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VITREOUS MATERIALS FOR RETROSPECTIVE DOSIMETRY: PROMISES AND PROBLEMS

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Abstract. Different kinds of vitreous materials produced by several factories and widely used in the former Soviet Union were studied to assess the prospects of their application in retrospective dosimetry. Almost all samples measured had rather intensive thermoluminescence, which, however, was prone to heavy fading. Nevertheless, some of these materials can successfully be used for purposes of retrospective dosimetry.

Key words: vitreous materials, glasses, dosimetry, retrospective dosimetry, accident dosimetry, thermoluminescence, fading, nuclear accidents.

INTRODUCTION

Materials that are widely used in our everyday life may prove very useful in retrospective dosimetry in case of accidents connected with radiation pollution of an area or premises without systematic monitoring. Ceramic construction materials such as bricks and roof tiles are routinely used for reconstruction of accident dose using thermoluminescence (TL) (Maruyama et al., 1987; Haskell, 1993; Hütt et al., 1993). Promising results for TL reconstruction have been obtained also using watch jewels (Majborn, 1983) and dental restoration porcelains (Mauricio et al., 1985).

We studied dosimetric properties of vitreous materials produced by well-known glassworks in the former Soviet Union.

EXPERIMENTAL PROCEDURE

Twelve samples of vitreous building materials were studied. These are listed in Table 1 with the producing factory also shown.

Before measurements samples were ground, the 0.200—0.315 mm fraction was separated and etched in 10% hydrofluoric acid for 10 min to eliminate surface defects. An aliquot of 0.02 g was used in measurements.

Samples were irradiated by β-source ^{90}Y—^{90}Sr, dose rate 0.01 Gy/s. Measurements of thermoluminescence were carried out by means of a TL-reader produced in Tallinn. The heating rate was 2.5 K/s. A photomultiplier THORN EMI type 9514SA with an C3C-22 filter (460^{+70}_{-80} nm FWHM, $\tau_{max}=0.93$) was used. The integral of TL around the temperature of the peak maximum (span of integration ±30 °C from T_{max}) was measured. Before repeated measurements samples were heated to 450 °C.

Table 1

Samples of vitreous building materials studied and their producing factories

No.	Material	Producer
1	Window glass	Salavatsteklo
2	Wall tile	Anzhero-Sudzhensk Glassworks
3	Wall tile	Anzhero-Sudzhensk Glassworks
4	Wall tile	October Revolution Glassworks, town of Konstantinovka
5	Slag-sitall wall tile	October Revolution Glassworks, town of Konstantinovka
6	Profile glass	Chernyatinsk Glassworks
7	Patterned glass	Avtosteklo, town of Konstantinovka
8	Slag-sitall	Avtosteklo, town of Konstantinovka
9	Glass-crystal tile	Dzerzhinsk Glassworks, town of Gus-Khrustalnyi
10	Profile glass	Irbitsk Glassworks
11	Glass block	Panevežis Glassworks
12	Headlight glass FG-140	Zaporozhye Glassworks

RESULTS OF MEASUREMENTS

Almost all the measured samples had rather intensive TL; the temperature maximums for different samples covered a wide temperature region. Table 2 presents some characteristics of TL glow curves of the materials studied.

As an example, a TL glow curve of car headlight glass is given in Fig. 1. Fading, the influence of natural light on the TL signal, and the effect of annealing on dose sensitivity of the material were investigated on most promising materials: wall tile very sensitive to dose (No. 2 in Table 1) and widespread headlight glass (No. 12).

Table 2

Some characteristics of TL glow curves of vitreous materials studied

No.	Temperature of peaks, °C		Sensitivity, arbitrary units/Gy
	The most sensitive	Others	
1	*	*	*
2	160	240, 335	2600
3	160	*	1400
4	135	*	16
5	310	115, 210	48
6	175	*	3
7	230	*	3
8	340	94, 135	240
9	160	*	300
10	*	*	*
11	250	*	2
12	225	*	16

* No corresponding peak was recorded.

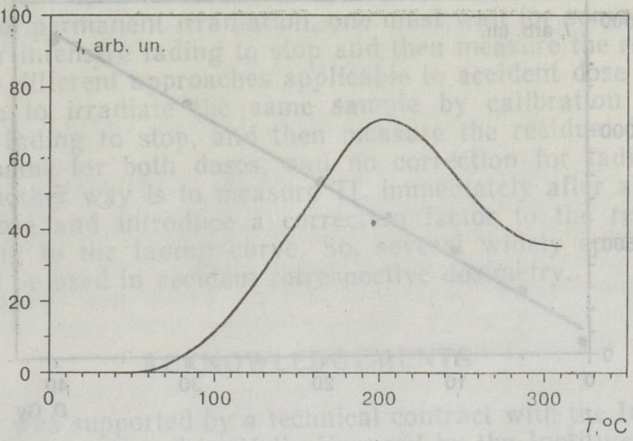

Fig. 1. TL glow curve of headlight glass powder after laboratory β-irradiation.
Before measurements samples were ground, the 0.200—0.315 mm fraction was separated and etched in 10% hydrofluoric acid for 10 min to eliminate surface defects. An aliquot of 0.02 g was used in measurements. *I*, TL intensity in arbitrary units.

It is shown that fading differs for samples stored at natural light and in darkness: for both samples the bleaching effect of natural light was observed (fading at light was speeded by about 20%). Fig. 2 illustrates fading in headlight glass (No. 12) and wall tile (No. 2) samples stored under sunlight conditions. After storing for 40 and 100 hours, respectively, from the time of irradiation the fading of the samples becomes much slower, and the residual signal may be treated as stable. Dose sensitivity changes were not detected after 30 annealings (heating to 450 °C) and a total dose of up to 25 Gy.

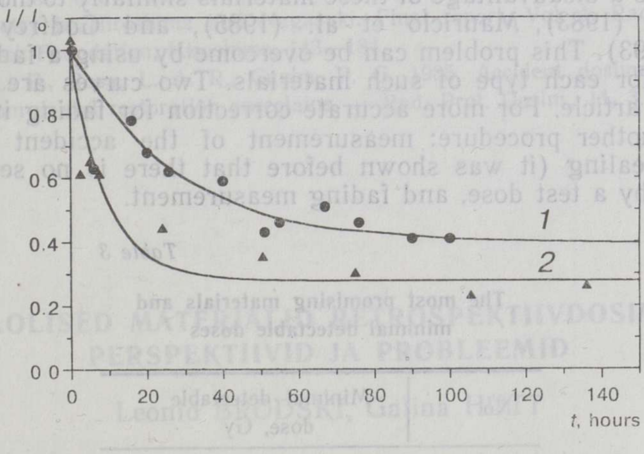

Fig. 2. Fading of the TL signal of vitreous materials after laboratory β-irradiation.
1, wall tile (No. 2 in Table 1); *2*, headlight glass (No. 12). Samples were irradiated with 0.5 Gy and then stored for different times at sunlight.
I, TL intensity; I_0, TL intensity measured immediately after irradiation; *t*, time after irradiation.

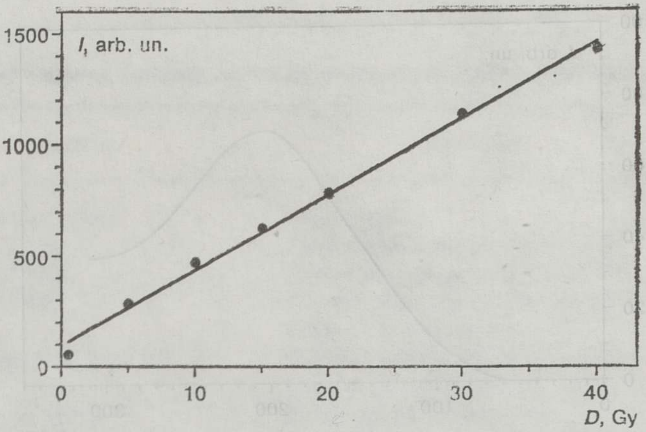

Fig. 3. Dose response curve for headlight glass.
Samples were irradiated with different doses, stored for 120 hours at sunlight and room temperature and then measured. Linear fitting was applied; there is a slight nonlinearity in the low dose region. *I*, TL intensity in arbitrary units; *D*, dose.

A dose response curve for headlight glass is presented in Fig. 3. Samples were irradiated with different doses, stored for 120 hours at sunlight and room temperature, and then measured. The residual TL signal recommended for dose reconstruction is dose-dependent, in spite of the influence of two different mechanisms of fading—bleaching by light and losses over time. Nonlinearity in the low dose region requires additional investigation; linear fitting will give overestimation of accident doses.

DISCUSSION AND CONCLUSIONS

It was found that some types of vitreous materials can well be used for the purposes of retrospective dosimetry. Table 3 presents the most promising materials and minimal detectable doses.

Fading is a disadvantage of these materials similarly to those described by Majborn (1983), Mauricio et al. (1985), and Godfrey-Smith and Haskell (1993). This problem can be overcome by using a fading calibration curve for each type of such materials. Two curves are supplied in the present article. For more accurate correction for fading it is possible to apply another procedure: measurement of the accident TL signal, sample annealing (it was shown before that there is no sensitization), irradiation by a test dose, and fading measurement.

Table 3

The most promising materials and minimal detectable doses

No.	Minimal detectable dose, Gy
2	0.002
3	0.004
5	0.15
9	0.02
12	0.45

If the moment of accident irradiation is not known exactly or if it was a period of permanent irradiation, one must wait for some time (30—100 hours) for intensive fading to stop and then measure the residual TL. There are two different approaches applicable to accident dose evaluation. It is possible to irradiate the same sample by calibration dose, wait for intensive fading to stop, and then measure the residual TL. Fading will be the same for both doses, and no correction for fading will be necessary. Another way is to measure TL immediately after applying the calibration dose and introduce a correction factor to the reconstructed dose according to the fading curve. So, several widely spread vitreous materials can be used in accident retrospective dosimetry.

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KLAASITAOLISED MATERJALID RETROSPEKTIIVDOSIMEETRIAS: PERSPEKTIIVID JA PROBLEEMID

Leonid BRODSKI, Galina HÜTT

Uuriti endise NSV Liidu territooriumil toodetud ja seal laialdaselt kasutatavaid klaasitaolisi materjale. Peaaegu kõigile mõõdetud proovidele oli iseloomulik üsnagi intensiivne termoluminestsents, aga samuti tugev feeding. Hoolimata sellest võib mõningaid nendest materjalidest kasutada edukalt retrospektiivdosimeetrias.

ИСПОЛЬЗОВАНИЕ СТЕКЛОВИДНЫХ МАТЕРИАЛОВ В РЕТРОСПЕКТИВНОЙ ДОЗИМЕТРИИ: ПЕРСПЕКТИВЫ И ПРОБЛЕМЫ

Леонид БРОДСКИЙ, Галина ХЮТТ

Изучено несколько типов стекловидных материалов, производимых различными заводами и широко распространенных на территории бывшего Советского Союза. Установлено, что почти все образцы имеют достаточно интенсивную термолюминесценцию, но проявляют склонность к значительному фэдингу. Тем не менее некоторые из стекловидных материалов могут быть успешно использованы для целей ретроспективной дозиметрии.