The features of Glass Badge for Personal Dosemeter

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Abstract.

The radiophoto-luminescence (RPL) glass dosemeter is the integrated-type passive dosemeter that has essentially excellent characteristics such as stability of sensitivity and repeatability of measurement for radiation dosimetry. The Glass Badge was developed as the latest personal dosemeter which applied this RPL glass dosemeter. To measure the photon dose in the energy range of 10keV to 10MeV and the beta-ray dose in the energy range of 300keV to 3MeV, newly developed RPL glass dosemeter GD-450 has two of deferent thickness plastic filters and three metal filters of Al, Cu and Sn. It was also designed in a compact size of 45mm x 13mm x 5mm and 5g weight. To achieve the personal monitoring service with high reliability, two kind of two-dimensional ID codes which enable to handle lots of measured data accurately were also introduced to GD-450. When the neutron dose measurement is required, the Glass Badge furthermore enables to measure the neutron dose in the wide energy range of thermal to 15MeV by adding the ADC (allyl di-glycol carbonate) plastic solid state nuclear track (SSNT) dosemeter with the converter of BN and polyethylene (called as wide range NeuPit : WNP). The Glass Badge enclosing both of GD-450 and WNP, therefore, enables to measure photon, beta and neutrons comprehensively. The personal dose equivalent of Hp(10) and Hp(0.07) for photon, and Hp(0.07) for beta rays are calculated from RPL in each filter parts of GD-450, and Hp(10) for neutrons is calculated from the etched pit density on the plastic detector of WNP which has two kind of converter materials.

1. Introduction

History of the radiophoto-luminescence (RPL) glass dosemeter which is made of silver-activated phosphate glass is long, that had been appeared as an accidental dosemeter for the first time in 1953(1). Because of high level pre-dose, the phosphate glass of those days was not suitable for usual low dose level monitoring. But improvement for component of the glass material by Yokota(2) in ’60s, it was put to practical use as a personal dosemeter. Though this dosemeter had dominant point on dosimetry, it could not spread because of handling difficulties in measurement. As the result it was only used for continuously in the part of country. Newly developed dosimetry system(3,4) in ’80s which used pulsed ultraviolet ray by nitrogen gas laser and further improved glass material attracted attention again(5,6), as it enabled eliciting inherent features of the glass. The other hand, to extend detectable energy range of the neutron in the personal dosimetry, we had developed Wide energy-range NeuPit (WNP) dosemeter in ’90s which applied solid state nuclear track detector (SSTD) techniques by CR-39 plastic(7).

In 2001, Glass Badge - using newly developed RPL glass dosemeter GD-450 and SSNT dosemeter WNP - has been developed as the latest personal dosemeter and was introduced as the major dosemeter of personal monitoring service in Japan(8). In this presentation, the basic dose estimation algorithm and some characteristics are reported.
2. Basic concept

The integrated-type passive dosemeter such as Glass Badge is irradiated to various type of radiations frequently in practice as that is used for a certain period. Therefore, dose estimation formula that need not the energy information of the incident radiations was designed basically.

(1) Photon estimation formula

The developed RPL glass dosemeter GD-450 has five filters showed in figure 1 and figure 2 to measure photon and beta dose. To estimate photon dose equivalent of \( H_{p}(10) \) and \( H_{p}(0.07) \), formula (1) was basically designed.

\[
\sum_{j} \left( NAD_{j} \cdot C_{ij} \right)
\]

where \( H_{p}(d) \) is personal dose equivalent for 1cm depth and or 70 micrometer depth, \( NAD_{j} \) is net appearance photon dose for each filter position \( j \) and \( C_{ij} \) is the constant.

In case of photon dose estimation, to establish such style formula becomes possible, as the basically each filter position indicates deferent peak response against incident photon energy. This formula need not the information about incident photon energies, therefore, it enables to estimate various energy photon incidence at once. To determine constant value of \( C_{ij} \), energy dependency of each filter positions are examined by irradiation experiment with lot kind of energy of X-rays and or gamma rays.

(2) Beta estimation formula

In case of beta dose estimation, each filter position dose not indicate peak of response unfortunately. All filter position indicate monotone increasing responses according to the increase of incident beta energy. It is, therefore, required to estimate the energy of the incident beta rays to estimate beta dose. As the result, formula (2) was designed for beta dose equivalent estimation.

\[
H_{p}(0.07) = NAB_{j} \cdot f_{j}(E) \cdot e^{-\mu_{0.07}}
\]

where \( H_{p}(0.07) \) is personal dose equivalent for 70 micrometer depth, \( NAB_{j} \) is net appearance beta dose for filter position \( j \), \( f_{j}(E) \) is sensitivity correction function of filter position \( j \) and \( \mu \) is the mass absorption coefficient of tissue.

To establish the sensitivity correction function \( f_{j}(E) \), energy dependency of each filter positions are examined by irradiation experiment with some kind of energy of beta rays.
(3) Neutron estimation formula

The SSNT dosemeter WNP was introduced in Glass Badge to meet neutron dosimetry. The detector chip of WNP has two kinds of charged particle converter boron nitride (BN) and polyethylene sheets as showed in figure 3. CR-39 plastic that is polymerized by our laboratory is used as the detector chip of WNP.

![FIG. 3. Schematic structure of WNP](image)

WNP is basically two element type dosemeter. Therefore, response of CR-39 at BN position contributes mainly thermal neutron and low energy part of neutron, and response at polyethylene position contributes higher energy part of neutron. As the result, to estimate neutron dose equivalent of Hp(10), formula (3) was basically designed.

\[ Hp_n(10) = P_{\phi_p} \cdot C_p + P_{\phi_b} \cdot C_b \]  

(3)

where \( Hp_n(10) \) is personal dose equivalent for 1cm depth, \( P_{\phi_p} \) and \( P_{\phi_b} \) are etched pits density at each converter position of polyethylene and or BN sheets, \( C_p \) and \( C_b \) are constant as the conversion factor of each position.

Lots of conditions for converter thickness and density of boron, polymerization of CR-39, etching procedure and or counting method of etched pits contribute to the final response of WNP. Many kind of experiment and Monte Carlo simulation, therefore, were required to determine constant value of \( C_p \) and \( C_b \). (7)

3. Experimental

(1) RPL glass dosemeter GD-450

Glass Badge which is mounted on PMMA slab phantom was irradiated lots kind energy of X rays, gamma rays and beta rays. From 12keV to 201keV energy of X rays and gamma rays emitted from \(^{137}\)Cs, \(^{60}\)Co and \(^{16}\)N gamma source were irradiated to Glass Badges to determine the constant values of formula (1). Some kinds of beta rays which have 0.54MeV, 1.3MeV, 1.6MeV and 2.0MeV residual maximum energy each were irradiated to establish the sensitivity correction function of formula (2).

(2) SSNT dosemeter WNP

WNP included to Glass Badge which is mounted on water phantom was irradiated lots kind energy of neutrons. From 8keV to 14MeV mono energetic neutrons by accelerator, thermal neutron by graphite pile and neutron emitted from 252Cf and 241Am-Be were irradiated to WNP to analyze the response.

4. Result and discussion
Figure 4 shows response of each filter position for photon. To analyze these data by approximate calculation, the excellent energy characteristic of Glass Badge (GD-450) showed in figure 5 was obtained as the result.

![Graph showing energy characteristic of Glass Badge](image)

**FIG. 4.** Response of each filter position of GD-450  
**FIG. 5.** Energy characteristic of Glass Badge

Energy characteristic of Glass Badge for beta rays showed in figure 6 was obtained from experimental data analysis. The experimental data for WNP was applied to Monte Carlo simulation, the excellent energy characteristic of WNP showed in figure 7 that is enable to measure from thermal neutron to fast neutron continuously was obtained as the result.

![Graph showing energy characteristic of WNP](image)

**FIG. 6.** Energy characteristic of Glass Badge  
For beta rays

**FIG. 7.** Energy characteristic of WNP

5. Conclusions

The application of these developed dose estimation algorithm in practice, Glass Badge that includes GD-450 and WNP enables to establish excellent personal monitoring system as the latest dosimeter.

References.
2. Yokota, R., Nakajima, S. and Sakai, E. High Sensitivity Silver-activated Phosphate Glass for the
Simultaneous Measurement of Thermal Neutrons, $\gamma$-and or $\beta$-rays. Health Phys. 5. 219(1961)


