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Comparisons of dosimetric properties between GD-300 series of radiophotoluminescent glass detectors and GR-200 series of thermoluminescent detectors

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Abstract In order to compare the dosimetric properties of two kinds of solid state detectors used for monitoring external exposures, experiments were performed for the GD-300 series of radiophotoluminescent glass detectors (RPLGD) and the GR-200 series of thermoluminescent detectors (TLD). X-rays and ^{137}Cs and ^{60}Co γ-rays were used to irradiate the RPLGDs and TLDs, their dose linearity, uniformity/reproducibility of signal, fading effect and energy dependence were compared. Both kinds of the detectors have generally good dosimetric properties. The dose linearity and energy dependence of the GD-351 dosimeters and the TLDs are nearly the same, but the RPLGD is much better than the TLD in terms of the uniformity and fading effect.

Key words Radiophotoluminescence, Thermoluminescence, Dose linearity, Fading effect, Energy response

CLC numbers TL818^{+}.7, R144.1

1 Introduction

Development of radiophotoluminescent glass dosimeters (RPLGDs) for radiation measurement can be traced back to 1950s[1], but they were not widely used in the early years, due to its high predose and the lack of matured measuring technology[2]. With great efforts made in the past years to improve the RPLGD materials and read-out devices[3], a fully automatic RPLGD system has become commercially available. A RPLGD can be readout with modes, i.e., standard-dose range (10 μGy–10 Gy) and high-dose range (1 Gy–500 Gy). Generally, the standard-dose mode is used in dosimetry of diagnostic X-rays or environmental exposures, whereas the high-dose mode is used for dosimetry in radiotherapy. With negligible fading effect and 100% repeatability of measurements, RPLGD has been widely used in various applications of X- and γ-ray measurements[4-7].

In mainland of China, the first RPLGD system was installed at the Institute of Radiation Medicine (IRM), Fudan University in November 2005. In order to compare its dosimetric properties to TLD (thermoluminescent dosimeter) systems, which are commonly used in China, dose linearity, uniformity/ reproducibility of the readout, fading effect and energy dependence of the two kinds of dosimeters were studied. The results showed that most of the dosimetry properties of the RPLGD were better than TLD. It indicates that the RPLGD system offers an alternative to TLD systems for monitoring personal external exposure, patient dose from medical exposure, and environmental radiation levels, etc.

2 Materials and methods

2.1 The RPLGD system

The RPLGD system mainly consists of metaphosphate glass detectors and a readout system. The rod-shaped and silver-activated RPLGD has an effective atomic number of 12.039 and density of 2.61g/cm^3 [7]. In this work, Model GD-301 and

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GD-351 glass rod dosimeters (Asahi Techno Glass Corporation, Shizuoka, Japan) were used. A GD-301 dosimeter, in Φ1.5 mm×8.5 mm, is usually used with a plastic holder. A GD-351 is a GD-301 rod capsulated in a tin holder of 1.5 mm thickness for energy compensation. The automatic readout system (Dose-Ace®, Asahi Techno Glass Corporation, Shizuoka, Japan) reads the RPLGDs using nitrogen gas UV laser excitation. The irradiated RPLGDs were preheated at 90℃ for 40 min for built-up before readout[8].

2.2 The TLD system

The TLD system mainly consists of crystalline chips of ^{7}LiF(Mg, Cu, P) detectors and a readout system. The effective atomic number of the TLD is 8.2[9]. In this work, GR-200A detectors (Research Institute of Chemical Defense, Beijing, China) were used. The size of GR-200A is Φ4.5 mm×0.8 mm. The readout system is RGD-3® (Research Institute of Chemical Defense, Beijing, China). The TLD readout was programmed at 135℃ preheating for 10 s and reading at 240℃ for 15 s.

2.3 Irradiation device and sources

The X-ray generator and ^{60}Co γ-ray source at Shanghai Institute of Measurements Technology (SIMT), a secondary standards dosimetry laboratory approved by IAEA and WHO, and the ^{137}Cs source (calibrated by SIMT) at IRM were used to irradiate the RPLGDs and TLDs. Dose linearity, uniformity/ reproducibility of the readout, fading effect and energy dependence of the dosimeters were experimentally studied.

3 Results and discussion

3.1 Dose linearity

Three groups of GD-351 and GR-200A dosimeters (5 per group) were irradiated to 0.2 mGy, 2 mGy and 20 mGy by X-rays. Four groups of GD-351 and GR-200A dosimeters (5 per group) were irradiated to 80 mGy, 200 mGy, 500 mGy and 1000 mGy by ^{137}Cs γ-ray. Fig.1 shows dose response of the RPLGDs and TLDs. The doses were averaged from five dosimeters, with a standard deviation of 1σ. It shows that both the RPLGD and TLD have a good linear relationship to the nominated dose ranging from 0.2 mGy to 1000 mGy. Their coefficients of variation are within ±0.9% and ±3.2% for the GD-351 and GR-200A dosimeters, respectively.

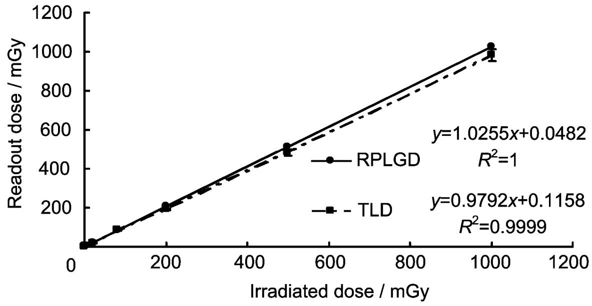

Fig.1 Dose linearity of the RPLGD and TLD.

3.2 Uniformity/Reproducibility

Three groups of GD-351 and GR-200A dosimeters (20 per group) were irradiated to 0.2 mGy and 20 mGy by X-rays and to 200 mGy by ^{137}Cs γ-ray. Uniformity of the signals from the RPLGDs and TLDs of 0.2 mGy X-ray irradiation is given in Fig.2, which shows the relative response of each dosimeter by normalizing its reading to the averaged signals of the 20 dosimeters. Uniformities of the signals from the 20 RPLGDs were ±1.7%, ±1.3% and ±1.1% for 0.2 mGy, 20 mGy and 200 mGy irradiations, respectively, whereas uniformities of the signals from the 20 TLDs were ±4.6%, ±3.9% and ±3.8% for 0.2 mGy, 20 mGy and 200 mGy irradiations, respectively. Obviously, the RPLGD is much better than the TLD in uniformity of the signals.

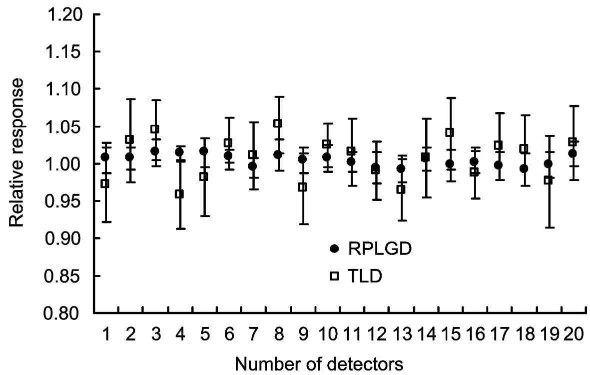

Fig.2 Uniformity of the RPLGD and TLD irradiated by 0.2 mGy of X-ray.

Readout of the irradiated RPLGDs was repeated 10 times in a day. The coefficients of variation calculated with Eq.(1) are listed in Table 1, with an average of 0.83, 0.62 and 0.59 for 0.2 mGy, 20 mGy and

200mGy exposures, respectively. Its excellent reproducibility was confirmed.

$$\mathrm{CV}=\sqrt{\frac{\Sigma(X_i-\overline{X})^2}{n-1}}\cdot\left(\frac{\sum_{i=1}^{n}X_i}{n}\right)^{-1} \quad (1)$$

Table 1 Coefficient of variation of GD-351 RPLGDs *

Dose /mGy	Range	Average ±1σ
0.2	0.43–1.17	0.83±0.19
20	0.32–1.01	0.62±0.18
200	0.43–0.93	0.59±0.15

* 20 dosimeters per dose group, the readout was repeated 10 times in a day.

3.3 Fading effect

Having been irradiated to 200 mGy by ^{137}Cs γ-ray and pretreated, 21 RPLGDs of GD-351 and 21 TLDs of GR-200A were stored in a lead container under normal room conditions. Three dosimeters of each group were read 6 h, 1 d, 2 d, 5 d, 10 d, 20 d and 30 d after irradiation. The signal fading of the RPLGDs and TLDs is shown in Fig.3. The relative response of each subgroup was normalized to the irradiated dose. From Fig.3, fading effect of the RPLGDs in 30 days is less than a negligible 0.8%, while the fading effect for the TLDs is about 2.1%.

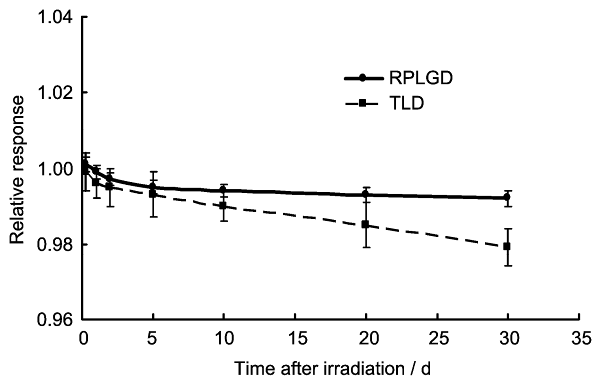

Fig.3 Fading effect of the RPLGD and TLD in 30 days after irradiation.

3.4 Energy dependence

Ten each of GD-301, GD-351 and GR-200A dosimeters were simultaneously irradiated in air by X-rays of 30 keV, 65 keV, 90 keV and 121 keV, or γ-rays of 662 keV (^{137}Cs) and 1250 keV (^{60}Co). By normalizing the X-ray and 1250 keV data to the 662 keV data, we obtained the dosimeters' relative energy response (Fig.4). It was found that from 30 keV to 1250 keV, energy dependences of the GD-351 and the GR-200A are nearly the same, varying from -8% to +15% for the GD-351, and from -11% to +12% for the GR-200A. The GD-301 (without energy compensation filter), however, has a poor energy dependence. Therefore, the characteristic of energy dependence of RPLGD without energy compensation filter should be carefully considered for its application in diagnostic radiology.

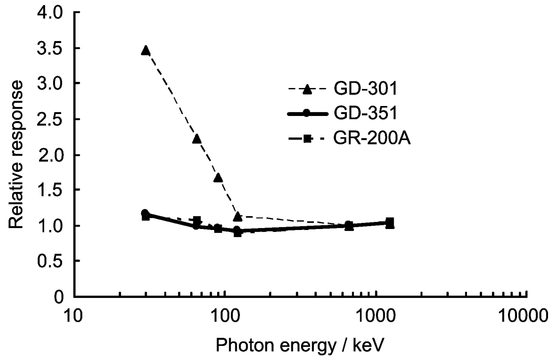

Fig.4 Energy dependence of the RPLGD and TLD for the X(γ) radiation from 30 to 1250 keV.

4 Conclusions

Dosimetric properties of either the TLD or the RPLGD meet the requirements of the Chinese Standards for thermoluminescence dosimetry for personal and environmental monitoring[10]. In comparison to TLD, the RPLGD system is advantageous in its good uniformity, long-term stability (little fading effect) and capability of repeating readouts. However, energy response of RPLGD of different models should be carefully considered for their applications. The RPLGD system provides another choice for monitoring external dose of radiation workers and for measuring the patient dose from medical exposures. And it is quite viable for long-term environmental monitoring.

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