Evaluation of glasses containing cadmium for high dose dosimetry by the thermoluminescence technique

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Abstract: New glass matrices were evaluated for high dose dosimetry by the thermoluminescence technique. Their nominal composition are $20Li_2CO_3.10Al_2O_3.15CdO.55B_2O_3$ and $20Li_2CO_3.10Al_2O_3.20CdO.50B_2O_3$ (mol%). The glass matrices were irradiated with different doses: 50, 100, 200, 500, 700 and 900 Gy, and the thermoluminescence emission curves were obtained for each of these values. The results show a great potential of using these matrices in high dose dosimetry.

Keywords: dosimetry, termoluminescence, glass matrix, high doses, radiologic protection.

1. INTRODUCTION

The usage of high doses of radiation is becoming a field with promising growth. The processes which involve doses in the range of 10 Gy to 100 kGy are characterized as high doses and are becoming more common.

High doses of radiation are used in a variety of processes, for example: gammagraphy, curable inks and varnishes, polymerization of wires and cables, irradiation of semiprecious stones and food, sterilization of surgical materials, among others [OKUNO *et al*., 2010].

In these processes, it is necessary the implementation of an efficient quality control to ensure that the correct amount of dose is delivered to the product. Usually, for high dose dosimetry, glass matrices are used and the reading process is made via the thermoluminescence technique [McLAUGHLIN *et al*., 1989].

The thermoluminescence (TL) process is a phosphorescence emission after an thermally stimulation. In an ideal insulating, the electrons host the valence band, the conducting band is empty and the separation between then is called forbidden band, where there are no energy levels [McKEEVER *et al*., 1995].

When the material is irradiated, if the photon's energy is enough to overcome the energy difference between the valence and conducting bands, the electrons will absorb that energy and transfer to the conducting band leaving holes (vacancy spaces) in the valence band.

If the material has a dopant - in our case CdO - there will appear energy levels within the forbidden band. These energy levels function as traps for the electrons and holes. The charges will remain trapped until a stimulation - in this case thermal - release then. When the electrons are back again to the conducting back, there is a probability of having a recombination with a hole and emit what is denominated a TL photon.

As the light emitted by the material turns more intense it means that there are more recombination of electron-holes pairs. As the material is heated it possible to obtain a curve of the intensity of the TL light in function of the temperature. This is called a TL emission curve.

The population of electrons that were trapped and then released represents the radiation dose that this material received. Therefore, there is a direct relation between the emission curve and the absorbed dose by the material [McKEEVER, 1988].

Several glasses have the potential to be applied as high-dose dosimeters, by its small size, low production cost and dosimetry properties [TEIXEIRA, 2004]. Glasses containing Cadmium (Cd) have been evaluated and showed promising results of being used as dosimeters [MANOHARA *et al*., 2015; ANJAIAH *et al*. 2014]. However, it is necessary more research to evaluate how the modification on the concentration of Cadmium affects in the dosimeter response, which justify this work.

2. METHODOLOGY

The glass matrices were synthesized by the fusion method in a silicon carbide at 1350ºC for 15 minutes over carbon atmosphere. The cooling process was made between two plates of copper-brass at 0ºC, and thermally treated at 350ºC for 12 hours. The irradiation took place in a Gamma Cell-220 equipment that uses a ^{60}Co source with a dose rate of 1.38 kGy/h.

The samples were positioned at 10 cm far from the source. The irradiation equipment used is located at Centro de Tecnologia das Radiações, Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN/SP) at room temperature. In order to guarantee electronic equilibrium during the irradiation, the samples were covered with a 3 mm layer of polymethylmethacrylate.

After irradiation, the termoluminescence emission curves were obtained in a Harshaw TLD 4500 reader, coupled in a computer, for data acquisition. The measurements were done from room temperature until the reader reaches 400ºC using a constant flow of N_2 of 2,5 L/min, and a heating rate of 10ºC/min.

3. RESULTS AND DISCUSSION

The first glass matrix composition used was $20Li_2CO_3.10Al_2O_3.15CdO.55B_2O_3$ (mol%). This matrix was irradiated with the following amount of dose: 50, 100, 200, 500, 700 and 900 Gy. After the reading process, it was obtained the TL emission curve showed in figure 1.

The TL curve has an increasing response as doses increases, but there is an indicative of saturation at 700 Gy. For 700 and 900 Gy, there is a single defined peak located at 225ºC and 200ºC, respectively.

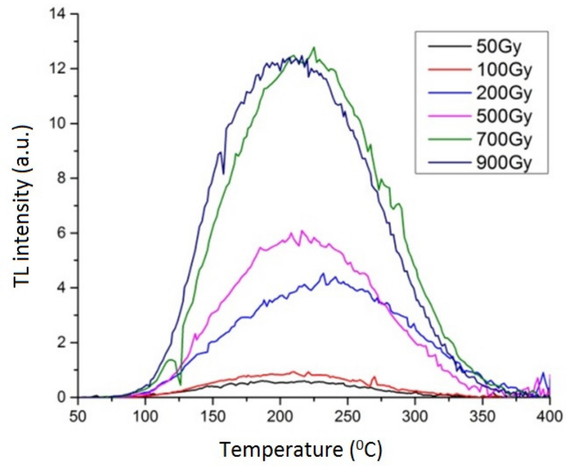

Figure 1 - TL emission curve of glass matrix of composition $20Li_2CO_3.10Al_2O_3.15CdO.55B_2O_3$ (mol%) for high doses.

The next glass matrix analysed had composition $20Li_2CO_3.10Al_2O_3.20CdO.50B_2O_3$ (mol%). It was irradiated by the same values of dose as the first matrix, and the TL emission curve is available in figure 2.

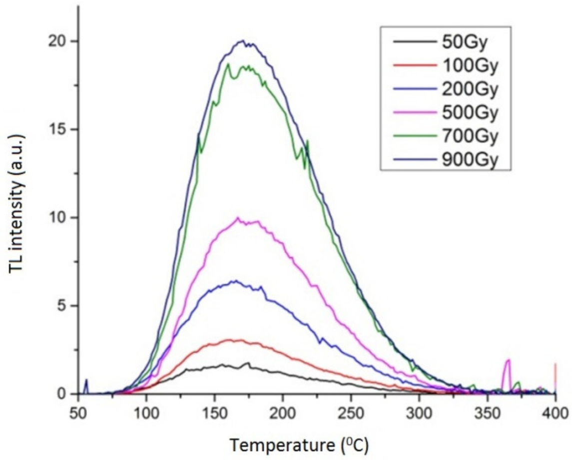

Figure 2 - TL emission curve of glass matrix of composition $20Li_2CO_3.10Al_2O_3.20CdO.55B_2O_3$ (mol%) for high doses.

In this case, there is a more uniform growth response than the previous matrix. The main dosimetry peak is located at 175ºC and it shows a slight saturation at 900 Gy that must be investigated through more tests.

4. CONCLUSION

It was observed that the matrix with a greater concentration of Cadmium (20 Cd) has a better response, that is easier to be treated quantitatively than the first matrix (15 Cd). Both of them presented their TL peaks above 150ºC. More tests will be made order to fully characterize the dosimetric properties of these materials, but these results demonstrate their potential for high dose dosimetry.

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