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TECHNICAL MATERIAL

Environmental Radiation Dosimetry by the Small OSL Reader

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Aluminum Oxide is well known as a TLD material for environmental dosemeasurement. The use of aluminum oxide TLD became popular due to its high sensitivity, small fading, and physical stability. However the TL material was not easy to analyze due to thermal quenching and light fading effect. The development of Optically Stimulated Luminescence (OSL) method made Aluminum Oxide simplified the analytical process and equipment. A light emitting diode (LED) stimulation method was developed, which enabled the development of a compact reader, called microStar. This study was conducted to understand the characteristic of low dose measurement using the microStar and its application for environmental dose measurement. OSL dosimeters (OSLD) were irradiated using a 74 GBq and 7.4 GBq Cs-137 radiation source at National Institute of Radiological Science. Irradiations included various delivered doses from 20 μGy to 1 mGy free in air. The microStar gets good read out results. The microStar can be used for environmental dose measurement. Over 10 microStar readers have been deployed around the Fukushima Daiichi Nuclear Power Plant (NPP) for monitoring members of the general public, workers, and environmental dose.

KEYWORDS: aluminum oxide, optically stimulated luminescence, environment dosimetry

I. Introduction

Thermo Luminescence dosimeters (TLD) have been used for environmental dose measurement around NPP.

TLD is known for easy handling and reliable measurement system, Aluminum Oxide TLD was known for its high sensitivity, physical stability and small fading.

However Aluminum Oxide has a thermal quenching[1)] and light fading issues[2)], so the process needs to be handled in a dark room and the analysis process needs to be tightly controlled. The development of Optical Stimulated Luminescence (OSL) eliminates several disadvantages of TLD by eliminating the heating process, and achieve fast and multiple reanalysis capability. The development of annealing method applied by light fading provides a stable material and sensitivity of when used as an OSL detector. The TLD method uses heat to anneal which results in changes to the sensitivity of the material over time.

Some measurement techniques can achieve precise measurement as OSL but cannot be read many times. Environmental measurement using OSL can be a suitable measurement system. OSL had been developed as personal dosimetry system in 1998, but this system was using Nd:Yag laser beam as the stimulation light. This stimulation technique could not be used and not used[3)] for in the development of a small reader for environmental measurement. Studies were conducted on requirements for low dose monitoring and the potential market applications of a small reader. These studies resulted in the development of a LED (Light Emitted Diode) stimulation technique[4)] and enabled the development of a small OSL reader called microStar. The microStar is note book size, easy to operate and can be powered by a car battery (**Figure 1**).

The reanalysis capability of the OSL technique also allows for incremental measurement and enables on-site measurement capabilities. In Fukushima Daiichi NPP accident over 10 microStars have been deployed near Fukushima area.

Fig. 1 The photograph of microStar reader and Laptop. A dosimeter is put into the slide on the left-hand side of microStar. A measurement point changes by turning the dial of the center of microStar. Measured value is displayed on Laptop screen.

II. Materials and Methods

For the study of low dose, every dose level used 10 dosimeters, which were irradiated by National Institute of Radiological Sciences. The dosimeters were irradiated using a 74 GBq and a 7.4 GBq Cs-137 source free in air (without phantom) at a distance of 100 cm from the source. The delivered doses were from 20 μGy to 1 mGy. Since OSL can be read multiple times with minimal depletion, the

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dosimeters were kept for several weeks and allowed to accumulate natural background radiation, then read again, after that the results were compared.

Long term background dose measurement experiment was performed using 5 EX dosimeters. These dosimeters were kept at second floor of Nagase Landauer Tsukuba office by the window. This experiment started on August 2010.

Regarding the incremental test, the dosimeters had been irradiated by a 74 GBq Cs-137 with 100 cm distance, after irradiation, dosimeters were read, and irradiated again, this procedure was carried out by 117 times using the micorStar. The dose was subtracted previous dose from accumulated dose, the dose was evaluated by high energy photon algorithm designed by Landauer.

$$D=((D_{Cu1}+D_{Cu2})/2/0.89-D_0)-D_{n-1} \quad (1)$$

D : Incremental dose
D_{Cu1} : Gamma converted dose for copper filter1
D_{Cu2} : Gamma converted dose for copper Fiter2
D_0 : Control badge dose
D_{n-1} : Previous measurement dose

III. Results and Discussion

Figure 2 shows the response by 10 dosimeters between 20 μGy through 10 mGy. In case of less than 100 μGy, the valuation was over 10%. But the valuation decreased along with the increase of delivered dose, and in case of 200 μGy, and 1 mGy, the valuation became within 5%, and 3% respectively.

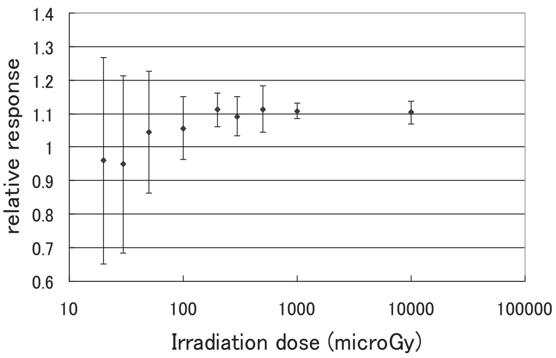

Fig. 2 The linearity test results in the low dose of microStar reader.
This is a relative response of 10 badges. Although it differs in lower 100 μGy, it is big, exposed dose becomes higher, standard deviation will decrease.

Figure 3 shows the reanalysis of dose from the day after irradiation through 35 days, it was observed that the increase of dose along with natural background dose. Background dose where it was kept these badges are 2 μGy/day. Background dose is higher than the lowest exposed dose 10 days after irradiation.

Figure 4 is long term background dose measurement results. Since the OSL dosimeter can be re-analyzed, additional testing was conducted on the stability of dosimeters over long period of time. For this study 5 dosimeters were placed near the window of second floor of

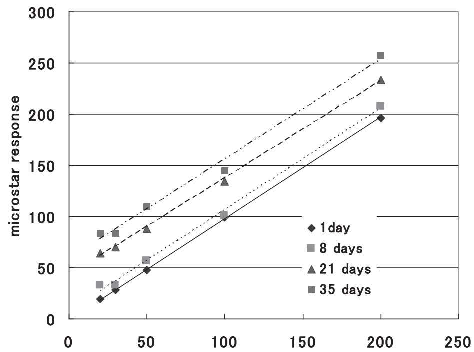

Fig. 3 We reread the badge which irradiated 20, 30, 50,100 and 200 μGy after irradiation on 1, 8, 21, and the 35th days. The measurement dose is also increasing with the increase in a background.

the Nagase Landauer Tsukuba building. This was a harsh environment with the dosimeter being in direct sunlight and temperatures exceeding 60 °F. The US Navy conducted testing using dosimeters wrapped in aluminum foil as controls, in accordance with ANSI N545, and this test is also being conducted with dosimeter wrapped in aluminum foil. The test started in August 2010 and the dosimeters have been read 4 times.

Unfortunately, there was nuclear accident happen in Japan at middle of March 2011, **Figure 4** shows before and after accident linearity, broken line is before and straight line is after accident. I think that both natural background radiation doses are not similar. Due to Fukushima accident, the natural background radiation dose has become higher than normal. The increase in background dose was estimated to be about 0.027 mGy.

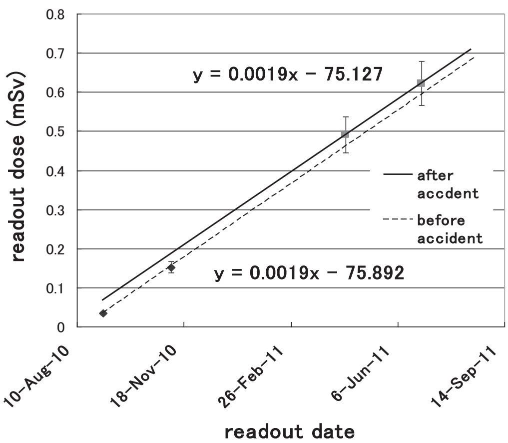

Fig. 4 Long term background dose measurement result.
The broken line is before and the straight line is after accident. Since incline of both of lines is equal, it has not changed to the environment dose rate in accident before and after.

Fiure 5 shows the incremental dose test results. In this study, 117 measurements were made on the same dosimeters the dosimeters were irradiated to 0.2 mGy. The data shows a slight decrease in the dose result for the 14th, 29th, 59th, and 89th reading. The interval between irradiation and reading was 18 minutes. This test took a few days to complete due to

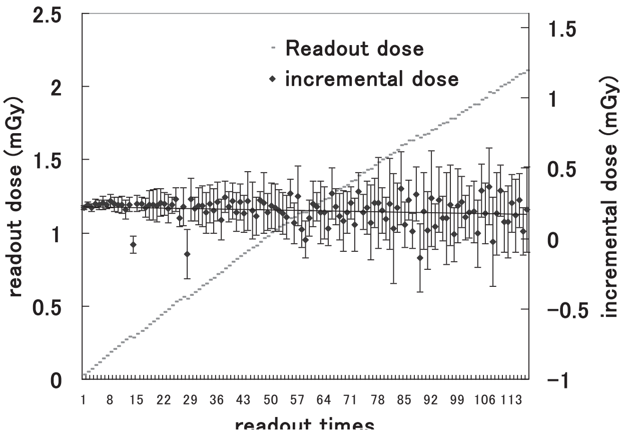

Fig. 5 Incremental test results.
Right side scale shows the incremental dose, left side scale is measured value at each time, i.e., the value of total irradiation dose.

the 8 hours irradiation time needed to deliver the dose at the irradiation. The last set of dosimeters irradiated at the end of the day was analyzed the next day so the time between irradiation and read was approximately 16 hours. A slight drop in response was observed as compared to the 18 minute reading set. This appears to be related to short term shallow trap fading.

The value of standard deviation is slightly increased by repeating the irradiation and rereading. In this study, when measured over 10 times, the standard deviation exceeded 5%. If you would allow 5% measurement error, and assuming that every three months the environmental dosimeter is analyzed the OSL dosimeter could be used in the same location for two years.

If incremental measurement method is allowed and implemented, it can reduce your time and cost of an environmental monitoring program.

IV. Conclusion

MicroStar was initially developed as a simple reader for counterterrorism and emergency response reader. Since the reader has been used successfully for personal dosimetry at customer sites and dose measurements for patients exposed to medical sources of radiation.

Fundamentally, the quality of LED and Photo Multi Plier are the same as the larger InLight readers and this study shows that microStar can measure environmental dose precisely.

It is expected that choosing suitable dosimeter and benefit of multiple reading can improve the accuracy and precision of measurements.

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