MEASUREMENT OF LOW PHOTON EXPOSURES USING A FULL AUTOMATIC PHOSPHATE GLASS DOSIMETRY SYSTEM WITH UV LASER EXCITATION

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ABSTRACT

The full automatic PLD system, to be PTB type tested in 1992, turned out to be superior to TLD systems mainly due to the intrinsic pre-dose suppression which provides dose measurements of 0.1 mSv with a variation coefficient of better than 5%. The results of consecutively irradiated and measured glasses demonstrate linearity and low random uncertainty of dose measurement in the low dose range.

INTRODUCTION

Retrospectively, the high pre-dose and the energy dependence of phosphate glass dosemeters prevented a large scale application of glass dosimetry so far. The most important progress of the last years have been found in the pulsed UV laser excitation of glasses which reduced the pre-dose dramatically (1). In the mean time, the modern, commercially available, full automatic Toshiba read-out systems FGD-10 and FGD-20 are expected to be reliable dosimetry systems for a large scale application in personnel and environmental monitoring (2,3).

With respect to the capability of measuring low doses within routine monitoring, it was of special interest to investigate linearity and random uncertainty of dose measurement in the low dose range.

DOSIMETRY SYSTEM

The flat glass dosemeter consists of a plastic encapsulation ($4 \times 3 \times 0.8$ cm^3) with energy compensation filters on both sides and a glass element ($16 \times 16 \times 1.5$ mm^3) fixed in a stainless steel card. The dosemeter is locked magnetically. In the PLD system Toshiba FGD-10 the automatic read-out includes: (a) opening and closing of the dosemeter, (b) reading of ID-No for capsules and cards, respectively, (c) exchange of high dosed by annealed glass cards during read-out, (d) the continuous reading of up to 500 dosemeters, (e) the calibration of the reader and (f) the print-out of the results.

Pulsed UV laser excitation reduces the pre-dose down to 30 µSv. The energy response of the flat glass dosemeter in Table 1 are recent results of an IAEA intercomparison experiment using frontal irradiations on a slab phantom and the read-out in terms of H'(10). After the PTB type test in 1992. the commercially available PLD system will be introduced in Germany as a governmental dosemeter within routine personnel monitoring.

The PLD system, now comparable with the best TLD systems regarding the lowest detectable dose, the dose range (0.03 mSv to 3 Sv) and the energy and angular response (10 keV to 3 MeV), is, however, superior with respect to the capability of repeated read-outs, the simultaneous indication of different dose quantities (exposure X or H'(10)) using the same irradiated dosemeter, and with respect to the interpretation of the read-out in terms of radiation quality and radiation incidence.

PRE-DOSE SUPPRESSION AND RANDOM UNCERTAINTY IN THE LOW DOSE RANGE

Fig. 1 illustrates the read-out after UV pulse excitation of an unirradiated and irradiated glass. During the read-out, the time dependent PL intensity I(t) is integrated in two different periods, namely the short-term component (total reading) in the period between 2 - 7 µsec, and the irradiation independent, long-term component of the residual reading in the period between 40-45 µsec. A multiple f_{ps} of the measured residual reading is subtracted from the total reading resulting in the radiation induced reading M. The "pre-dose suppression factor" f_{ps} is measured only once after the initial annealing.

The internal pre-dose suppression during each read-out reduces the pre-dose value of the conventional UV excitation of 1 mSv by two order of magnitudes to about 0.03 mSv and also renders glass cleaning unnecessary.

Fig. 2 compares the frequency distribution of the variation coefficient, (a) for the pre-dose of dosemeter batches (mean value 25-35 µSv) after 15 times of re-use immediately after oven annealing at 400°C, and (b) for a 10 times daily reading at 6 mSv. The mean value of the variation coefficient was found to be 6.7 % (2µSv) for the pre-dose of 30µSv of annealed glasses and 0.46% (28µSv) for a dose of 6 mSv of an irradiated calibration glass. On the basis of these data, the variation coefficient for the dose reading was calculated and presented in Fig. 3 as a function of the uncorrected dose reading $H_u = H + H_0$ as well as after subtraction of the individual pre-dose H_0 of about 0.03 mSv or of an accumulated "pre-dose" of 3 mSv as a function of the dose accumulated in the actual monitoring period. Using an annealed glass dosemeter, the variation coefficient for a dose measurement at 0.1 mSv was found to be 3%, at 3 mSv only 0.5%.

CONSECUTIVE MEASUREMENTS IN INDIVIDUAL MONITORING

The glass dosemeter reading is the total dose accumulated since the last annealing. During routine monitoring, personal dosemeters accumulate the natural radiation background and additional contributions of occupational exposures.

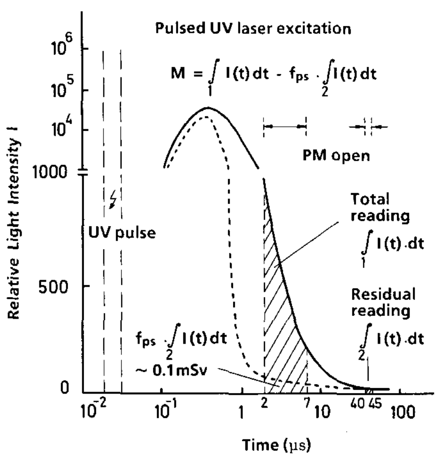

Fig. 1 Subtraction of the residual dose reading of PL dosemeters using pulsed UV laser excitation

Tab. 1 Glass dosemeter results, 1990 IAEA Intercomparison for Individual Monitoring

E (keV)	H / H'(10,0°)
20	0.94
37	0.98
57	1.01
104	0.97
205	0.93
374	0.96
662	1.04
1250	0.99
mean ± max/min	0.985 ± 5.5%

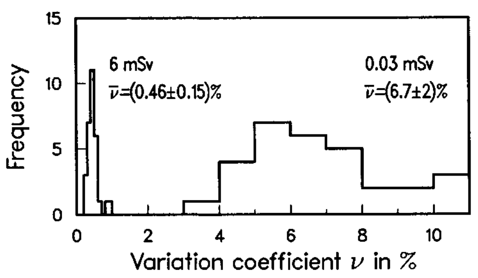

Fig. 2 Frequency distribution of the variation coefficient for the pre-dose (mean value 0.03 mSv) of annealed glass dosemeter batches and the repeated readings of the calibration glass.

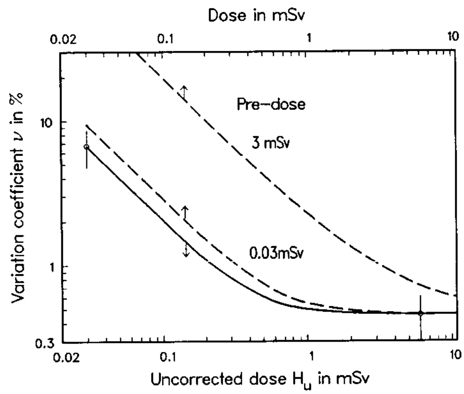

Fig. 3 Variation coefficient of the dose measurement using the same glass dosemeter vs. the uncorrected dose H_u and the measured dose $H = H_u - H_0$ at pre-doses of 0.03 and 3 mSv.

The actual dose contribution of the last monitoring period is given by the difference of two consecutive measurements at the beginning and the end of the monitoring period of usually 1 month.

Batches of glass dosemeters have been irradiated and measured consecutively over periods of more than three months using low exposures in steps of 0.05 mSv and 0.1 mSv, respectively. Fig. 4 shows for the consecutive measurements the ratio of the actual dose and the reference dose. For all exposures the mean values have been found to be within ± 1.3%. This scatter can be interpreted as the long-term

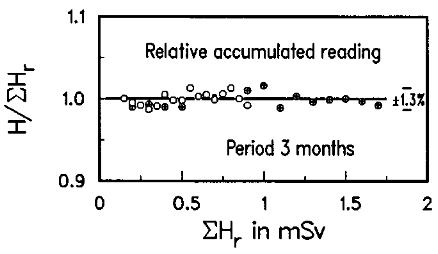

Fig. 4 Ratio of the actual dose reading and the reference dose for repeated irradiations of a batch vs. dose. Mean value of 8 dosemeters.

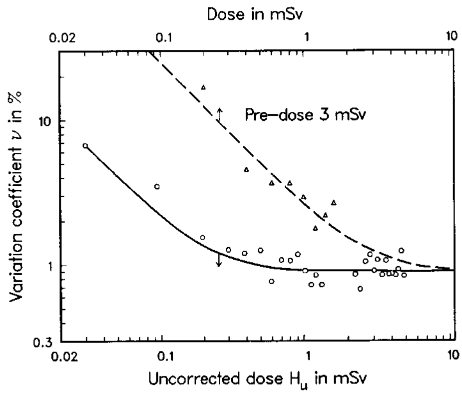

Fig. 5 Variation coefficient of the dose measurement using a batch of 10 dosemeters within vs. dose.

instability of the dosemeter system, including errors of the consecutive irradiations of the batches and the repeated reader calibrations using the calibration glass. In the upper dose range, the variation coefficients for dosemeter batches (Fig.5) are slightly higher by about 0.4% to those for one glass only (Fig.3), because of the small scatter in the photon response of individual glass detectors within the batch. In the case that the total accumulated "pre-dose" is 3 mSv, a contribution of 0.1 mSv of the last monitoring period can be measured with a variation coefficient of 25%.

MEASUREMENT OF THE NATURAL RADIATION BACKGROUND

In a similar experiment, a dosemeter batch was exposed to the natural radiation background and measured consecutively over a period of 3 months starting with a pre-exposure of 0.1 mSv. For all read-outs, the variation coefficient for the mean value of 8 detectors was smaller than 2% (4% for two detectors). Within environmental monitoring, the dosemeter pair usually used may indicate the natural radiation background already after 10 days with a random uncertainty of about 25%. Because annealed glasses are used for environmantal monitoring, only the intrinsic pre-dose of 0.03 mSv will be subtracted. The corresponding variation coefficient for a single detector reading is shown in Fig. 3 as a function of the accumulated dose.

CONCLUSION

PLD systems, unlike other systems, do have the capability of combining, on the one hand, repeated read-outs at any time during the monitoring period by the user and, on the other hand, control measurements after long-term monitoring periods by independent services of the authorities with a relatively high precision of 1% as already demonstrated for the UV excitation with Hg lamps (4).

The full automatic PLD system, now improved and commercially available offers an unexpected new approach in routine monitoring and the breakthrough of a technique, so far neglected but now a potential alternative in personnel and environmental monitoring.

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