PHOSPHATE GLASS DOSIMETRY: A POTENTIAL ALTERNATIVE IN PERSONNEL MONITORING

Ernst K.A. Piesch and Dieter F. Regulla

Health Physics Division, Karlsruhe Nuclear Research Center and Gesellschaft für Strahlen- und Umweltforschung mbH München, Institut für Strahlenschutz, Neuherberg, F.R.G.

INTRODUCTION

Radiophotoluminescent phosphate glass was the first solid state dosimeter in personnel monitoring produced in millions of species already in the middle of the fifties. Later on, however, it decreased in importance as compared to TLD due to unbalanced efforts of researchers and manufacturers on these subjects, particulary in USA. This trend may be explained by somehow emotional reasons as well as by the dosimetric imperfections of the early glass generation with respect to background luminescence (predose), non-reproducibility and energy dependence of reading. The new generation of low-Z glass dosimeters that meanwhile has been developed in Japan remained rather disregarded in spite of remarkable improvements of the dosimetric properties such as sensitivity, batch uniformity and precision.

Mainly in Germany this type of glass dosimeter found application in personnel monitoring and, to a limited extend, replaces or backs up the so far official film dosimeter. From review, the predose and the energy-dependent detector material may be considered the main reasons that prevented a major break-through of glass dosimetry. The missing development of appropriate automatic readers is only a consequence of this situation.

Contrary to glass dosimetry there are at least 12 automatic TLD reader versions commercially available. But inspite of promising earlier prognosis also this dosimetry method does not easily penetrate into personnel monitoring since a number of institutions concerned rejected or postponed to replace the film by TLD. To a certain extend, this may be explained by the high financial investment for a system at a state of technology, which is characterized by considerable malfunctioning and not yet elaborated standard of dosimetric reliability.

Under these aspects and on the basis of long-term experiences with both TLD and glass dosimetry we feel encouraged to draw the attention again to glass dosimetry as a so far neglected but potential alternative in personnel monitoring. This holds the more since essential physical and technological advance has recently been achieved.

RECENT TECHNOLOGICAL ADVANCES

For better understanding of the essential advances of glass dosimetry the following properties are compared with LiF TLD-systems. <u>New glass composition</u>: A new glass type FD-7 [1] or DOS8 [2] offers <u>a lower energy dependence</u> with an oversensitivity of a factor 3.6 related to ^{60}Co which hitherto was a factor 7 for the still used FD1

(Toshiba) or DOS2 (Schott) glass. Both glass types show a high batch uniformity of <±0.5% compared to the TLD response which may vary up to ±30% calling for individual calibration. Individual predose values of 20 mR to 250 mR depending on the reader type can be determined reproducibly. The zero dose reading of TLD detectors, on the other hand, may scatter by one order of magnitude due to batch quality and radiation/annealing history of the single detector.

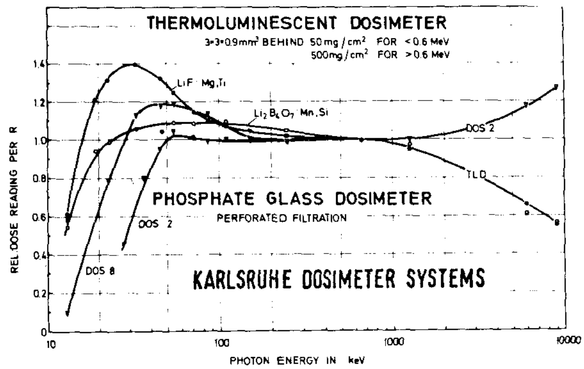
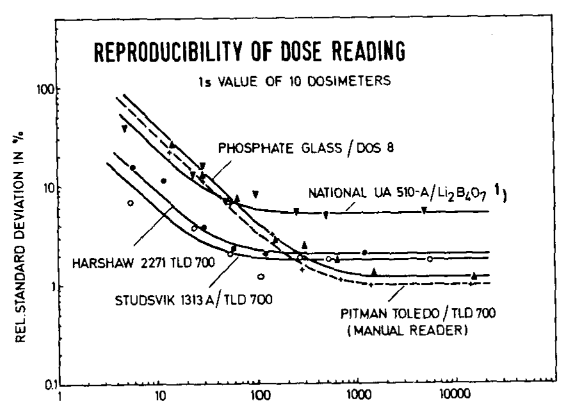


Fig.1 Energy dependence of the automatic DOS 8 [4] and the spherical DOS 2 [3] glass dosimeter system compared to TLD systems

In RPL dosimetry perforated filter are used to improve energy dependence. This is shown in Fig. 1 for the routinely used DOS 2 in the spherical capsule [3,11] and for a new automatic RPL system on DOS 8 basis [4] resulting in energy independence within ±20% above 25 keV. The RPL characteristic is similar to LiF for low energies and differs mainly for high energy photons above some MeV. Sophisticated combinations of glass and filter may be chosen such that the reading is proportional to specific depth doses [5] or fits new quantities such as dose equivalent or dose equivalent index [6].



1) according to prototype reader, 1978

Fig.2 Reproducibility of the automatic glass dosimeter systems [4] and TLD systems of an interlaboratory test [12]

Automatic readout: At Karlsruhe a glass dosimeter system with automatic readout device has been developed which uses a glass plate of 14x15x1.5 mm^3 and a perforated energy compensation filter resulting in an energy independence within ±20% above 25 keV (Fig.1) [4]. In addition, dose fractions in the energy ranges $E < 30$ keV, $30 \text{ keV} < E < 100$ keV and $E > 100$ keV can be assessed by applying movable screens during readout. The reproducibility of the automatic glass dosimeter system (Fig.2) is characterized by a relative standard deviation of s = 1% above 1 R and due to predose influences s = 15% at 40 mR. According to these figures the automatic glass system is comparable to automatic TLD systems [12]. Present readout frequency is around 250 h^{-1} which figure can still be increased.

Multi-directional scanning: An experimental setup for automatic scanning along the three axis of a glass cube of 8x8x8 mm^3 has been realized for a microprocesser assisted estimation of radiation quality and direction of radiation incidence [7]. In addition to dose assessment this technique offers the advantage to identify unidirectional exposures above 1 R and to discriminate between penetrating and nonpenetrating radiation by means of the directly measured depth dose profile in glass.

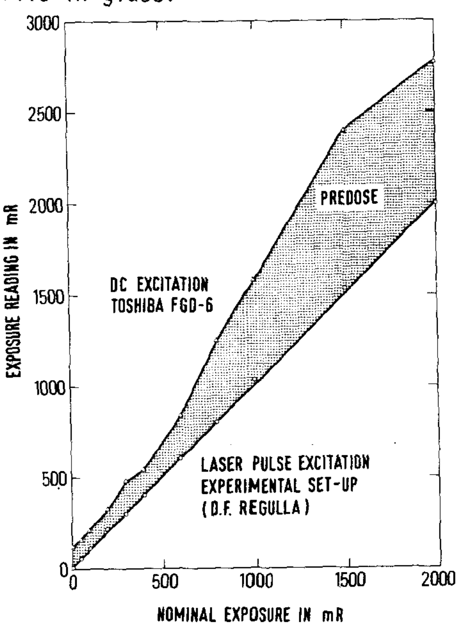


Fig.3 Conventional and laser pulse readout of heavity surface contaminated glass detectors vs. exposure

Laser pulse excitation: The conventional readout technique of glass dosimeters provides a refined cleaning of the glass with detergents before readout which procedure probably does not fit to automation. Recently, the fluorescence phenomenon of predose was found to follow an intrinsic mechanism different from radiation induced fluorescence (RPL) [8] and was correlated to surface contamination. It decays rapidly after UV pulse excitation with time constant of $\tau < 100$ ns, i.e. 10 times faster than RPL. This effect was successfully elaborated for a general predose suppression using laser pulse excitation (FWHV 10 ns). Fig. 3 compares results of conventional DC with laser pulse excitation for a heavily surface contamined glass detector without any cleaning procedure applied. The new readout technique is good for exposure assessment as low as 10 mR or even down to 0.1 mR when using the time constant τ itself as a measure for dose [9]. Present improvements at Neuherberg concern the application of a compact nitrogen laser, electronic noise suppression and computer assissted signal processing and data interpretation [10].

CONCLUSION

Large-scale application in personnel monitoring apparently by-passed phosphate glass dosimetry in the past. The reason for this evolution seems rather random, retrospectively. Definitly, glass dosimetry combines the capabilities for repeated evaluation, long-term documentation and analysis of radiation field parameters appreciated from film dosimetry, with the advantages of solid state dosimetry, i.e. the accuracy of dose measurement, the long-term stability of the stored RPL signal and the ability to perform intermediate evaluations during long-term exposure. Unlike other solid state dosimetry methods, glass dosimetry lends itself to automation because of the simple and straightforward reader calibration and read-out procedure. Reading time can be a fraction of a second. Based on known fluorescence centers that are not distroyed by readout and an extremely good batch and inter-batch uniformity, detector readout is by far independent of the reader. This enables, with the same dosimeter, repeated or even frequent readout during the monitoring period, e.g. for exit controls in power reactors, and subsequent control reading at a central dosimetry service if necessary.

These capabilities may truely simplify and improve the organization of operational radiation protection. Another aspect is the permanent availability of information on a person's accumulated dose without any further data processing. Last not least, the energy dependence may be adjusted by change of glass composition and filters such that it fits the energy function of the quantity of interest, e.g. exposure or absorbed dose, organ dose or deep dose equivalent index.

REFERENCES

[1] Jokota, R., Muto, Y, Navi,J. and Yamaji: Health Physics 20, 1971, 662

[2] Manufacturer Schott u.Gen., Mainz, F.R.G.

[3] Piesch, E.: Developments in RPL Dosimetry, in Topics in Rad. Dosimetry, Academic Press, New York, 1972, p.462-527

[4] Röber,H.-G., Burgkhardt,B.,Piesch,E.: 6th Int.Conf.Solid State Dosimetry 1980, to be published

[5] Piesch, E.: Health Physics 15, 1968, 145

[6] Sapiecha, H.: private communication

[7] König, W.: KfK report to be published

[8] Regulla, D.F.: GSF report NoS 466, 1977

[9] Barthe,J., Bonvard,G., Commanay,L.: Health Physics 29,1975,213

[10] Regulla,D.F., Schneckenburger, H., Unsöld,E.: to be published

[11] Koelzer,W., Kiefer,H.: 5th Int.Conf.IRPA, 1980, Abstract No 1030

[12] Piesch,E., Burgkhardt,B.: report KfK 2626, 1978