RECENT DEVELOPMENT OF FLUORO-GLASS DOSIMETER IN JAPAN

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In most of the developing countries there are no centers for the calibration of instruments and sources. They have to ask the developed countries to calibrate the secondary standards (instruments and radiation sources) and then use these standards for the calibration of laboratory and/or field instruments. Naturally,such a practice leads to an increase of expences for radiological measurements. It might be possible that there would be a decrease in the accuracy of measurements because of the lack of proper operating knowledge by local personnel and changes in the calibrated instrument during shipment, in addition to the various inconveniences involved in the shipment of radiation sources and primary instruments for calibration. Therefore, it was proposed in 1968 to carry out the assessment of the accuracy and the reliability of the radiation protection measurements in Member States laboratories by mailing TOSHIBA radiophotoluminescent glass dosimeters. For this purpose a postal radiophotoluminescent glass dosimetry program was initiated in 1969-1970 by the IAEA. The TOSHIBA dosimeter glass pieces sent to the participating Member States laboratories for irradiation were returned to the IAEA and read out with a single reader,TOSHIBA Type FGD-6, to achieve a high degree of precision and avoid various sources of error. The results obtained in the past were considered extremely useful for the participating laboratories. For some time,this program was interrupted, but after the Three Mile Island Accident,the importance of Intercalibration Program is emphasized in some developing countries.

When silver activated phosphate glass is exposed to ionizing radiation, a stable luminescent center appears in it. When it is excited by ultraviolet light,the glass emits an orange luminescence having a peak wavelength of 500 to 750 nm. This is called radiophotoluminescence(RPL). Since the quantity of the luminescent emission is proportional to the radiation dose absorbed by glass, its application to the glass dosimeter has been developed. This was first applied to dosimeter by J.H.Schulman and others in the U.S.A. using radiophotoluminescence based on silver activated phosphate glass. Later it was improved several times by R.Yokota,Y.Nishiwaki,T.Omori and others in Japan, to develop the glass with a predose at 1/300,three times sensitivity,and little energy dependence. Special glass for neutron dosimetry was also developed.

The new TOSHIBA dosimeter system is not significantly affected by reading operation and enables repeated measurement and recording of the integrated dose. (Table-1, Fig-1, Fig-2).

Table-1. Glass Composition. (wt %)

	FD-1	FD-3	FD-3L	FD-4	FD-5	FD-6	FD-7
Li	3.67	3.58	Li 3.62	3.48	-	-	-
Na	-	-	-	-	8.94	6.60	11.00
P	33.45	34.53	34.52	34.04	33.13	33.16	31.55
O	53.71	53.51	53.49	52.74	51.34	51.39	51.16
Al	4.65	5.11	5.11	4.97	6.08	5.49	6.12
Ag	3.68	3.27	3.27	4.77	0.52	1.41	0.17
Mg	-	-	-	-	-	1.95	-
B	0.85	-	-	-	-	-	

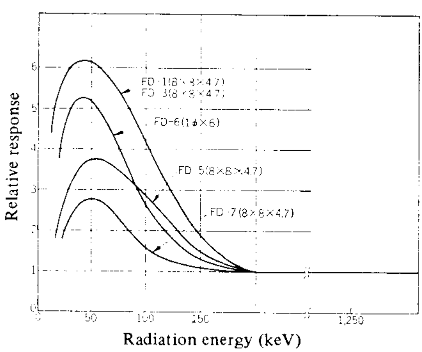


Fig-1. Energy dependence of different kinds of glass.

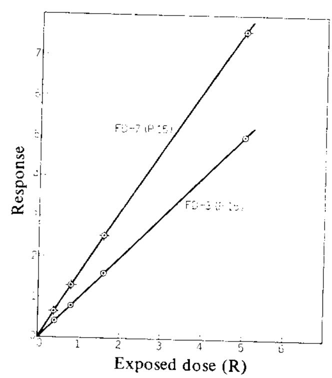
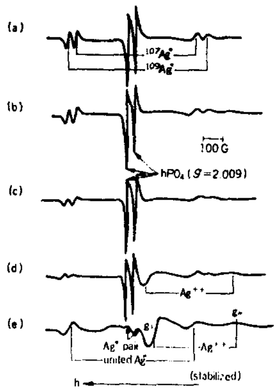


Fig-2. Dose characteristics of FD-3, FD-7.

The ESR spectral change after the $AgPO_3$ 1.07% doped with its composition of $LiPO_3$ 80% and $Al(PO_3)_3$ 20% is exposed to ^{60}CO gamma-ray radiation at 77K is shown in Fig-3. The structure of metaphosphate glass shares the oxygen with a PO_4 tetrahedron on its top and is in chain combination. When the PO_4 tetrahedron is exposed to radiation, it loses its electron and is stabilized, then seizes positive holes (hPO_4). Simultaneously with this, the Ag^+ ion in glass seizes a single electron and changes into the Ag^0 ion.



1.5×10^4 r exposure (at 77K)

1.4×10^4 r exposure (at 77K)

Item(b) is retained for 15 minutes at 195K

Item(c) is retained for 60 hours at room temperature.

Item(d) is retained for 360 hours at room temperature.

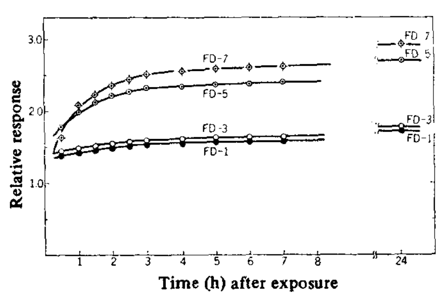
Fig-3. ESR spectra of Li-Al-metaphosphate glass

Once the positive hole has been seized by the PO4 tetrahedron, hPO_4 is assumed to move to the Ag^+ ion due to the lapse of time and heat treatment, and then generate Ag^{++} ion. The Ag^o is also assumed to form a more stable Ag^o pair. Build-up indicates that the quantity of luminescence increases and is stabilized with time and temperature, and sufficient build up is required in order that these Ag^o, Ag^o pair and Ag^{++} can function as the stable luminescent center of the dosimeter glass.

The build-up time depends on basic glass composition, mainly on silver concentration. The smaller the silver concentration in glass is, the more hPO_4 is generated, and the build-up time is required to accelerate the reaction

$$Ag^+ + hPO_4 \longrightarrow Ag^{++}$$

The build-up curves of different kinds of dosimeter glass are shown in Fig-4.



Note here that the build-up rate of the FD-7 containing only about one twentieth Ag concentration of the FD-3 which contain comparatively more Ag concentration is almost equal to that of FD-3 in three hours after exposure. This is the reason why the latter is the Li glass with tight

Fig-4. Build-up characteristics of dosimeter glass.

structure,but the former is the Na glass allowing the Ag and Ag^{++} ions to be apt to move in glass and the RPL build-up to be rapidly completed. Also,the higher retaining temperature is,the more rapidly the RPL build-up is completed. When glass is heated at 100 to 120°C for 10 minutes,the build-up is immediately completed and the value with 1.1 times the normal value is obtained.

In order to improve the glass dosimeter, we tried to use the UV pulse (3371Å) by N_2 gas laser.
The pulse duration is 15 n sec and peak power is about 5KW. N_2 gas pressure is 6 Torr. Both ends of the laser tube have silica glass window with Brewstar angle.

The luminescence decay time of the predose and the oil or other organic surface contaminants is about ten times shorter than that of the RPL of the glass exposed to the ionizing radiation. Therefore, the signal due to radiation exposure can be measured separately by a delay circuit. With this method, the sensitivity can be greatly improved and it is possible to measure 1mR without being disturbed by a high predose or a surface contamination.

One of the difficulties was that the potential to be applied to the N_2 gas laser is high and the power source is large and expensive, but we succeeded in developing a small N_2 gas laser for this purpose.

In addition to the personnel dosimeter for relatively low dose range 1-100mR, a small portable reader for a relatively high dose range 0.5-1000R was developed as a personnel emergency dosimeter for accident and civil defence purposes. In this type of reader, a Xenon flash lamp is used as a source of UV excitation and a solar photocell with a high sensitivity for infrared is used as a sensor.

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