Radiation Measurements 88 (2016) 55–58

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

A radioactive contamination monitoring system with a bead-type radiophotoluminescence glass dosimeter

Naoki Zushi [a,*], Fuminobu Sato [a], Yushi Kato [a], Takayoshi Yamamoto [b], Toshiyuki Iida [a]

[a] Graduate School of Engineering, Osaka University, 2-1 Yamada-oka, Suita-shi, Osaka 565-0871, Japan
[b] Chiyoda Technol Corporation, 1-7-12 Yushima, Bunkyo-ku, Tokyo 113-8681, Japan

HIGHLIGHTS

- An RPL glass sheet was constructed with a bead-type RPL dosimeter.
- An RPL monitoring scope system was constructed with a pulse-operated image intensifier and optical components.
- RPL from an X-ray irradiated glass sheet was detected with this system.
- The brightness of the RPL image exhibited acceptable linearity to the absorbed dose of the glass sheets.

ARTICLE INFO

Article history:
Received 27 September 2015
Received in revised form
17 January 2016
Accepted 4 February 2016
Available online 27 February 2016

Keywords:
Radiophotoluminescence (RPL)
Bead-type RPL glass dosimeter
Remote monitoring
Radioactive contamination

ABSTRACT

A radiophotoluminescence (RPL) monitoring scope system was constructed to evaluate radioactive cesium contamination. RPL glass sheets were constructed by bonding RPL glass beads to a backing sheet. The RPL scope was constructed using an image intensifier and a CCD camera to detect RPL from the RPL glass sheet. A UV floodlight was also prepared as an excitation light source. The UV floodlight and an image intensifier were pulse-operated for high signal-to-noise RPL detection. In experiments, the RPL of X-ray irradiated glass sheets was measured with this present system. The RPL intensity, which is calculated from the brightness of obtained images, exhibits acceptable linearity to the absorbed dose. Another experiment showed that RPL can be detected at a distance of 10 m between the RPL glass sheets and the RPL detector.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

The severe earthquake and tsunami that occurred in March 2011 caused a serious accident at the Fukushima Daiichi nuclear power plant. A large amount of radioactive materials including radioactive cesium (^{134}Cs and ^{137}Cs), which remains in the natural environment in the disaster-stricken area due to its long half-life, was emitted from the plant to the atmosphere. According to the Nuclear and Industrial Safety Agency of Japan (NISA), the total atmospheric release of ^{134}Cs and the total atmospheric release of ^{137}Cs was estimated to be 18 PBq and 15 PBq, respectively (NISA, 2015).

Numerous studies of radiative contamination measurement in Fukushima were performed after the accident. The measurement of the distribution of radioactive contamination is essential for efficient decontamination. In a high-contamination area, workers who are engaged in decontamination or radiation measurement must be protected from excessive radiation exposure. Gamma cameras and Compton cameras have been utilized for the detection of radiation hotspots (Kataoka et al., 2013; Woodring et al., 2003). These types of instruments have high sensitivity to gamma rays. In addition to these methods, a simple method for observing radioactivity distribution is necessary for the measurement of a vast scope of locations.

We have proposed a remote monitoring method for radioactive contamination using glass dosimeter materials (Zushi et al., 2014). Few studies have attempted to employ these materials to monitor radioactivity distribution. Silver-activated metaphosphate glass, e.g. FD-7, is a major material for accumulation-type solid-state dosimeters for individual dosimetry. The glass emits orange radiophotoluminescence (RPL); its intensity is proportional to its absorbed dose by the excitation of ultraviolet (UV) light (Yokota and Imagawa, 1966; Piesch and Burgkhardt, 1994). This type of glass is frequently referred to as RPL glass. RPL glass exhibits high

* Corresponding author.
E-mail address: zushi@nf.eie.eng.osaka-u.ac.jp (N. Zushi).

http://dx.doi.org/10.1016/j.radmeas.2016.02.010
1350-4487/© 2016 Elsevier Ltd. All rights reserved.

sensitivity, high accuracy, and superior long-term stability. RPL readout was performed without a loss of dose information. Considering these advantages, this glass is considered to be suitable for the detection of radioactive contamination. For flexible use, sheet-type glass instead of plate-type glass was prepared by bondage of small glass beads to a backing sheet. The RPL glass sheet was placed on the target position once, and two-dimensional RPL imaging was performed after an appropriate time span, depending on the degree of contamination.

In this study, a remote RPL detection system was constructed for radioactivity distribution measurement in a highly contaminated area. Selection of an appropriate distance between the measuring object and the detector can minimize excessive radiation exposure during measurement. RPL glass that was suitable for radioactive contamination monitoring was prepared. A RPL monitoring examination was performed with X-ray irradiated RPL glass sheets to evaluate the characteristics of this system.

2. Materials and methods

RPL glass was constructed from a mixture of reagent-grade $NaPO_3$, $Al(PO_3)_3$ and AgCl at 1200 °C in an electric furnace. The detailed process of fabricating RPL glass was described in our previous paper (Sato et al., 2013). The weight composition of the glass was 31% P, 51% O, 6% Al, 11% Na, and 0.2% Ag. The glass lot was pulverized into particles with diameters that ranged from approximately 0.1–1.0 mm. The particles were reheated to melt and then form spherical shape with their surface tension. The beads were uniformly bonded to flexible aluminum foil. The shape of the RPL glass sheets was rectangular with a side length of 40 mm.

In personal dosimetry, a UV laser and a photomultiplier were employed for excitation and RPL detection. The two-dimensional detection of feeble RPL due to a decrease in geometrical efficiency was required. Thus, this RPL detection system was composed of a CCD camera and an image intensifier (II).

Fig. 1 displays a schematic of the detection system. The system consists of a camera lens (CL), two relay lenses (RLs), an II and a CCD camera. Feeble RPL was guided to the II through the CL, and the RL and was subsequently intensified with the II. The intensified RPL image was photographed with the CCD camera through another RL. Each image frame was added for highly sensitive RPL imaging. A personal computer (PC) was prepared for the storage and indication of these images. The II requires three types of voltage supplies: photocathode voltage (V_k), micro-channel plate voltage (V_{MCP}), and phosphor screen voltage (V_S). In this instrument, V_k was pulsed between +50 V (OFF state) to −200 V (ON state) for gate operation of the RPL scope. V_{MCP} was adjusted by a potentiometer to ensure that V_{MCP} enables the adjustment of II gain. V_S, which is employed for conversion from MCP output electrons to photons for indication of the phosphor screen, was fixed to 5.0 kV.

Luminescence from RPL glass was divided into two components: RPL and PL. PL has a relatively short decay time of less than 0.3 μs, whereas RPL has long decay time of 2 μs. To achieve high signal-to-noise ratio measurements, RPL and PL components should be differentiated to ensure that PL intensity has no proportionality to the absorbed dose. Both time-based discrimination and wavelength-based discrimination are required for high signal-to-noise ratios in RPL selection due to the overlap of the decay time and the wavelength of these two components. An optical long-pass filter was prepared for wavelength-based discrimination of the RPL component.

As the excitation light of the RPL glass, an LED floodlight that was composed of 1000 UV LEDs was employed. LEDs were pulse-operated and synchronized with the II, as shown in Fig. 2. The ON time and frequency of the LEDs were set to 50 μs and 1 kHz, respectively. Two II operation time patterns were prepared for the system. Pattern A in Fig. 2 was utilized for RPL detection, and Pattern B was utilized for the detection of background light because RPL was almost decayed in this pattern. The RPL intensity was calculated using a comparison of images, which were obtained with these two II patterns, for the reduction of the background light component.

A 90 kV X-ray source of which target material is tungsten was used for sample irradiation. X-rays were selected for evaluation of the response of RPL glass sheets under simple condition. X-rays used have lower energy than major cesium gamma-rays, but

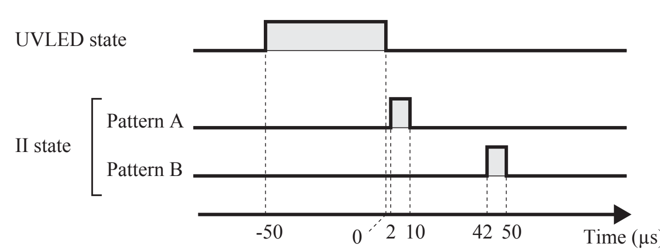

Fig. 2. Timing chart of UV LED floodlight and image intensifier.

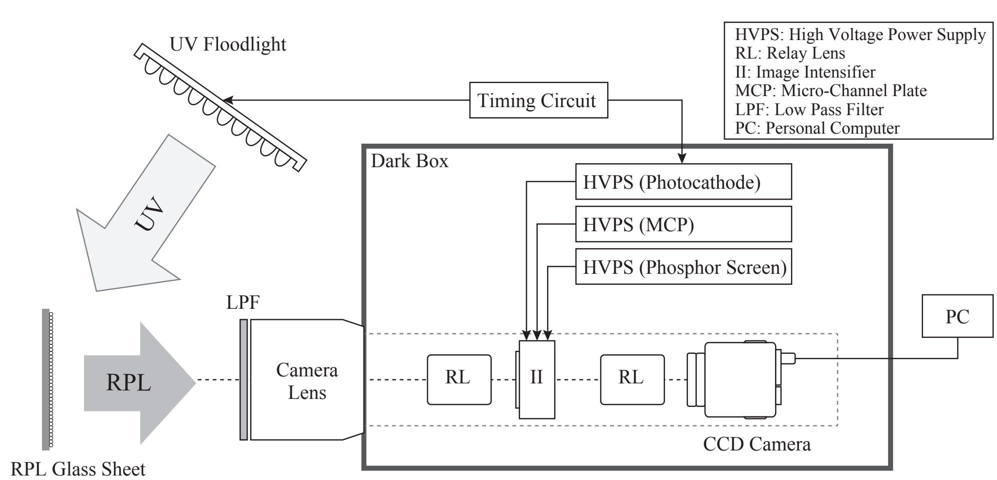

Fig. 1. Schematic of remote RPL monitoring system.

Download English Version:

https://daneshyari.com/en/article/1881190

Download Persian Version:

https://daneshyari.com/article/1881190

Daneshyari.com