Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Evaluation of Fast Neutron Response of OSLD by ^{252}Cf Neutron Source

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1. Introduction

The Pohang Accelerator Laboratory (PAL) consists of the PLS-II (Pohang Light Source), the PAL-XFEL (PAL X-ray Free Electron Laser), and other small-size accelerator facilities. The PLS-II and the PAL-XFEL accelerate electron beam up to 3 GeV and 11 GeV, respectively. These facilities generated several types of radiations that are low energy x-ray coming from klystron or RF cavity, high-energy neutrons coming from photon-induced reaction with accelerator components, and photons coming from radio-activated materials by activation. The PAL have a personal dosimetry service licensed by the government as a self-assessment facility. It is required annually to carry out the performance test in compliance with the Korean legislation on nuclear safety. Recently, the demand of fast neutron dosimetry has been issued, especially by increasing accelerator facility. The Nuclear Safety and Security Commission (NSSC) is considering to introduce the new standard including fast neutron field in Korean personal dosimetry system like the ANSI/HPS N13.11-2009[1]. This study is the preliminary experiment of evaluating the fast neutron response of Optically Stimulated Luminescence Dosimeters (OSLD) used in the laboratory for future change.

2. Methods and Results

These experiments were performed using the OSLD including ^{6}Li for neutron measurements at the PAL calibration room which has a bare ^{252}Cf neutron source. The experimental condition was simulated using the Monte Carlo code, MCNPX2.7.0 [2]. Both results are compared and the performance of the OSLD was tested.

2.1 OSLD dosimetry system

The PAL operates a Landauer InLight Reader (ZPA-710A) as the personal dosimetry system. The operating principle is to count the blue light (~420 nm) produced stimulating it with green light (~530 nm) [3-4]. The model of the personal OSLD used in PAL is InLight Albedo neutron dosimeter (OSLN). The OSLN dosimeter reponds to beta, photon, and neutron radiation fields and is used to measure whole body Hp(0.07), Hp(0.3), and Hp(10) resulting from beta, photon, and neutron radiation. The element number 1, 3, and 4 consist of Al_2O_3:C and element number 2 consists of Al_2O_3:C coated with $^{6}Li_2CO_3$ for neutron evaluation. The obtained counts each elements by dosimetry system are converted to neutron dose through algorithms.

2.2 Experimental setup

A calibration room has been constructed in PAL for the calibration of radiation detectors. The experiments were performed in calibration room at 1 meter far from center of neutron source without moderator. Dosimeters were irradiated with attached to the front of the PMMA (30×30×15 cm^3) phantom. During the irradiation, control dosimeters were located outside the calibration room for subtraction of background radiation. It is assumed that neutron beam from ^{252}Cf was uniformly irradiated to dosimeters during the irradiation. There are three categories of dose groups in one experiment, and two experiments were conducted. 10 dosimeters were used in one dose group. Totally, there are 5 groups for delivered neutron dose with 0.5, 1.0, 1.5, 3.5, and 4.9 mSv, respectively. The delivered neutron dose was deduced by using LB6411 neutron survey meter that has calibration traceability, although there is no traceability of the emission rates of ^{252}Cf source. The dose rate was measured using the neutron survey meter at a distance of 1 m from source to center of survey meter, which is 24.75 ± 0.38 uSv/hr and irradiation time was determined based on these measurements for each dose groups. The experimental setup is shown in figure 1 for fast neutron irradiation. After irradiation, the dosimeters were evaluated in the ^{252}Cf-Bare mode built into the assessment system.

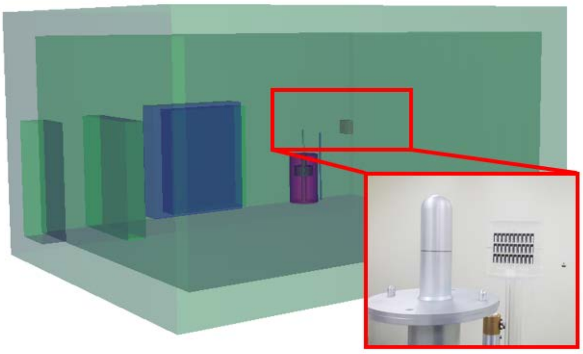

Fig. 1. Experimental setup of neutron irradiation

2.3 Monte-Carlo Simulation

The code used for this simulation is MCNPX 2.7.0 [2]. Geometric structures are described as neutron irradiator, PMMA phantom, shielding door, and concrete wall in calibration room. The dose calculation location is PMMA phantom. The dose calculation position is the same as the size of the dosimeters in front of the PMMA phantom and the ICRP74 neutron dose conversion factor is used in this simulation. The neutron source term is Watt fission spectrum for ^{252}Cf included in the code. The calculated dose rate is 24.4 uSv/hr with relative uncertainty less than 5%.

2.4 Assessment of neutron dose

The comparison results of experiment and simulation are represented in figure 2. Simulation results are underestimated with delivered dose. On the other hand, reported dose results of dosimeters tend to be overestimated whole range of delivered dose. Nevertheless, results of reported dose have linearity. Neutron dose assessment are represented in table 1 and evaluated figure of merit such as the bias, standard deviation, and limit values. According to ANSI/HPS N13.11-2009 performance in a given category is considered acceptable if [1,5]:

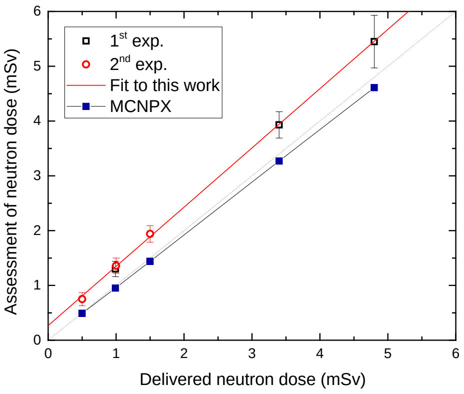

Fig. 2. Neutron dose assessment of fast neutron irradiation.

Table 1. Neutron dose assessment

H_i (mSv)	H_i' (mSv)	MCNPX (mSv)	$\|B\|$	S	$\sqrt{B^2+S^2}$
0.50	0.75 ± 0.12	0.49	0.49	0.38	0.62
1.00	1.30 ± 0.14	0.95	0.30	0.21	0.37
1.50	1.94 ± 0.15	1.44	0.29	0.16	0.33
3.49	3.93 ± 0.24	3.27	0.13	0.11	0.17
4.92	5.45 ± 0.48	4.61	0.11	0.15	0.19

$$B^2 + S^2 \le L^2 \quad , \tag{1}$$

where L is the tolerance level. L is 0.3 for neutron category. The “bias”, B, given by

$$B = (1/n) \cdot \sum_{i=1}^{n} \frac{H_i' - H_i}{H_i} \quad , \tag{2}$$

where, H_i is the delivered dose by neutron survey meter with traceability, H_i’ is the reported dose by dosimetry system, and the “standard deviation”, S [6]. The figure 3 shows the values of figure of merit for each neutron dose group. The current performance is out of the limit of regulation below minimum dose in ANSI/HPS N13.11-2009 for fast neutron category.

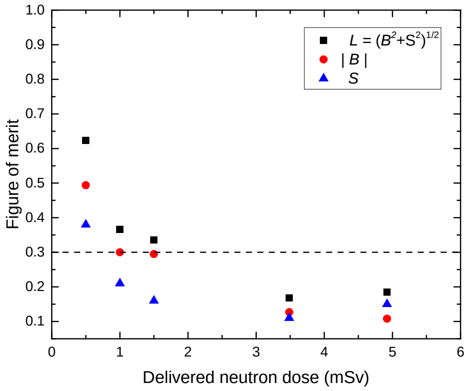

Fig. 3. Variation of Figure of merit versus neutron doses

3. Conclusions

This study was performed to determine the fast neutron response of OSLD (OSLN) used in PAL for monitoring radiation worker’s external dose. The neutron irradiation was conducted in 5 groups of dose level. The irradiated dose was determined using a neutron survey meter with traceability, which was agreed well with the results of the Monte Carlo calculation. Although there was a tendency which the measured doses overestimate the designed neutron dose, the good linearity of reported dose up to 5 mSv was verified. In near future, the ^{252}Cf neutron source will be calibrated with neutron emission rates, which has traceability, and then the same kind of study will be carried out. The neutron conversion factor in algorithms of Landauer InLight should be re-evaluated for fast neutrons if considering the present results.

REFERENCES

[1] American National Standard Institute, Personnel Dosimetry Performance – Criteria for Testing, ANSI/HPS N13.11-2009, McLean, VA, 2009
[2] D. B. Pelowitz, J. W. Durkee, J. S. Elson, M. L. Fensin, J. S. Hendricks, M. R. James, R. C. Johns, G. W. McKinney, S. G. Mashnik, J. M. Verbeke, L. S. Waters, T. A. Wilcox, MCNPX 2.7.0 Extensions, LA-UR-11-02295
[3] M. Agarwal, S. K. Garg, K. Asokan, P. Kumar, Applied Surface Science, Vol. 444, p. 819-828, 2018
[4] E. G. Yukihara, S. Mckeever, M. S. Akselrod, Radiation Measurements, Vol, 71, 9. 15-24, 2014
[5] A. Romanyukha, M. D. Grypp, G. R. Fairchild, A. S. Williams, Radiation Measurements, Vol. 93, p. 7-12, 2016
[6] C. G. Soares, IM 2005 European workshop on individual monitoring of ionizing radiation Bool of abstract, p. 196, 2005