ESTABLISHING PERSONAL DOSIMETRY PROCEDURE USING OPTICALLY STIMULATED LUMINESCENCE DOSIMETERS IN PHOTON AND MIXED PHOTON – NEUTRON RADIATION FIELDS

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2. L.N.Thiem, N.N.Quynh, H.Q.Tuan, T.V.Giap, N.T.Khai, N.H.Quyet; Neutron Calibration Field at Institute for Nuclear Science and Technology; J. Nuclear Science and Technology; ISSN 1810-5408; Vol. 6, No. 4, pp. 1-7, 2016.
3. B. D. Ky, V. M. Khoi, T. V. Giap, L. N. Thiem, H. Q. Tuan, T. T. Ha; A study on Personal Dosimetry for photon using optical stimulated luminescence dosimeters; accepted to be published in Journal of Nuclear Science and Technology; ISSN 1810-5408.

Abstract: According to Vietnamese Law on Atomic Energy, personal dosimetry (PD) for radiation workers is required periodically in order to fulfil the national legal requirements on occupational radiation dose management. Since the radiation applications have become popular in Vietnamese society, the thermal luminescence dosimeters (TLDs) have been used as passive dosimeters for occupational monitoring in the nation. Together with the quick increase in radiation applications and the number of personnel working in radiation fields, the Optically Stimulated Luminescence Dosimeters (OSLDs) have been first introduced since 2015. This work presents the establishment of PD measuring procedure using OSLDs which are used for measuring photons and betas known as Inlight model 2 OSL (OSLDs-p,e) and for measuring mixed radiations of neutrons, photons and betas known as Inlight LDR model 2 (OSLDs-n,p,e). Such following features of OSLDs are investigated: detection limit, energy response, linearity, reproducibility, angular dependency and fading with both types of OSLDs-p,e and OSLDs-n,p,e. The result of an intercomparison in PD using OSLDs is also presented in the work. The research work also indicates that OSL dosimetry can be an alternative method applied in PD and possibly become one of the most popular personal dosimetry method in the future.

***Keywords**: Personal Dosimetry, Optically Stimulated Luminescence Dosimeters, Microstar*

I. INTRODUCTION

The passive dosimetry method is one of most effective approaches used in personal dosimetry owing to its low cost, simple procedures and reliable. Together with thermoluminescence dosimeters (TLDs), the optically stimulated luminescence dosimeters (OSLDs) have been widely applied in personal dosimetry (PD) both in the mixed radiation field of photons and betas (those dosimeters are hereafter referred as OSLDs-p,e); and in the radiation field of neutrons, photons and betas (those dosimeters are hereafter referred as OSLDs-n,p,e). Both of these OSLDs (i.e. OSLDs-p,e and OSLDs-n,p,e) were used in this work for checking their compliance with the corresponding international technical requirements of IEC[0] and ISO[0]. Once the characteristics of both OSLDs satisfy the international requirements, they were applied in PD experiments through an intercomparison in order to confirm the reliability of OSLD applications in the practical works of PD.

OSLDs have been studied since 1950s for radiation dosimetry in archaeological dating and geological researches. Applications of OSLDs in PD field have been widely applied since 1990 and recently being used in many countries as USA, France, Canada, Japan, Korea and so on [3,4]. However, Al_2O_3:C crystal based OSLDs are first time applied in Vietnam at the Institute for Nuclear Science and Technology (INST) for PD.

In this study, OSLDs structure and operational principle of corresponding Microstar reader are concerned. Dosimetric characteristics of OSLD used as personal dosimeters such as detection limit, linearity, reproducibility, energy response, angular response, fading are also presented in this study accompanying with the uncertainties of PD results.

II. MATERIALS AND METHOD

II.1. Construction of OSLDs

The OSLDs-p,e used in this study consist of three main parts: an outer holder, a XA type case and one slide holding 4 elements denoted as E1 to E4 which are made by 0.3 mm thick Al_2O_3:C crystal with the diameter of 0.5 cm. The elements from E1 to E4 are respectively located at the positions of different corresponding filters as well as open window polyethylene (thickness of 29 mg/cm^2), plastic (thickness of 275 mg/cm^2), aluminum (thickness of 375 mg/cm^2) and copper (thickness of 545 mg/cm^2) for dealing with the personal dose calculation algorithm of $H_p(10)$, $H_p(0.07)$, $H_p(3)$ caused by photons and betas together with beta dose is separately reported. Figure 1 shows the construction of OSLDs-p,e

The chip elements E1, E3, and E4 of OSLDs-n,p,e have similar construction with those in OSLDs-p,e. However, the difference is at the element E2 which is Al_2O_3:C chip coated by $^6Li_2CO_3$ for the purpose of neutron dosimetry. The OSLDs-n,p,e construction allows measuring $H_p(10)$, $H_p(0.07)$, H_p (3) caused by neutrons, photons and betas including neutron dose (H_n) separately reported.

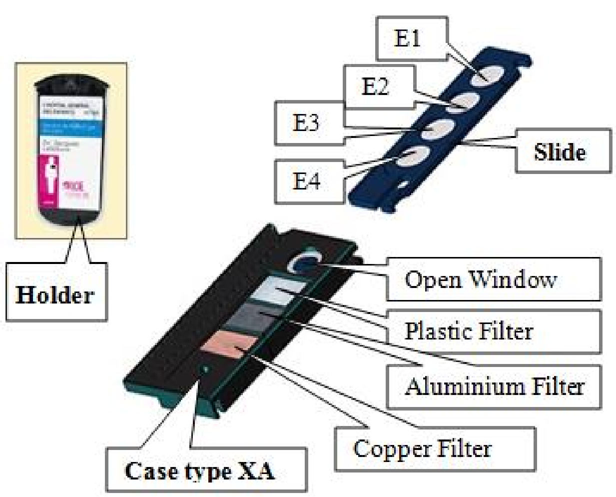

Figure 1: The Landauer Inlight Model 2 personal dosimeter

II.2. Microstar reader

Microstar reader is a portable one with the dimensions of 32.7 cm x 23.0 cm x 11.0 cm and the weight of 15 kg. It is applied by conventional electric power source of 110 – 240 kV, 1.5 Amp, 50 -60 Hz. The reader is connected to an external computer via a USB cable to control the setup parameters and data analysis/recording. Quality control for the reader is needed at least once a year or after transport/ repair to ensure the accuracy of personal dose assessment [5]. Figure 2 shows the Microstar reader connected to a computer.

Figure 2: The Microstar reader connected to a computer

II.3. Experimental method

The OSLDs were irradiated on a tissue equivalent slab phantom at 1.0 m meter under the controlled conditions of temperature and pressure at the Secondary Standard Dosimetry Laboratory of INST to the photon doses from ^{137}Cs-137 and the neutron doses from ^{241}Am-Be standard sources to determine their main characteristics as well as detection limit, linearity, reproducibility, energy response, angular response, fading. The data were analyzed and compared to the requirements from IEC [0] and ISO [0].

III. EXPERIMENTS AND RESULTS

III.1. Detection limit

The detection limit is the minimum detectable dose of the blank dosimeters which are not irradiated to any radiation sources. The detection limit is defined as a dose value of 3*δ_{BG} [**Error! Reference source not found.**,**Error! Reference source not found.**]. Here, δ_{BG} is the experimental standard deviation of the background and expressed by Eq. (1), where Ph_i is the background of i^{th} dosimeter, $\overline{Ph}$ is the average background of n dosimeters.

$$\delta_{BG} = \sqrt{\frac{(Ph_i - \overline{Ph})^2}{n-1}} \qquad (1)$$

The detection limit of both OSLDs-p,e and OSLDs-n,p,e is evaluated as around 0.05 mSv

III.2. Angular dependence

The angular dependence of OSLDs is tested by irradiating OSLDs-p,e and OSLDs-n,p,e to ^{137}Cs and ^{241}Am-Be standard sources, respectively at the different angles of ± 15^0, ±30^0, ±45^0 and ± 60^0 (0^0 is the angle between the central beam and the normal direction to the phantom). The obtained results of the OSLDs-p,e show the difference within 15% compared to that at 0^0 for the incident angles of $\pm 15^0$, $\pm 30^0$, $\pm 45^0$ and 60^0 while for OSLDs-n,p,e, those differences are found as around 30% at some angles. Figure 3 shows the angular dependence of OSLDs (left: for OSLDs-p,e and right: for OSLDs-n,p,e).

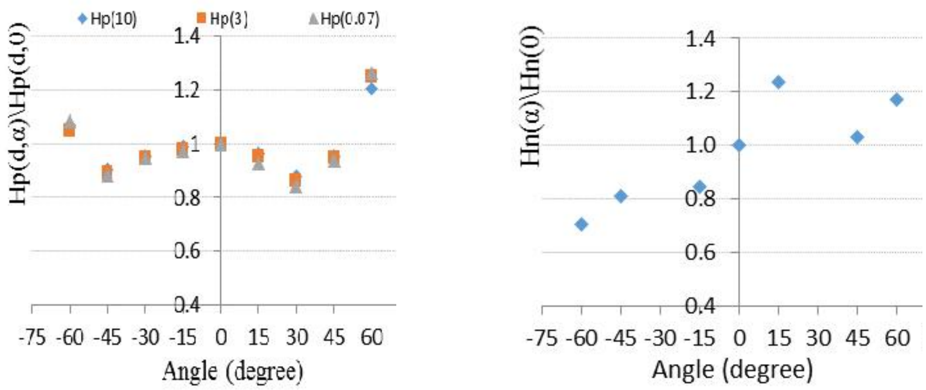

Figure 3: Angular dependence of OSLDs (left: for OSLDs-p,e and right: for OSLDs-n,p,e)

III.3. Linearity

The linearity of OSLDs-p,e and OSLDs-n,p,e was investigated in the doses ranged from 0.5 mSv to 300 mSv and 0.5 mSv to 100 mSv, respectively. The differences between the reference doses and the delivered ones were found as less than 10% for OSLDs-p,e and around 30% for OSLDs-n,p,e. Figure 4 depicts the linearity of OSLDs-p,e on the left and OSLDs-n,p,e on the right.

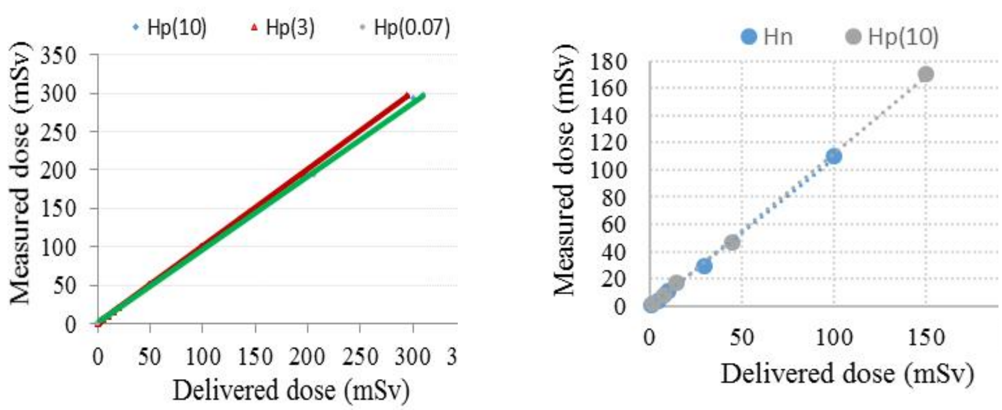

Figure 4: The linearity of OSL and OSLN dosimeters

III.4. Energy response

The energy response was investigated for OSLDs-p,e only so that OSLDs-p,e were irradiated to different average photon energies ranged from 33 keV of X ray to 662 keV of ^{137}Cs. The energy response was also investigated for all OSLDs-p,e chip elements (i.e. from E1 to E4). Figure 5 shows the element response as a function of energy. One can figure out that energy response of individual element shows the strongly dependence at the energies lower than 100 keV.

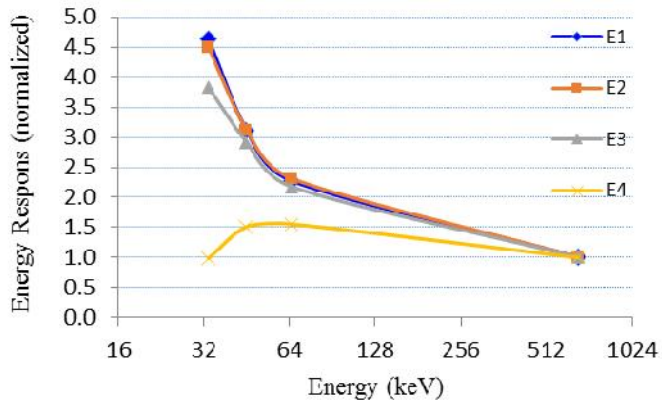

Figure 5: Response of OSLDs-p,e elements as a function of energy

III.5. Reproducibility

The reproducibility of OSLDs was investigated based on the international criteria as expressed in Eq.(2) and Eq.(3) for OSLDs-p,e and OSLDs-n,p,e respectively. Where S_{E_j} is the standard deviation of ten experiments, $\overline{Ej}$ is the average value of five read-out times in each experiment and l_j is confidence interval of S_{E_j} in ten experiments; s_i is experimental standard deviation, $\overline{H}_{a,i}$ is arithmetic mean of reference dose and $l_{s,i}$ is the half width of the confidence interval of s_i which is expressed as Eq.(4) in which n is the number of dosimeters. The obtained results show the reproducibility of OSLDs-p,e in good compliance with the requirement in Eq.(2) while the reproducibility of OSLDs-n,p,e is exceeded the international criteria in Eq.(3).

$$R_1 = \frac{S_{E_j} + l_j}{\overline{E}_j} \leq 0.075 \qquad (2)$$

$$R_2 = \frac{s_i + l_{s,i}}{\overline{H}_{a,i}} \leq 0.2 \qquad (3)$$

$$l_s = t_n\sqrt{0.5(n-1)} \qquad (4)$$

III.6. Fading effect

The signal fading effect of OSLDs was investigated by irradiating OSLDs to a conventional true value of dose then those dosimeters could be read-out at different time point after irradiation. The time point can be ranged from some hours up to couple months. The obtained results is consequently compared to the international criteria [0,0]. Figure 6 depicts the fading of OSLDs which are satisfied the international requirements. One can see that the fading of OSLDs-p,e is as low as around 3% during 4 months stored in normal environmental conditions while the fading of OSLDs-n,p,e is found as higher as round 8% during 3 months.

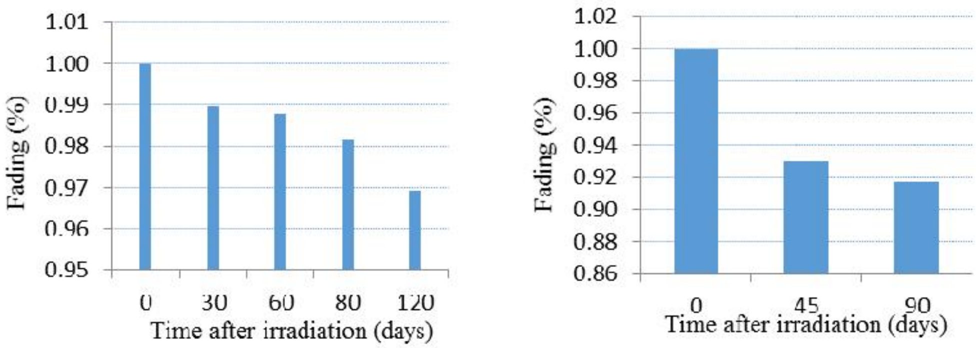

Figure 6: The fading of OSLDs after irradiation (left: for OSLDs-p,e and right: for OSLDs-n,p,e)

III.7. Intercomparison in personal dosimetry using OSLDs

In this section, an international comparison in personal dosimetry was carried out applying the procedure established in the work. There were several laboratories in Southern East Asian countries participated in this intercomparison so that the irradiated OSLDs-p,e were sent between participated laboratories asking for determining the blind dose and/or asking for delivering a conventional true value of dose. The personal dosimetry procedure established in this work was applied in the intercomparison and shown a good agreement around 10% compared to the conventional true value designated by the pilot laboratory. This implies that the procedure established in the work can be applied in practical tasks of personal dosimetry. Table 1 shows the measured dose to the true one ratio obtained from the intercomparison program in terms of $H_p(10)$ and $H_p(0.07)$ quantities in the mixed radiation field of photons and betas.

Table 1: Ratio between the measured dose and the true one of the intercomparison program in terms of $H_p(10)$ and $H_p(0.07)$ quantities

Nuclide	Quantity	True dose (mSv)	Measured dose (mSv)	$\frac{Measured\ dose}{True\ dose}$
Cs-137	Hp(10)	0.35	0.39	1.11
		1.00	0.91	0.91
		3.50	3.18	0.91
Sr-90	Hp(0.07)	2.50	2.54	1.02
		5.00	4.90	0.98
		8.00	7.96	1.00

IV. PERSONAL DOSIMETRY PROCEDURE

This section presents the sequent steps for personal dosimetry procedure using OSLDs

Step 1: Ensure the control nob of the Microstar reader at "H/P" position. Turn on the Microstar reader and wait at least 30 minutes for the system warm up;

Step 2: Open Microstar software and choose the tab "Configuration" in order to set up "Dosimeter Type" as "Inlight"; "Accreditation type" as "NVLAP"; "Holder type" as "Landauer Inlight"; and choose the suitable "XA or BA" in "Default case";

Step 3: Select the “Reading” tab in the software window. Enter the user code in the “User ID” pane manually if needed (or may be skipped). Disassemble the dosimeter case from the holder and enter the code of the dosimeter case in the “Process #” pane automatically by the dosimeter code sensor. Pull out the dosimeter drawer of the Microstar reader to put the dosimeter case into;

Step 4: Push the dosimeter drawer into the fixed position for reading. Turn the control nob clockwise respectively to the position from E1 to E4; (Note: The indicator light is on during the reading time and off when ready for another read). When all 4 positions are read out, the software will automatically calculate $H_p(10)$, $H_p(0.07)$, $H_p(3)$, beta dose (XA case type) or neutron dose (BA case type) together with radiation type information.

Step 5: Record the measuring results manually or automatically by the software in an Excel file which is can be accessed via a computer.

Step 6: Turn the control nob back the “H/P” position. Pull out the dosimeter drawer of the Microstar reader back the ready position. A new dosimeter can be read by repeating the procedure from Step 3

V. CONCLUSION

In this work, such following features of the OSLDs were investigated: detection limit, linearity, reproducibility, energy response, angular response and fading effect. The personal dosimetry procedures were also established and successfully applied in an intercomparison implies the reliability of the established procedures which can be applied in the practical works.

REFERENCES

[1] CEI/IEC 1066:1991; Thermoluminescence dosimetry systems for personal and environmental monitoring, 1991.

[2] ISO 21909 : 2005 (E); Passive Personal Neutron Dosimeters – Performance and Test Requirements; 2005.

[3] Waraporn Sudjai et al.; Inlight Optically Stimulated Luminescence for Occupational Monitoring Servive in Thailand. http://www.aesj.or.jp/publication/pnst003/094.pdf (accessed on Nov.15-2016).

[4] Eduardo G. Yukihara, Stephen W. S. McKeever; Optically Stimulated Luminescence Dosimetry – Fundamentals and Applications; p. 388, John Wiley and Sons, Ltd., Publication, 2011.

[5] Christopher A Perks, Cliff Yahnke, Marc Million; Medical dosimetry using Optically Stimulated Luminescence dots and microstar readers; http://www.landauer.co.uk/documents/LANDAUER_EUROPE_Poster_microstar_in_medical_dosimetry_octobre08.pdf (accessed on Nov.15-2016).