THE DISPERSION OF THE ELEMENTAL COMPOSITION OF SAMPLES FROM THE SAME BATCH OF OPTICAL MATERIALS USED IN DOSIMETRY APPLICATIONS

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Abstract. In this paper, a study of the dispersion of the elemental composition of samples from the same batch of an optical material used in dosimetry applications was performed, by using XRF spectrometry. Optical materials are widely used in many dosimetry applications, one of the most frequent ones being the retrospective dosimetry, meaning post-event dose measurements. Besides many other aspects that must be carefully considered, the dispersion of the elemental composition of the optical materials from the same batch is very important due to the fact that it can have a significant impact on the precision and the accuracy of the results.

Key words: XRF spectrometry, optical materials, dosimetry.

1. INTRODUCTION

As it is known, due to their outstanding optical proprieties, the glass-based optical materials are the perfect candidate for a wide range of applications, covering many fields. Either we are talking about their use in industry or in any other connected field, the quality of the glass plays the main role.

In this paper, the main focus on the glass-based optical materials is to their usability in nuclear physics-related applications [1–7]. One of the very important applications of the glass-based optical materials in nuclear physics-related applications is the dosimetry, which may be generically seen as the science of measuring a quantity called dose and shows the energy deposited by ionizing radiation to a material, as a consequence of being exposed to a source of ionizing radiation [8–15]. The dosimetry based on the use of optical materials is part of a bigger branch of the dosimetry named Solid State Dosimetry [12]. The Solid State Dosimetry based on optical materials is widely used in many applications [7], one of the most frequent ones being the retrospective dosimetry, meaning post-event dose measurements (accidental over-exposed personnel, nuclear incidents, etc.). In this kind of post-event analyses, the glass-made materials surrounding the area are the key elements, as cell phone displays, windows of the buildings, etc. [1–3]. These optical materials can be analyzed by *Radiation Induced Absorption* (RIA) or TLD/OSL methods. In all these cases, the calibration process (analyzed parameter as a function of the absorbed dose) is very important and it must be carefully approached (from the metrological point of view). In metrology, obtaining high precision and high accuracy results is one of the

most important aspects (carefully providing the associated uncertainty budget). In order to fulfill these metrological requirements, all the aspects related to the optical materials–based dosimetry must be considered.

The main property of the glass-based optical materials that makes them perfect candidates to be used in dosimetry is their capacity of having many of their parameters changing linearly when exposed to ionizing radiation (increasing dose values). These changes appear mostly due to the occurrence of the color centers, which are strongly related to the elemental composition of the exposed optical materials [9, 10]. This means that it is very important to use as similar as possible optical material samples [16–18]. To check whether the elemental composition of the samples from the same batch is identical or not, a batch of 12 BK-7 glass samples was analyzed, by using the XRF spectrometry method, in order to see the dispersion of their elemental composition.

2. MATERIALS AND METHODOLOGY

A batch of 12 BK-7 glass samples (cylindrical shaped, with 10 mm diameter and 5 mm thickness) were analyzed, by using a portable XRF spectrometer (Figure 1).

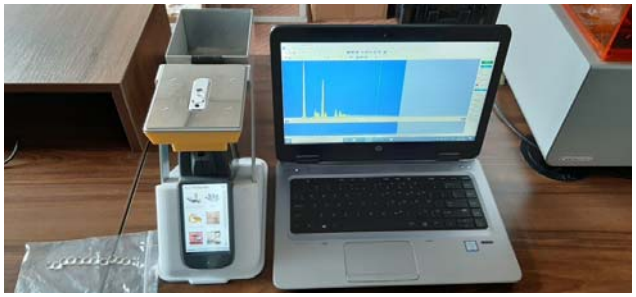

Fig. 1 – Measuring set-up.

The portable XRF spectrometer used for making the measurements is an EDXRF type (*Energy Dispersion*), ElvaX ProSpector 3, Elvatech Ltd. Ukraine. It is able to detect elements from Na to U. It contains an air-cooled Rh anode X-rays generator and a 150 μm Be window. The voltage that can be set is between 4 and 50 kV and a current between 0 and 200 μA (a maximum of 5 W power). The detector of the spectrometer is a Fast SDD (Silicon Drift Diode) type, cooled by the Peltier effect and having a 12 μm Be window. The detecting resolution is of 140 eV for the Mn kα line and a counting rate > 500 000 pulses/s. The spectrometer contains also a pile-up rejection digital processor that offers also the automatic selection of pulse shape (involving automatic adjustment of the counting rate). It is equipped with a two fixed positions collimator (5.5 mm and 2 mm). The acquisition time can be selected between 1 s and 120 s and the detection limit is 10 ppm.

Before being used, the energy calibration was performed using a 316 Steel standard; the resulting spectra are presented in Figure 2. The voltage and the

current applied on the X-rays tube for performing the measurements were 10 kV and 25 μA, respectively. The measuring time for each sample was set to 100 s.

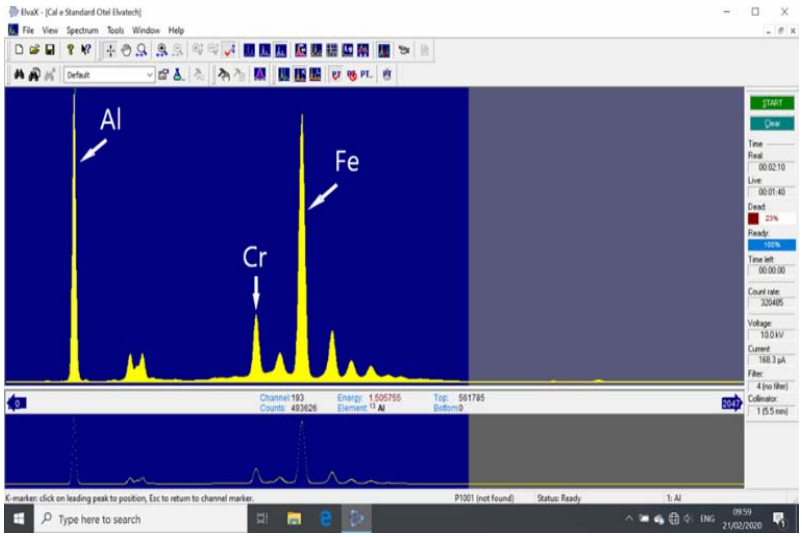

Fig. 2 – XRF spectra for a 316 Steel calibration standard.

All the 12 samples were analyzed on both their surfaces and the mean values were reported. An example of a BK-7 glass sample associated with XRF spectra can be seen in Figure 3.

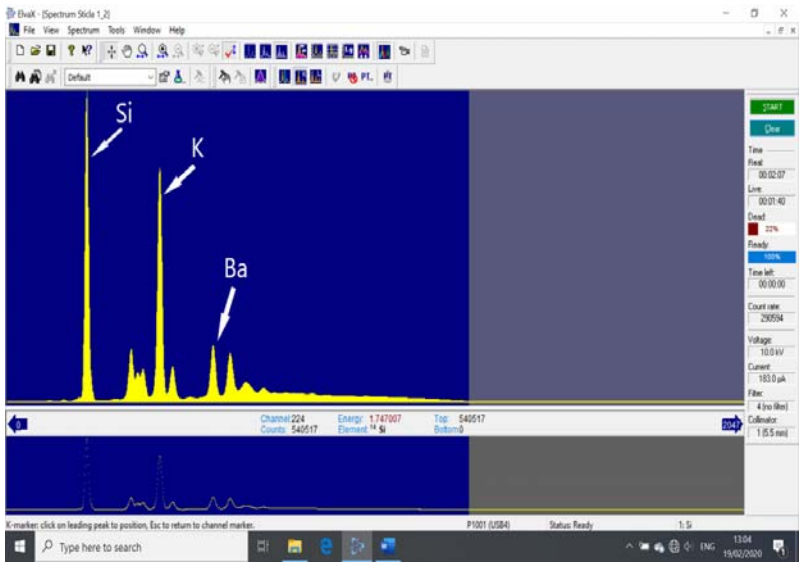

Fig. 3 – XRF spectra for a BK7 glass sample.

3. RESULTS AND DISCUSSIONS

The XRF analysis results for all 12 BK-7 glass samples are presented in Table 1. As can be seen in Table 1, by relatively analyzing the elemental composition of all 12 tested BK-7 glass samples (from the same batch), relevant differences are observed. Only the first three main elements (Si, K, Ba) identified were taken into consideration (the major ones). These differences show that before being used in dosimetry applications, the optical materials should be checked individually by XRF spectrometry, even if they are coming from the same batch. In order to have more consistent dosimetry related results, it is recommended (as the results showed) to use multiple samples for the same determination and to report the mean values. In this way, also the uncertainty associated with the optical materials–based dosimetry can be decreased, leading to better precision and better accuracy.

Table 1

XRF spectrometry analysis results for all 12 BK-7 glass samples

Sample code	Si	K	Ba
	Net Aria (K Series)	Net Aria (K Series)	Net Aria (K Series)
1	4300043	3608846	1284458
2	3875564	4596909	1212196
3	4413587	3592521	1151626
4	4381904	3503859	1155177
5	3447598	5750070	1009196
6	4054156	4702263	1217901
7	3966668	4344507	1215885
8	3935958	4359708	1229605
9	4395049	3582694	1172449
10	3634407	6066946	1066442
11	3966424	4368740	1227168
12	4432552	3567508	1150012
Max. value [counts]	4432552	6066946	1284458
Min. value [counts]	3447598	3503859	1009196
Mean [counts]	4010412	4352107	1192322
Max. – Min. [counts]	984954	2563087	275262
SD [%]	8.096675	19.75581	6.368336
Mean SD [%]	7.751976	18.91475	6.097218

4. CONCLUSIONS

In this paper, the elemental composition analysis of 12 samples from the same batch of BK-7 glass cylinders was performed using XRF spectrometry. The BK-7 glass type was chosen due to its wide usability in many applications, including nuclear physics-related ones (as optical materials–based dosimetry). By performing the presented study, it was proven that the glass samples from the same batch of glass could have slightly different elemental composition, which can lead

to poor accuracy and poor precision of the results (when are used in dosimetry applications). It was shown that before using a batch of optical materials in dosimetry, it would be a good practice to check their elemental composition consistency. By doing this, the estimation of the uncertainty budget associated with this dosimetry method could be also improved. By increasing the performances of optical materials–based dosimetry, its usability could be extended to a wider range of applications, where more precise measurements are needed.

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