂ O ₃ :Tb ³⁺	3.0 × 3.3 × 0.78*	19.90
Gd ₂ O ₃ :Er ³⁺	3.1 × 3.3 × 0.92*	20.80	Y ₂ O ₃ :Tm ³⁺	3.0 × 3.2 × 0.73*	19.80
Gd ₂ O ₃ :Eu ³⁺	3.0 × 3.2 × 0.95*	20.70	Y ₂ O ₃ :Pr ³⁺	3.0 × 3.1 × 0.83*	18.55
La ₂ O ₃ :Tb ³⁺	3.0 × 3.1 × 0.90*	19.80	Y ₂ O ₃ :Er ³⁺	3.0 × 3.2 × 0.85*	19.03
La ₂ O ₃ :Tm ³⁺	3.1 × 3.2 × 0.91*	20.90	Y ₂ O ₃ :Eu ³⁺	3.1 × 3.3 × 0.87*	20.05
La ₂ O ₃ :Pr ³⁺	2.9 × 3.2 × 0.90*	20.20			

Table (3.1): The mean dimensions of the phosphors, * The thickness

The thickness of the chips should be small enough to avoid the non-ideal thermal contact between dosimeter and heating tray (planchet) of TLD reader, and the variable thermal gradients across the sample that may cause the measured temperature differ considerably from the sample temperature (Piters 1994).

Bad thermal contact often results in a broadening of the glow curve with an increase in the high temperature tail (Makinlay 1981).

3.2.2 The range of percentage error in the reading of the chips

Four chips of each lanthanide oxide phosphor have been exposed to deuterium UV lamp to determine the percentage error. The error range in the sensitivity of these chips is showing in the following table (3.2).

Phosphor	TL intensity (Arb. unit)	Percentage error %	Phosphor	TL intensity (Arb. unit)	Percentage error %
Gd ₂ O ₃ :Tb ³⁺	69.2 ± 2.38	3.4	La ₂ O ₃ :Eu ³⁺	-	-
Gd ₂ O ₃ :Tm ³⁺	62.8 ± 3.70	5.9	La ₂ O ₃ :Er ³⁺	35.9 ± 3.70	10.3
Gd ₂ O ₃ :Pr ³⁺	-	-	Y ₂ O ₃ :Tb ³⁺	17.9 ± 2.20	12.3
Gd ₂ O ₃ :Eu ³⁺	58.1 ± 4.20	7.2	Y ₂ O ₃ :Tm ³⁺	27.0 ± 2.70	10.0
Gd ₂ O ₃ :Er ³⁺	150 ± 10.6	7.1	Y ₂ O ₃ :Pr ³⁺	-	-
La ₂ O ₃ :Tb ³⁺	33.5 ± 2.49	7.4	Y ₂ O ₃ :Eu ³⁺	44.8 ± 5.20	11.6
La ₂ O ₃ :Tm ³⁺	17.5 ± 0.81	4.4	Y ₂ O ₃ :Er ³⁺	28.5 ± 3.20	11.2
La ₂ O ₃ :Pr ³⁺	-	-			

Table (3.2): The percentage error in the reading of Ln₂O₃:RE³⁺ chips

3.3 Calibration

Calibration is usually accomplished by the method of substitution (Moore 1980) by which one source of known spectral distribution is used to calibrate unknown source (Bassi 1976).

Wavelength (nm)	Irradiance (mW/m ² nm)	Relative irradiance *	Wavelength (nm)	Irradiance (mW/m ² nm)	Relative irradiance *
200	0.46572	1.00000	310	0.10756	0.23095
210	0.39911	0.85697	320	0.09459	0.20310
220	0.35827	0.76928	330	0.08228	0.17667
230	0.33500	0.71932	340	0.07216	0.15494
240	0.30708	0.65937	350	0.06326	0.13583
250	0.26907	0.57775	360	0.05649	0.12130
260	0.22801	0.48959	370	0.05067	0.10880
270	0.19465	0.41795	380	0.04708	0.10109
280	0.16731	0.35925	390	0.04205	0.09029
290	0.14466	0.31062	340	0.03898	0.08370
300	0.12492	0.26823			

Table (3.2): The calibration value of irradiance against the wavelength at 50 cm
* Calculated

Standard deuterium lamp BL4392 was used for calibration. The calibration chart in figure (3.4) was carried out by ORIEL on 5.12.1997 at distance 50 cm, and was operated at the calibration current of 300 mA. The data of this graph is represented in table (3.2). Due to the limited sensitivity of the Minolta UV detector (model UM-A22), it is difficult to detect light at 50 cm from the UV lamp, therefore, the calibration chart was re-calculated at distance ($d = 10$ cm) using inverse square law ($1/d^2$) figure (3.5).

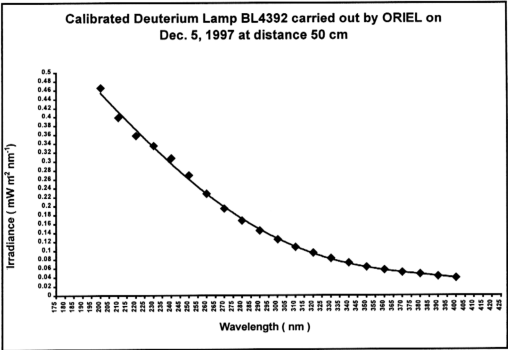


Figure (3.4): Calibration chart at 50 cm (measured)

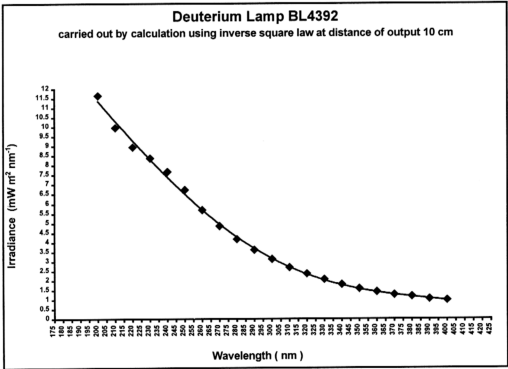


Figure (3.5): Calibration chart at 10 cm (calculated)

3.3.1 Calibration of Minolta UV meter

Two Minolta UV receptor models UM-25 and UM-36 were calibrated. They were calibrated at wavelength 255 and 365 nm respectively. Their specifications are shown in table (3.3).

		UM-25	UM-36
Receptor	Silicon Photodiode		
Spectral response		220-390 nm	310-400 nm
Peak wavelength		255 ± 5 nm	365 ± 5 nm
Half bandwidth		40 ± 7 nm	33 ± 7 nm
Cosine error	30°	Within ± 15%	Within ± 3%
	60°	Within ± 35%	Within ± 10%

Table (3.3): Specifications of the receptors

The irradiance measuring range of this Minolta UV meter is between 0.001 to 19,990 mW/cm². The spectral response of its receptors is shown in figure (3.6). The receptor of UM-36 has a maximum response at wavelength 365 nm whereas UM-25 at 255 nm. UV receptor was placed at a distance 10 cm from the standard deuterium UV lamp. The reading of the UV meter was corrected using the calibration chart of figure (3.5). The meter is checked for its stability in the readings at least once every month.

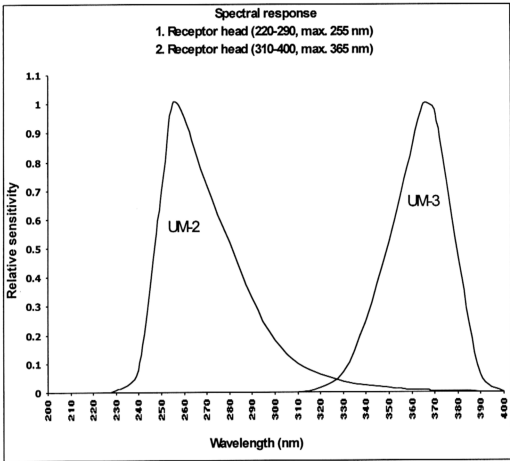


Figure (3.6): The spectral response of the receptors

3.3.1.1 Calibration results

The UV irradiance at 10 cm for the wavelength 255 nm, figure (4.1), is:

$$= 6.1 \text{ mW/m}^2 \text{ nm}$$

By multiplying this value to the the wavelength 255 nm, the UV irradiance is:

$$= 6.1 \times 255 = 1555.5 \text{ mW/m}^2 = 0.1556 \text{ mW/cm}^2$$

The UV irradiance at 10 cm was measured by UM-25 is:

$$= 0.016 \text{ mW/cm}^2$$

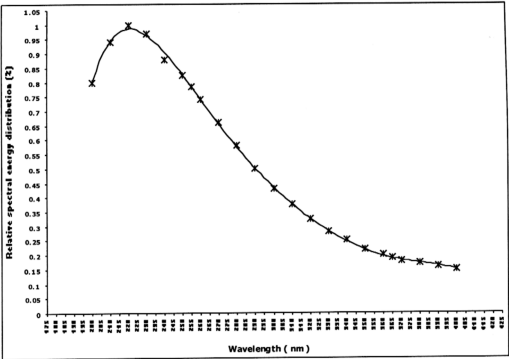


Figure (3.7): Spectrum distribution of deuterium UV source

The intensity of UV light from the deuterium UV source was compared to that standard one. We found that, the intensity of UV from both sources is slightly different as shown in the following Table (3.5):

UV mater	Deuterium source (mW/cm ²)	Standard source (mW/cm ²)	Correction factor for Deuterium source
UM-36	0.0432	0.0486	1.125
UM-25	0.1455	0.1552	1.067

Table (3.5): The values of UV irradiance at 10 cm

This slight different in the readings due to the similarity in the shape of spectrum distribution at wavelength between 220 and 400 nm as shown in figures (3.5 and 3.7).

3.3.2.1 Irradiance measurement of deuterium UV lamp at 8 cm

Lanthanide oxide powder and commercial TLD were exposed to deuterium UV lamp at 8 cm. The irradiance of this lamp at this distance was measured by UV receptors UM-25 and UM-36 at different exposure times. The data is shown in table (4.1) and plotted in figure (4.1).

Exposure time (m)	UM-36		UM-25	
	mWh/cm ²	J/m ² * calculated	mWh/cm ²	J/m ² * calculated
5	0.011 **	400.0 **	0.024	864.0
30	0.057	2,052	0.194	6,984
60	0.114	4,104	0.388	13,968
90	0.171	6,156	0.598	21,528
120	0.228	8,208	0.792	28,512

Table (4.1): The irradiance energy of deuterium UV lamp after correction.
* 1 Wh = 3600 J, ** estimation from figure (4.1)

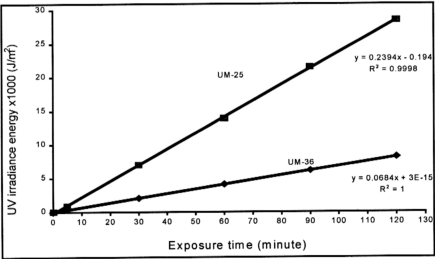


Figure (4.1): the variation of UV dose against exposure time at 8 cm

3.4 Measurement of UV using thermoluminescence materials

3.4.1 Lanthanide oxide $\text{Ln}_2\text{O}_3:\text{RE}^{3+}$

It includes Y_2O_3 , La_2O_3 and Gd_2O_3 doped with Er_2O_3 , Eu_2O_3 , Pr_6O_{11} , Tb_4O_7 and Tm_2O_3 . Some of them such as $\text{Y}_2\text{O}_3:\text{Eu}$ and $\text{Gd}_2\text{O}_3:\text{Eu}$ (Yeh 1996) have been suggested previously to be used in UV dosimetry.

3.4.2 Commercial TLD

TL materials from Harshaw were used in this study. These TL materials are namely, $\text{LiF}:\text{Mg,Cu,P}$ (TLD-100H), $\text{CaF}_2:\text{Dy}$ (TLD-200), $\text{CaF}_2:\text{Mn}$ (TLD-400), Al_2O_3 (TLD-500), $^7\text{LiF}:\text{Mg,Cu,P}$ (TLD-700H) and $\text{CaSO}_4:\text{Dy}$ (TLD-900) mix with teflon. Most of them have been previously suggested for environmental measurements. Their dimensions and commercial names are shown in Table (3.6).

Phosphors	Commercial name	Dimensions (mm)	Weight (mg)
$\text{CaSO}_4:\text{Dy}$ Teflon	TLD-900	$2.98 \times 3.05 \times 0.95^*$	18.84
$\text{LiF}:\text{Mg,Cu,P}$	TLD-100H	$3.24 \times 3.24 \times 0.92^*$	20.18
$^7\text{LiF}:\text{Mg,Cu,P}$	TLD-700H	$3.19 \times 3.19 \times 0.61^*$	14.20
$\text{CaF}_2:\text{Dy}$	TLD-200	$3.21 \times 3.21 \times 0.89^*$	28.13
$\text{CaF}_2:\text{Mn}$	TLD-400	$3.20 \times 3.20 \times 0.89^*$	28.80
Al_2O_3 (Disc)	TLD-500	$5.03^{**} \times 0.97^*$	75.85

Table (3.6): Dimensions of the commercial TL materials

* The thickness, ** Diameter

$\text{CaSO}_4:\text{Dy}$ was used mixing with teflon (Azrin 1989, Campos 1986 and Bhatt 1997)

in the ratio of 1:2. The fabrication of the chip is described in section (3.2.1).

The chips of these materials was selected randomly and their percentage error in the reading to the average value was in the range as shown in the following table (3.7).

Phosphor	TLD-100H	TLD-700H	TLD-200	TLD-500	TLD-900
TL intensity (Arb. unit)	6276 ± 1787	253.7 ± 68.6	27.8 ± 4.7	3518 ± 380	549 ± 112
Percentage error %	28.5	27.0	16.9	10.8	20.4

Table (3.7): the percentage error in the sensitivity for the commercial TLD chips

3.5 Exposure

Four chips of each phosphor were selected in order to check their TL sensitivity to deuterium UV lamp and sunlight.

Due to the composition of solar radiation, the exposure to sunlight was made with/without the light filter to cut the visible light.

3.5.1 UV light

The calibrated deuterium UV source was used to test the sensitivity of these TL materials.

It provides a high intensity, continuous output range from 185 to 370 nm, with a little output in the visible and infrared ranges. Its spectral distribution is shown in figure (3.7), where the maximum UV intensity occurs at 220 nm.

The source is mounted in an aluminum box. The inside of the box is painted black in

order to reduce the scattered (indirect) radiation, which may contribute to the direct UV radiation measurement.

As recommended by the manufacturer, the UV source required a period of warm up at least 20 before the exposure was made, and to get a highly intense UVR. The high intensity UVR is obtained using the current ~ 300 mA.

The chips were placed circularly on transparent plate of Perspex as shown in figure (3.8). Then, they were exposed to UV light at a distance of 8 cm, where the temperature was 32°C at this position. This distance was fixed for two reasons:

1. To avoid the lost of deposit UV dose inside TL chips due to the high temperature near to the UV lamp ($\sim 50^{\circ}\text{C}$), which can release some trapped electrons i.e. some UV dose.
2. To make sure the intensity of UVR received by all chips are identical.

The exposure was carried out inside a dark room to avoid the effect of room light to the TL intensity.

3.5.1.1 Safety with UV lamp

For safety, the following guidelines were followed during the operation of the UV lamp:

1. UV goggles and gloves are worn to protect the eyes and hands from short wavelength UV.
2. Because of the production of ozone that may harm the respiratory system, we avoided staying for long periods near the UV lamp during operation.

3. The UV source was operated in a large ventilated area and the fan was used to dissipate the ozone.
4. The UV lamp was not touched during operation and after the first 10 minutes of shut off because of the extreme heat of the UV lamp that may burn the bare hand.

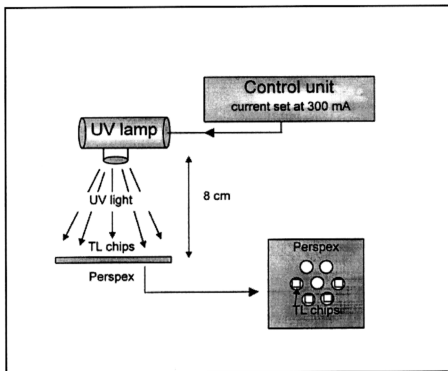


Figure (3.8): The experimental set up for exposure of the samples to UV radiation

3.5.2 Sun light

The chips have been exposed to sunlight around noontime with and without light filter to get the ratio of their sensitivity to UV light and visible light.

The reason why the measurement was carried out during noontime, because the detection of solar UVR at this time is mainly caused by the direct radiation, and the

high intensity of UVR.

The filter has a characteristic to absorb UVA radiation and transmit all band of visible light. Its absorption characteristic is measured using Minolta UV meter. The result is shown in Table (3.8).

UV meter	Spectral response	Sunlight
UM-36	310-400 nm	99.8 %
UM-25	220-390 nm	70.8 %

Table (3.8): The percentage absorption of the filter

From the data above, the filter is totally absorbed UVA that was measured by UV meter model UM-36. It can also transmit UVB that represent 29.2% of the total solar UVR measured by the head receptor of UM-25. From this result, it is clear that the filter can only absorb UVA part of UV radiation. The absorption of the filter is shown in figure (3.9). The chips were placed over the Perspex plate as shown in figure (3.10). The Perspex should be transparent to reduce the self-reflection of UVR that may contribute to the direct UVR, and high thermal dispersal to avoid the release of some UV intensity.

3.6 The electronic circuit noise of TLD reader

To insure the accuracy and consistency of the TLD reader, the electronic circuit was checked periodically.

The PMT noise, background noise and test light readings were taken at least five

times at the beginning of the reading. The way to check these noises was explained in the following sections.

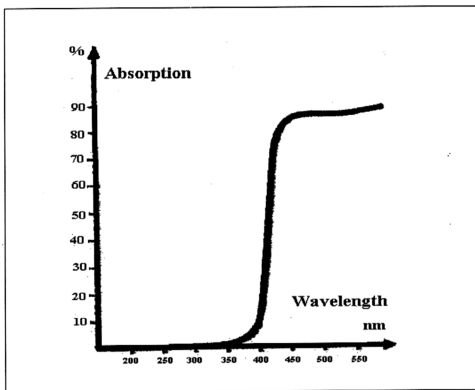


Figure (3.9): The absorption of the light filter

3.6.1 PMT noise

PMT noise is the reading produced by the PMT when there is no light source under the PMT. The reading of PMT noise was taken by closing the sample drawer completely, then open it approximately 1/4 inch. The screen should indicate that it is in the "between" position. The results should remain reasonably consistent from day to day.

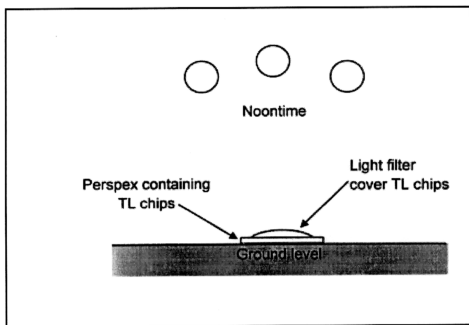


Figure (3.10): The experimental set up for the exposure to sunlight

3.6.2 Background noise

Background noise is the reading produced by the reader with heat applied, but with no TL material in the planchet. It consists of any signal generated by contamination on the planchet, light leaks and stray infrared radiation. The reading of background is taken by pushing the drawer all the way in with no TL material in the planchet.

3.6.3 Test light

This reading was taken by pulling the drawer all the way out. This places the test light under the PMT. The message "Test Light" will appear on the screen. The actual value of the test light reading will vary depending on the high voltage setting.

3.6.4 The noise reading of TLD reader

The reading of PMT noise, background noise and test light is shown in table (3.9). The readings of PMT and Background noise were less than the background of the TL materials, (see figure (3.11)). These readings may be neglected at high readings of TL intensity.

This low reading of PMT and background noise and small change in the reading of the test light indicates that the detection system of the TLD reader is almost stable.

	PMT noise (nC)	Background noise (nC)	Test light (nC)
Reading	0.049 ± 0.013	0.22 ± 0.045	130.7 ± 0.43
The percentage of the deviation	26.45 %	20.3 %	0.33 %

Table (3.9): TLD reader noise

It was observed that the values of PMT and background were changing slightly high from time to time, see the percentage error in table (3.9). It is better if we measure high number of readings of PMT and the background noise to estimate the average.

3.7 Reading of the TLD chips

After exposure to UV lamp or sunlight, the samples were kept at room temperature for 24 hour. This storage time is important to allow the unstable glow peaks at low temperatures to disappear. This glow peak is normally undesirable in dosimetry.

TLD reader 3500 Harshaw was used for the reading of TL intensity. The TLD reader was warmed up for 30 minute to stabilize the electronic circuits.

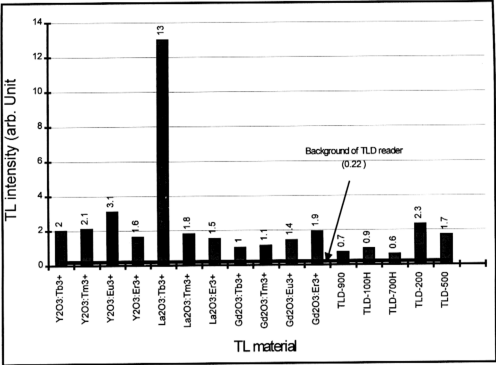


Figure (3.11): The background of the TL materials

The parameters of the TLD reader were set at Pre-heat (50 °C), heating rate (10 °C/sec) and the maximum heating temperature (300 °C).

It is important to inject the nitrogen gas around the planchet during the readings to eliminate oxygen and to reduce the effect of noise signal (black body radiation) caused by heat radiation from the heated planchet. This radiation may be produced by the planchet at high heating temperature, and may be detected by the detector and could contribute to the TL signal. Nitrogen gas is also routed through the photo multiplier tube (PMT) chamber to eliminate moisture caused by condensation (TLD reader 3500 manual).

The leakage of the room light to the detection system of the TLD reader may also add some reading to the TL intensity at low temperatures. Therefore, it is important to read the chips in a dark room to avoid the contribution of the room light to TL intensity.

3.8 Thermal and light Fading

If TL signal (intensity) decreases with the time after irradiation, the signal is said to have faded. Fading can have several causes, but the most prevalent is thermal fading.

Unwanted fading of the TL signal can also occur by optical excitation of the electron from the traps. Absorption of photons of energy greater than optical trap depth will result in releasing of trapped electron and cause the reduction in the TL signal.

For the thermal fading, the chips are kept at room temperature ($\sim 24^\circ\text{C}$) for a certain time after exposure to UV lamp. TL intensity against storage time is plotted to check the stability in the TL reading of the phosphor.

For the light fading, after exposure to UV lamp, the chips were kept at room temperature for 24 hour and then exposed to the sunlight or 100W bulb using light filter. The intensity of the TL output against exposure time to visible light is plotted to check the effect of visible light on the residual of TL intensity.

3.9 Reproducibility

To check the reading consistency of the phosphors, they were exposed many times to UVR for the same dose. The average of TL intensity was plotted against the

repeating number of the exposure to check the consistency in the readings. In the reproducibility graph, i.e. TL output versus number of irradiations, we can check the range of deviation in the readings of the phosphor. The high value of deviation in the readings indicates the instability in detection of the phosphor to UV radiation.

Approximately 5-6 homogeneous irradiation of a group of at least 10 dosimeters may be sufficient for the evaluation of the reproducibility as suggested by Zarand 1996.

3.10 Reuse of TLD materials

The purpose of pre-irradiation annealing is to re-establish the thermodynamic defect equilibrium that existed in the material before irradiation and read out.

Thermolyne furnace 1500 was used for the annealing process. The maximum heating temperature is $\sim 1400^{\circ}\text{C}$.

The phosphors need to be annealed at high temperatures to allow the rest of the trapped electrons to be released and return to the "Background State".

It is not easy to make the background reading of the chips at exactly zero or at the background of the TLD reader as shown in figure (3.11), but it can be reduced to the background reading of TL reader. The high background reading of some TL material in figure (3.11) was due to insufficient annealing temperature. These materials may need to be annealed at temperatures higher than 300°C , but because of the Teflon softening point, the materials were kept annealing at 300°C and all TL reading was being subtracted from the background reading.

Table (3.10) shows the annealing temperature that was applied for each TL material.

TL material	Annealing temperature (°C)
TLD-100H and TLD-700H	240 °C for 10 minutes
TLD-200, TLD-400 and TLD-500	400 °C for one hour
TLD-900 teflon	300 °C for one hour
$\text{Ln}_2\text{O}_3:\text{RE}^{3+}$ teflon	300 °C for one hour

Table (3.10): Annealing temperature

Because of teflon softening point at 327 °C, $\text{Ln}_2\text{O}_3:\text{RE}^{3+}$ and TLD-900 were annealed at 300 °C to avoid teflon melting point.

When the samples were annealed, they were placed at the center of the heating chamber. The heat leakage is high at the entrance of the heating chamber and temperatures here may not be the same as displayed on the control panel that is lower than the required one. Incorrect heating temperatures may not release sufficient trapped electrons and therefore results in a high in the background reading of the sample.

After annealing, the samples were taken out from the heating chamber and allowed to cool quickly to room temperature. This fast cooling procedure is not a critical factor in the annealing procedure (Piters 1996).

3.11 Estimation of TL parameters (E & s)

TL intensity was measured at a certain heating range of temperature. This range should be around a few percent of the maximum intensity of the glow peak. At least 4 readings of TL intensity at each heating temperature were measured for plotting

between \ln intensity of TL (I_{TL}) and the inverse of the heating temperature ($1/T$). The straight line of this plot was obtained. The slope of this straight line is equal to the quantity of E/k . By multiplying this value to the Boltzmann's constant (k), the activation energy (E) was determined. Then, the frequency factor (s) was calculated using equation (2.15) in chapter 2.

3.12 Measurement of solar UV radiation using UV meter

Solar UVR at the campus of University Malaya in Kuala Lumpur (3.5 °N, 100.5 °E and 19 m in height) was measured during hazy time (August - December 1997).

The average duration of the sunshine in Kuala Lumpur is between 5-7 hours, its average maximum shade temperature is between 31-32 °C and the rain season is between October and December.

The change in humidity and the non-shade temperature was measured with Thermo-Hygro recorder at different weather conditions is shown in figure (3.12).

The purpose of these measurements is to determine the UV level at this site and compare its intensity with other locations, and to detect the solar UVR at different circumstances such as time of the day, haze concentration, cloud cover, rain etc.

The measurement was carried out ten times every month for both the daily accumulation and hourly variations starting from 8:00 in the morning until 6:00 in the evening.

To reduce the amount of scattered UV radiation from any nearby construction, the receptor was placed in the horizontal plane in an open area. The accumulated measurements are monitored as shown in position A of figure (3.13). The receptor of

The UV meter was covered with a thin plastic to protect it from the rain. The absorption of light from the sun and UV lamp by the plastic was measured and the results is shown in table (3.11).

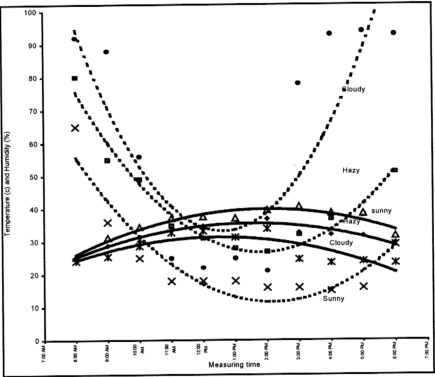


Figure (3.12): The average daily change in Humidity (- - -) and the temperature (—) from morning to evening (August - December 1997)

UV meter	Spectral response	Sunlight	UV lamp
UM-36	310-400 nm	11.4 %	12.5 %
UM-25	220-390 nm	10.0 %	13.6 %

Table (3.11): The absorption percentage of the plastic

For the hourly variations, solar UVR was measured directly and indirectly. The UV intensity was measured directly by facing the UV meter to the sunlight, and

indirectly by placing the UV meter in a horizontal plane as shown in position A in figure (3.13).

3.13 Calibration of TL material

The most sensitive TL material and has a linear response to solar UVR is calibrated by placing it and the calibrated UV meter in the same position under sunlight around noontime.

The change in TL intensity against the reading of UV meter for different exposure time is plotted. From this graph we can convert the unit of TL intensity to mwh/cm^2 that is the unit of irradiance.

This graph will be the reference for every measurement of solar UV radiation by calculates the mean value of TL intensity of TL materials. The reading in TL intensity will reflect the amount of UV irradiance for that day.

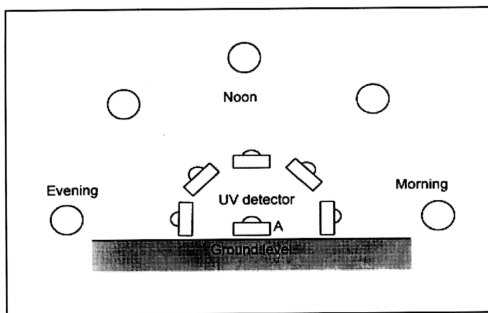


Figure (3.13): The arrangement of the receptor in indirect and direct measurements