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Effects of Ionizing Radiation on Bromine Doped Cesium Iodide Scintillator Crystals

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1. Introduction

Since the beginning of the study of radiation at the end of the 19th century and beginning of the 20th century, scintillating materials have been used as detectors. Rutherford, in 1910, used the scintillation produced on a zinc sulfide screen as an alpha particle detector. The method used, however, involved counting the scintillation points with the help of a microscope, which made the process very time-consuming and inefficient[1] and, therefore, the scintillation detectors were left in the background for several years. However, in the 1940s, photomultiplier tubes, capable of amplifying and transforming the weak light emitted by scintillators into an electrical signal, became commercially available, which made scintillation radiation detection one of the most used to this day, with various types of detectors for different applications.

Continuous exposure to high-energy radiation, however, contributes to detector degradation. The appearance of absorption bands, decreased light emission and unwanted phosphorescence are just some of the possible products of this degradation[2]. Therefore, it is necessary to understand how prolonged interaction with ionizing radiation affects detector materials so that these materials can be used in the best conditions and for as long as possible.

2. Methodology

High quality and high purity CsI (99.99%) and CsBr (99.99%) raw materials in powder forms were obtained commercially. The cesium iodide salt was weighed and then added to the quartz crucible, then cesium bromide was added with a concentration of 10^{-2} M in relation to CsI. The quartz crucible was taken to the vacuum line at 10^{-5} Pa and heat treated to remove moisture from the salts. In this procedure, a temperature of 200 °C was applied for 4h.

0.05% of metallic iodine was added in granules in relation to the mass of CsI. For this procedure, a glovebox was assembled, which was filled with argon gas in order to leave an inert atmosphere, without the presence of oxygen. After inserting the iodine, the crucible was taken to the vacuum line until it reached 10^{-5} Pa and then sealed.

After being sealed, the crucible was taken to the vertical oven for crystal growth using the Bridgman technique. The thermocouple was coupled to the crucible in order to monitor the temperature variation in the furnace. The crucible moved to the hottest area of the oven, where it remained until all the salt was melted. After the salt was melted, oven programming began. The crystal growth process using the Bridgman technique requires special care in preparing the starting material, choosing the material from which the crucible is made and its geometric

Figure 1: CsI:Br crystal before (left) and after (right) the heat treatment.

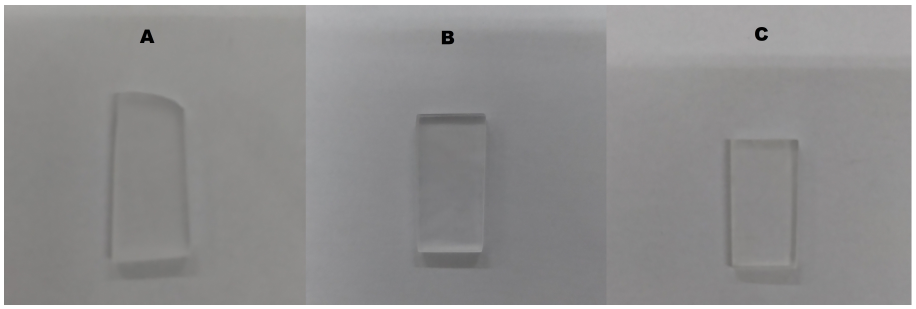

Figure 2: Samples used for transmitance measurements.

configuration and growth speed. This process lasted 96 hours, in which the quartz crucible was moved to the coldest area of the furnace, the entire process had a speed of 1mm/h.

After growth, heat treatment began, transferring the CsI:Br crystal with dimensions of Ø 26 mm X ↑ 40.60 mm to a clean quartz tube. In this procedure, a continuous vacuum of 10^{-5} Pa and a temperature of 350 ^{o}C were used for 24 h. Figure 1 shows the CsI:Br crystal before and after heat treatment.

After heat treatment, the crystal was cut with the Buehler cutting equipment, ISOMET 11-1180, with a disc with a diamond edge and ethylene glycol P.A. ($C_2H_6O_2$) for lubricating the disc; obtaining three crystals, shown in figure 2, with dimensions 29.0 mm x 11.0 mm x 3.2 mm, with sample A having a shorter end at 10.2 mm due to problems with the blade during cutting. The cut was made slowly, avoiding mechanical shocks. Then, Sontara material (DuPont), a highly absorbent and resistant non-woven fiber, composed of 70% viscose and 30% polyester, was used to polish the crystal. To carry out the polishing, fiber was used together with ethylene glycol, used as an abrasive, to facilitate polishing, on a flat glass plate, on which light movements were made in the shape of a "figure of eight". This movement is important so that the crystal has a uniform surface. The process was completed when a transparent crystal with uniform dimensions was obtained. The crystals were irradiated with ^{60}Co gamma radiation in an irradiator Gammacell 220 from Atomic Energy of Canada in doses of 9 kGy (sample C), 20 kGy (sample B) and 30 kGy (sample A), with sample B being irradiated 3 more times with doses of 20 kGy and one of 30 kGy, resulting in measurements of 40 kGy, 60 kGy and 90 kGy.To do so, the samples were placed in a Styrofoam holder to centralize them in the exposure chamber and ensure that all measurements were in the same position.

Transmittance measurements were taken immediately before and after the irradiation and in set intervals afterwards.

3. Results and Discussion

Figure 3 shows the transmittance of the samples before irradiation, right after it, and then after 14 and 28/29 days, except for sample A, which was not measured again after 29 days.

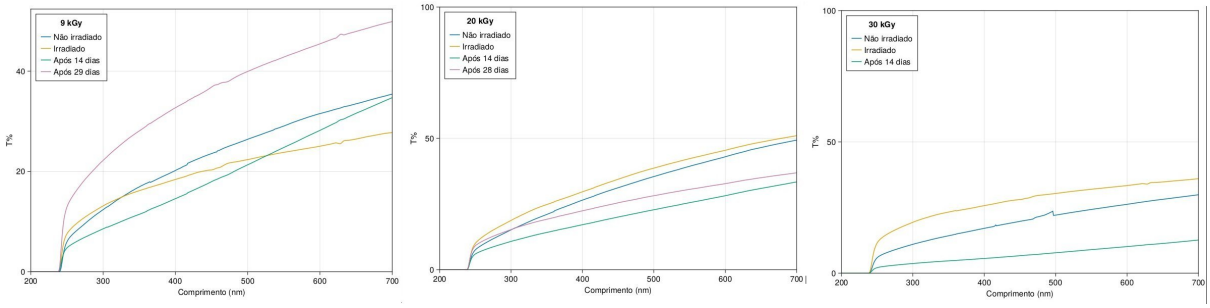

Figure 3: Enter Caption

Sample C showed a decrease in transmittance right after irradiation, followed by an increase in longer wave lengths and another decrease in smaller ones after 14 days, but a high increase overall after 29 days. Sample B showed similar patterns, but with a lower increase on the last measurement, which might be an effect of the higher dosage. Sample A seems to follow the others, however, with the missing measurement after 29 days, it is not possible to tell confidently. Their behaviour might have to do with the fact that, for ionic crystals, when an atom is diplaced to interstitial positions in their cells, the increase in electrostatic force in the region might be enough to force said atoms to more stable positions over time, a proccess that could be enhanced simply by protecting the crystals from direct light [3, 4, 5].

4. Conclusions

The transmittance of the crystals is a property heavilly affected by irradiation. All samples showed a decrease in it after irradiation, with some being capable of recovering slightly as time passes. This susceptibility might be linked to the fact that high energy radiation can dislodge atoms from their positions, creating interfaces e scattering and color centers that eventually diminish the material's ability of emiting light.

Acknowledgments

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