SOME PRACTICAL APPLICATIONS OF SINTERED BeO AS TL DOSIMETER

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Abstract

Following the investigations reported in previous papers and symposia, some new experiments have been carried out in order to get further information about the possible application of the thermoluminescence of ceramic undoped beryllium oxide to some specific practical fields, such as health physics measurements and dose intercomparisons.

The results of these experiments are described and a conclusion is drawn that ceramic BeO, even of commercial electronic grade, can be used with success and advantage in the specific dosimetric fields referred to above, in addition to its týpical use in mixed radiation fields of neutrons and gamma rays.

Introduction

The general dosimetric characteristics of BeO as a thermoluminescent material have been extensively described and discussed in previous papers and reports [1,2,3].

From these investigations it has become rather evident that BeO, even in the form of plain, undoped, ceramic material as commercially manufactured for the electronic industry, possesses so many interesting properties to put itself among the most promising TL materials for routine dosimetric use. This applies in the first place to dosimetry of mixed fields of neutrons and gammas [3], because of the very low sensitivity of BeO to thermal neutrons.

But also in the field of conventional dosimetry of X and gamma rays BeO exhibits considerable advantages over other TL materials: low cost, absence of low-temperature or spurious peaks, semplicity of annealing cycle, high unsensitivity to mechanical shocks and most chemical agents and long-term stability of response. These features are of special relevance in some specific fields of applied dosimetry, such as radiation protection measurements and dose intercomparison experiments.

In order to better define and study the possible application of BeO to the above mentioned dosimetric activities, a new set of specific experiments have been undertaken.

The three main topics covered by these experiments were: a) the linearity of response-to-exposure relationship with different radiation qualities; b) the energy dependence at various dose levels and c) the change of response with time elapsed from annealing to irradiation and from irradiation to readout.

All experiments have been carried out using the same instrumental equipment described in previous papers [2,3].

Measurements and results

a) Response-to-exposure relationship.

Figure 1 is a log-log plot of some results, already published, obtained using ^{60}Co gamma rays, compared with a new set of measurements performed with 2 mm Cu HVL X-rays (effective energy: about 100 KeV). What is apparent is that the supralinearity, which begins in the region of 20-30 R, is more marked for gamma- than for X-rays.

This is better shown in figure 2, which is a plot of the linearity index versus exposure; it can be seen that the index is distinctly lower in the case of X-rays, at least for exposures of up to 1000 R, where the two curves approach each other again.

As linearity index the exponent n of the expression

$$A = K \cdot D^n$$

was assumed, in which A is the area of the glow-peak and D is the corresponding exposure. This index can be graphically derived as tangent of the angle between curve and abscissa axis.

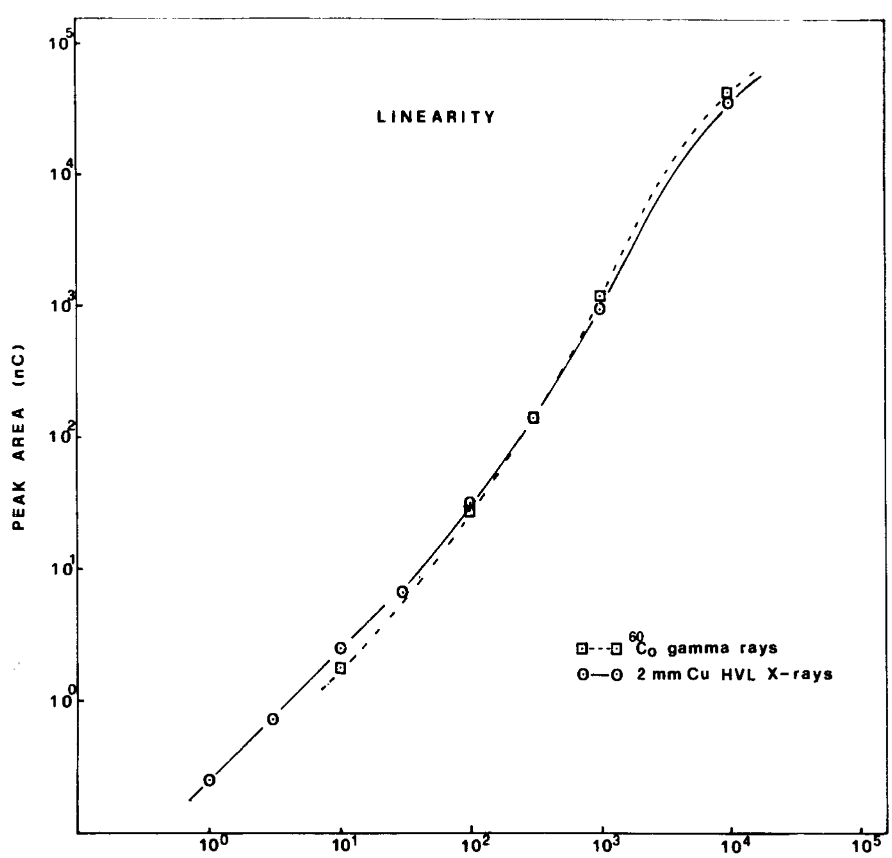

Fig. 1- Response-to-exposure relationship for gamma- and X-rays.

The different supralinearity of the two radiation qualities could be, at least partly, related to a dependence of supralinearity on LET, even if the difference between X- and gamma-radiation is relatively little in this respect. This dependence has been experimentally found by several authors in LiF and other TL materials [4].

Tochilin et al. [5] have published a comparison of dose response curves of BeO exposed to ^{60}Co gamma rays and 9 KeV X-rays: the agreement with the above results is remarkable.

b) Energy dependence.

The energy dependence of the response of BeO to X- and gamma-rays was investigated at two different exposure levels: 10 and 100 R. Gamma rays emitted by ^{60}Co and ^{137}Cs sources and well filtered X-rays were used.

The results, normalized to unity for ^{60}Co gamma rays, are shown in figure 3. For both exposure levels a broad peak is apparent between 100 and 150 KeV; the experimental points at 100 R, however, are lower than those at 10 R. This is simply due to the fact that BeO exposed to 100 R already behaves supralinearly and, as shown in figure 2, the supralinearity is less marked for X- than for gamma-rays.

As a consequence, only the 10 R points can be regarded as representative of the real energy response of BeO. These points roughly agree with the curve published by Tochilin et al. [5] and included in figure 3, even if most of them are slightly below Tochilin's curve. A comparison with data published for LiF commercial solid dosimeters gives a slight advantage of BeO in this respect.

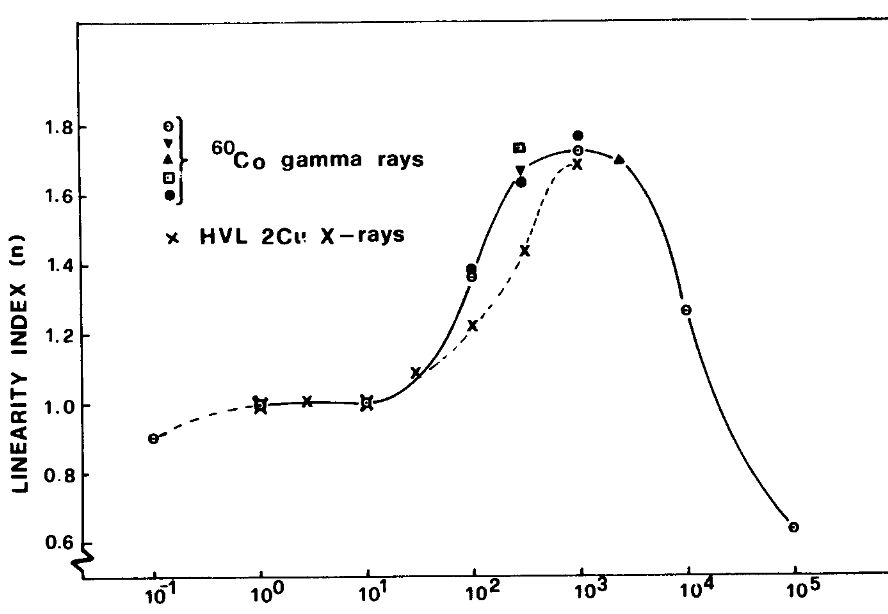

Fig. 2- Linearity index versus exposure for gamma- and X-rays.

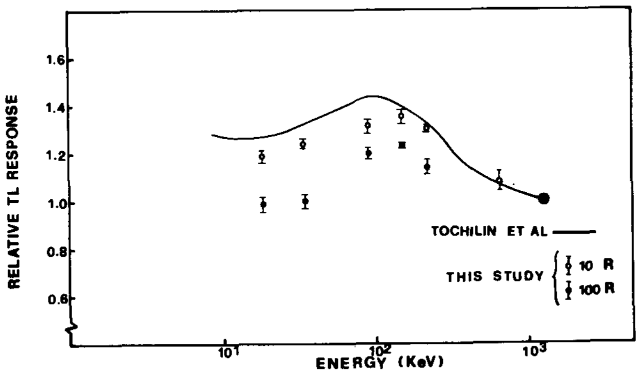

Fig. 3- Energy dependence of Beo irradiated to 10 and 100 R. Curve published by Tochilin et al.[5] is included.

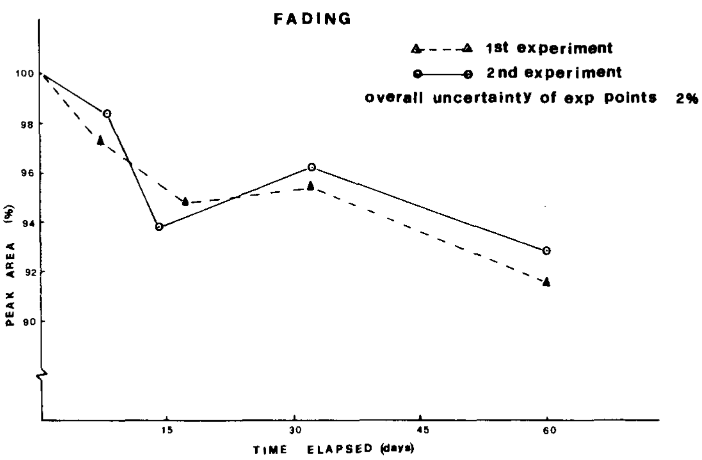

Fig. 4- Fading of BeO as resulted from two standard experiments.

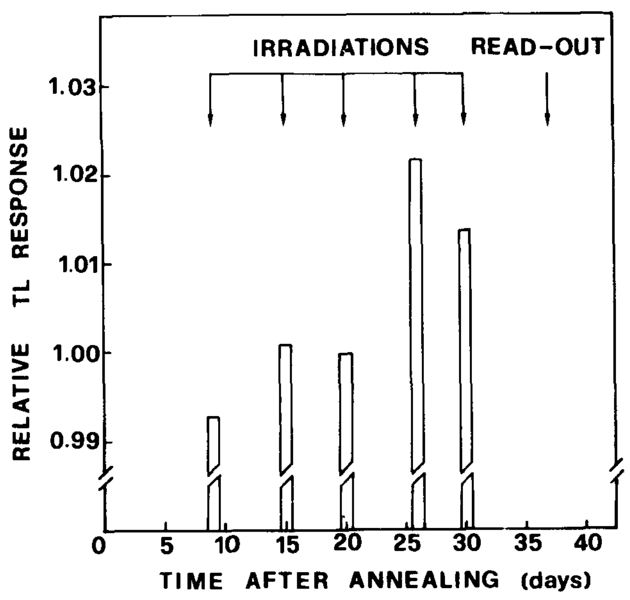

Fig. 5- Time-dependent variations of response of BeO in a typical time sequence simulating conditions met in health physics monthly measurements and dose intercomparisons.

c) Time-dependent variations of response.

A typical set of curves representing the fading characteristics of BeO is shown in figure 4. These curves were obtained by a standard experiment on fading, carried out by irradiating a number of freshly-annealed BeO discs and storing them (in the dark and at room temperature) for a variable period of time before readout. The initial drop of 5 to 6% during the first two weeks, the slight "recovery" at the end of the first month and the rather slow decay afterwards, reaching 8% at the end of the second month, are clearly illustrated.

Another experiment was then arranged in order to simulate more closely the actual time sequence of the above mentioned applications of TLD, i.e. health physics personnel dosimetry and postal intercomparisons of absorbed dose, in which all the dosimeters are initially annealed and finally read simultaneously, but irradiated at different time intervals in between.

As diagrammatically shown in figure 5, in this experiment a 37-days interval was selected between annealing and final readout, as an approximation to typical conditions met both in monthly badge checks and in international dose comparison runs.

The results are included in the same figure 5 in terms of average TL response of each single set of dosimeters, normalized to unity for the set irradiated on the 20th day after annealing.

Even if a slight build-up trend can be observed, the deviations are rather small, not exceeding $\pm$ 2%. From this relative stability of response a sort of compensatory effect can be inferred between fading on one side (as shown in figure 4) and something equivalent to an increase of sensitivity to radiation with annealing-to-irradiation time, on the other side.

Comments

Basing on the results of the present study and of previous contributions [1,2,3], and comparing these results with the ones reported for other TL solid dosimeters, it is apparent that ceramic BeO of commercial electronic grade could be used instead of doped LiF and $Li_2B_4O_7$, both in radiation protection measurements and in intercomparisons of dose by mailed dosimeters.

As far as health physics measurements are concerned a distinction should be made between routine personnel dosimetry (low dose levels) and accident dosimetry (medium and high dose levels).

Below 20-30 R the dosimetric characteristics of ceramic BeO are roughly the same as those reported for solid LiF: this applies to sensitivity (background equivalent to about 30 mR for 0.25 in. discs and model 2000 Harshaw reader), energy dependence (top value: 1.35 at 150 KeV) and fading in the dark (see above).

Irradiated BeO is highly sensitive to ambient light, with special reference to u.v. component, but this drawback can be easily overcome using the ordinary light-tight kind of badge used in film dosimetry.

On the other hand, as mentioned at the beginning of this study, distinct advantages of BeO over LiF and other TL materials are the very simple and quick annealing procedure (only 5 min at 600 °C), the absence of multiple and spurious peaks in the useful part of the glow-curve, the high insensitivity to mechanical shocks, the chemical inertness, the low cost (around 50 cents for 0.25 in. diameter discs) and the absence of appreciable changes of sensitivity even after very heavy irradiations (up to 10^5 R).

As to the accident dosimetry, a drawback of BeO could be the lower dose level at which supralinearity appears (20-30 R, compared to 500-1000 R for LiF and $Li_2B_4O_7$). This requires a set of calibrations to be carried out in order to derive the whole response curve. On the other hand, all the above mentioned advantages still apply in this field.

Dose intercomparisons made by very small sized dosimeters, deliverable by ordinary post, are an ideal field of application of TLD. In this respect, the good mechanical and chemical properties of BeO, its high long-term stability, its moderate energy-dependence and its very good reproducibility in the medium range of doses, seem to put this material in a position of privilege. This had to be confirmed by pratical experiments: for this purpose BeO ceramic discs have been added to ordinary LiF powder filled containers during the second dose intercomparison among radiobiologic laboratories organized by the European Late Effect Project Group (EULEP). The results of this experiment, though still under evaluation, seem to give further support to the concrete possibility of using BeO as transfer dosimeter in intercomparisons.

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