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INTER-LABORATORY STANDARDIZATION OF GLASS DOSIMETERS

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Intercalibration charts for various glass dosimeters have been prepared using Fleischer's glass as reference standard. Calibration constants have been determined using two different irradiation thermal neutron doses. The geometry factor and uranium content for these glasses are determined. The U-content of the dosimeters varies from 0.35 ± 0.02 ppm to 41.93 ± 1.0 ppm and the geometry factor G lies within the range 0.57–0.77.

1. Introduction

A neutron fluence measurement using an activation foil technique is a complicated problem. In practice, most of the SSNTD laboratories use standard glass dosimeters for this purpose. The integrated thermal neutron flux, F, is related to surface track density, ρ, by the eq. [1]

$$F = K\rho, \tag{1}$$

where K, the calibration constant, depends upon various factors, viz. composition of the glass material, reactor irradiation position, etching and annealing conditions and environmental factors etc.

Fleischer et al. were the first to calibrate the soda lime microscope glass slide of known uranium content (0.35 ± 0.02 ppm) for thermal neutron dose measurement of a reactor by comparison of both the fission track count and the radiochemical technique. The calibration constant determined is 2.26×10^{11} neutrons/track. Standard glasses were later prepared and calibrated by many workers [2–8]. The glass standards prepared by General Electric Company, Schenectady, New York; Corning Museum of Glass, Corning, New York and National Bureau of Standards, Washington, DC, U.S.A. have been adopted by most of the workers as reliable standards.

The measurement of absolute neutron dose with accuracy for fission track work is a difficult task which has engaged the attention of various research workers [1–8]. Hence the need to calibrate the glass standards and to prepare an intercalibration chart for the control of results between the various laboratories.

2. Experimental procedure

Samples were prepared from Fleischer's GEC glass, National Bureau of Standards SRM 962, 610, 612 to 614 and 616, Corning glass G-I to G-IV, Lead borate glass and Blue Star (PIC-2 and A-I) microscopic glass slides. The samples were thoroughly cleaned with alcohol and distilled water and were packed in two different aluminium capsules. These were irradiated with different integrated thermal neutron doses of 10^{15} (nvt) and 10^{16} (nvt) respectively using a neutron fluence of 10^{13} neutrons/cm^2 in IC-1 self-served position of the CIRUS reactor of BARC, Trombay, Bombay, wide irradiation can No. S-8823 and S-8824. The induced tracks were etched with 24% HF for 40 s at 23°C. Track densities were determined using a binocular microscope (Olympus make) at a total magnification of 600×.

To find the geometry factor G i.e., the ratio of track counts on the external and internal surfaces of glass dosimeters ($2\pi/4\pi$), the samples were repolished to a depth of nearly 30 μm. They were then re-etched under the same conditions and the track densities on the internal surfaces were recorded. The uranium content in these glasses is calculated by the method of comparison using the following equation [3].

$$W_{\mathrm{ux}} = W_{\mathrm{us}} \frac{I_s}{I_x} \frac{\rho_x}{\rho_s} \frac{R_s}{R_x}, \tag{2}$$

where

W_u = weight fraction of uranium,
I = isotopic ratio of $^{235}U/^{238}U$,
ρ = induced track density,
R = average diameter of tracks in μm, and s and x denote standard and unknown.

3. Results and discussion

The values of the calibration constant K for various glass detectors are determined by comparison with standard glass using eq. (1). The accuracy of our results depends upon the reliability of the K value of the standard glass. The thermal neutron doses measured with Fleischer glass using the standard value of K (2.26×10^{11} neutrons/track) are in good agreement with the nominal values (tables 1 and 2). Hence it is used as reference standard in the present work.

The calibration constants for SRM 962 and SRM 612 were determined to be 6.4×10^9 and 6.7×10^9 respectively. The K value for SRM 612 is in good agreement with the value determined by Hurford and Gleadow [5]. Saini et al. [8] have calibrated SRM 962 for inter-laboratory use. They determined $K = 5.12 \times 10^9$ neutrons/track which is lower than the value reported in table 1. The values of K for SRM 962 and SRM 612 are in close agreement and confirm that these glasses are identical in nature. The calibration constants of SRM 610, SRM 613 and SRM 616 are found to be 5.3×10^3, 6.3×10^9 and 1.3×10^{12} respectively. It is also evident from the data that SRM 962, SRM 612 and SRM 613 are having nearly the same K values and are prepared from the same lot [10]. The uranium content for these glasses is calculated using eq. (2). It is found that the results are in very good agreement with that of the National Bureau of Standards [10] except for a slightly higher U content for SRM 962 [9].

The values of the calibration constant K and uranium content for the glasses G (I to IV) are reported in tables 1 and 2. The glasses G-I and G-II have 39.42 ppm and 32.36 ppm uranium respectively. The U-content for G-I

Table 1
Calibration constants for glass dosimeters
Total thermal neutron fluence (nominal value = 10^{15} (nvt).
Total thermal neutron fluence (Fleischer glass value) = 1.1×10^{15} (nvt).
Total thermal neutron fluence (SRM 962 value) = 1.28×10^{15} (nvt).

Sr. no.	Glass dosimeter	Track density $\rho \times 10^{-2}$/cm^2	U. conc. (ppm) [c]	Calibration constant $K \times 10^{-10}$ neutrons/track	Geometry G
1.	Fleischer Glass	50.08 (622) [b]	0.35 ± 0.02	22.60	0.57
2. [a]	SRM962	2000.00 (1750)	41.93 ± 1.01	0.64	0.77
3.	SRM610	189.73 (2887)	460.26 ± 10.06	0.05	0.64
4.	SRM 612	1637.00 (852)	34.32 ± 1.11	0.67	0.68
5.	SRM 613	1602.00 (901)	38.53 ± 1.28	0.63	0.68
6.	SRM 614	54.50 (178)	0.99 ± 0.07	20.18	0.64
7.	SRM 616	7.75 (63)	0.072 ± 0.005	130.00	0.65
8.	G-I [d]	5640.00 (8469)	39.42 ± 0.42	0.20	0.64
9.	G-II	463.00 (5789)	32.36 ± 0.42	0.24	0.61
10.	G-III	61.51 (173)	0.43 ± 0.03	17.88	0.71
11.	G-Iv	664.00	4.64 ± 0.06	1.66	0.62
12.	Glass slide (Blue Start PIC-2)	126.00 (767)	0.88 ± 0.03	8.73	0.63
13.	Glass slide (Blue star A-I	112.00 (868)	0.78 ± 0.02	9.82	0.62
14.	Lead borate glass	118.40 (439)	0.83 ± 0.04	9.20	0.62

[a] Standard reference material supplied by National Bureau of Standards, Washington (USA).
[b] Number of tracks counted are given in brackets.
[c] Weight part per million.
[d] J.W.H. Schreurs, Corning glass Works, Corning, New York, private communications (1981)

Table 2
Calibration constants for glass dosimeters.
Total thermal neutron fluence (nominal value) 10^{16} (nvt).
Total thermal neutron fluence (Fleischer glass value = 1.01×10^{16} (nvt).

Sr. no.	Glass dosimeter	Track density $\rho \times 10^{-4}$ cm^{-2}	U. conc. (ppm)	Calibration const. $K \times 10^{-10}$ neutrons/track
1.	Fleischer Glass	4.47 (1514)	0.35 ± 0.02	22.60
2.	SRM 614	5.05 (781)	1.19 ± 0.04	19.80
3.	G-III	5.67 (1011)	0.44 ± 0.01	17.64
4.	G-IV	56.64 (2655)	5.19 ± 0.10	1.50
5.	Glass slide (Blue Star PIC-2)	11.20 (1120)	0.88 ± 0.02	8.93
6.	Glass slide (Blue Star A-1)	9.77 (916)	0.77 ± 0.02	10.20
7.	Lead borate glass	10.80 (875)	0.84 ± 0.03	9.26

is the same as reported by Schreurs [11] whereas the G-II records the lower value in our case. In the case of G-III no uranium content has been reported [11] whereas we have found 0.43 ppm of uranium. Our results show that the G-IV glass contains 4.92 ppm of uranium (mean value from tables 1 and 2) whereas the other laboratories reported 5.24 ppm and 6.5 ppm uranium [11].

It is observed that the U-content and K values for soda lime microslide glass (Blue Star PIC-2 and A-I) and lead borate glass lie within a narrow range. The uranium present in them is homogeneously distributed and they can serve as useful glass standards for high neutron fluence measurements ($10^{16}-10^{20}$ neutron/cm^2). The calibration constant and U-content for microslide glass are in good agreement with the values determined by Virk [6].

It can be observed from tables 1 and 2 that the values of U-content and calibration constant K for most of the dosimeter glasses show close agreement even at two different irradiation doses. At a higher irradiation dose (10^{16} nvt) the track density recorded was too high in the case of glasses with a U-content more than 5 ppm to render the tracks countable by using optical microscope.

The error shown in the results for U-content is based on the number of tracks counted (1σ). The error in the calibration constant K is the not shown explicitly in the results. However, it is of the order of $\pm 15\%$ [1] even if we do not take the statistical error due to track counting into consideration.

The geometry factors for these glasses were determined (table 1). The G value for Fleischer glass is very low as compared to the value reported by Reimer et al. [12] and Virk [6], however, for SRM 962 our result shows good agreement. For microslide and lead borate glasses, the G value is found to be nearly the same and concordant with the value determined by Virk [6]. In general, G shows a variation from 0.57 to 0.77 depending upon the composition of the dosimeter glasses.

The present calibration is based on the Fleischer glass standard which was calibrated by using a radiochemical technique. Hence even if we consider this calibration as tertiary, it will prove highly useful for inter-laboratory comparison of dosimeter glasses.

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