2015 International Nuclear Atlantic Conference - INAC 2015
São Paulo, SP, Brazil, October 4-9, 2015
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-06-9**

HIGH-DOSE DOSIMETRY OF BETA RAYS USING BLUE BERYL DOSIMETERS

Lucas S. do Carmo[1], Shigueo Watanabe[2] and José F. Bittencourt[2]

[1]Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
lsatiro@usp.br

[2]Instituto de Física – Departamento de Física Nuclear
Universidade de São Paulo
Rua do Matão, Travessa R, 187
05314-970 São Paulo, SP
Lacifid@if.usp.br

ABSTRACT

High dose radiation is widely used in industrial applications as sterilization of medical products, improvement of materials properties, color enhancement of jewelry stones, etc. The radiation dosimetry of high doses is quite important for these applications. In this work we have investigated the usage of blue beryl crystal also known as aquamarine in high dose dosimetry of beta rays. Some works have shown that silicate minerals exhibit a good Thermoluminescent response when irradiated up to 2000 kGy of gamma rays. Here, we have produced small beryl pellets of approximately 5 mm in diameter and 3 mm thickness to measure high doses of beta rays produced at an electron accelerator at IPEN. Twelve beryl dosimeters were made and six of them were irradiated from 10kGy up to 100 kGy. The technique used to create a calibration curve was the thermoluminescence using the glow peak at 310°C.

1. INTRODUCTION

Nowadays, activities involving high-doses of ionizing radiation are very common. The measurement of the absorbed dose involved in these activities became a very important task. Since long back, the thermoluminescence technique has been used in radiation dosimetry [1] and different materials have been developed for measure low doses as for high doses of ionizing radiation. For high-dose TL dosimetry we can highlight the LiF: Mg, Cu, P (MCP) that can measure doses up to 1 MGy. This material was extensively studied by IFJ group from Krakow, Poland. This group has tested these materials under irradiation with γ-rays, electrons and protons beams, alpha particles and also neutrons. Their most important result is that these materials, particularly the MCP materials, exhibit interesting and unexpected behavior when irradiated with high doses of up to 500 kGy. A high-temperature TL peak is observed at above 300 °C, and this peak shifts to higher temperatures of up to 460-470 °C as the dose reaches approximately 500 kGy. These authors refer to this peak as peak B[2-5].

Natural Brazilian silicates have been also reported to measure high-doses of ionizing radiation. Souza et. al. [6] have analyzed the usage of natural Brazilian topaz as radiation dosimeter in two different configurations. The first one consists in topaz powder mixed with

Teflon in the ratio 1:2 (wt) to produce small pressed pellets with 6 mm diameter and 1 mm thickness. The second one consists in topaz powder mixedwith glass powderin the ratio 1:1 (wt) to produce small pressed pellets with 6 mm diameter and 1 mm thickness as well. The results reported that doses raging from 10^{-4} to 10^{5}Gy can be measured using this Brazilian topaz pellets.

Natural beryl silicates have also been reported as high-dose dosimeter. Watanabe et. al. [7] have submitted to high-doses of gamma rays three different varieties of a beryl silicate: aquamarine (blue), goshenite (transparent) and morganite (reddish). Aquamarine and goshenite have been exposed to radiation doses from 100 kGyup to 2000 kGy and morganite has been exposed to radiation doses from 1 kGy up to 20 kGy. The result reported that the TL signal from aquamarine and goshenite grows up to 250 kGy and 1250 kGy, respectively, and thenit saturates, but if doses are applied beyond these limits, the TL signal starts to decrease regularly until the dose reaches 2000 kGy, this decreasing in TL signal can be used in radiation dosimetry.

In this work a dosimeter made of aquamarine (blue beryl) was used to measure high-doses of beta rays. Here, we refer as "high-dose" any absorbed energy above 1 kGy. All the irradiation process and TL readouts was carried out at IPEN (Institute for Nuclear and Energy Research) and LACIFID (Laboratory of Ionic Crystal, Thin Films and Dating) respectively.

2. MATERIALS AND EXPERIMENT

As it's well known, beta rays (or accelerated electrons beam) interact differently with the matter compared to gamma rays, then in order to produce a beta rays dosimeter some parameters have to be considered as the electron energy, the dosimeter shape and the dose range. We first tried to use powdered blue beryl, but the TL signal from the irradiated powder showed a high variation between the readouts, indicating that the dose was not being regularly distributed through the beryl grains. In order to solve this problem, was proposed using small pressed pellets. The advantages in using pellets are the constant exposed area to the electron beam, the constant mass and the possibility in reuse many times the same dosimeter. The irradiation process was done using a 1.5 MeV Radiation Dynamics electron accelerator from CTR (Radiation Technology Center) at IPEN.

The blue beryl pellets production follows some steps. 1)crushing and sieving of a blue beryl natural stone to retain grains between 0.180 mm and 0.075 mm; 2) an amount of 2 grams from this powder was put together with silica balls inside a well-locked pot. This set was put in a rotating mill for 2 day (48 hours) to produce very small grains of blue beryl; 3) the resulting powder was pressed and sintered at 850°C for five hours to get beryl pellets ready for use. Twelve dosimeters were produced, but for experimental reasons only six were irradiated.

Radiation dose ranges from 10kGy up to 100 kGy and the TL measurements were performed in a nitrogen atmosphere using a model 4500 Harshaw TL reader equipped with twophotomultiplier tubes, which could record luminescence signalsindependently. The reader was controlled by WinREMS Software, which was supplied with the spectrometer and was run on a Windows computer. The heating rate used in the TL measurements was 4 $C.s^{-1}$.

3. RESULTS

As mentioned before, twelve dosimeters were made but only six were tested. The characteristic adopted in order to choose six from twelve dosimeters was the shape of the glow curve that is seen in fig. 1. The glow curve should exhibit a regular growth of TL intensity as function of the applied dose.

Fig. 2 shows the TL response as function of dose (namely, calibration curve) for each dosimeter irradiated. The dosimetric peak adopted here is that at 310 °C due to be located at higher temperatures, which means a high stability. It exhibits a constant growth with dose and seems to move towards higher temperatures as the dose increases, such feature has also been seen in the LiF: Mg, Cu, P [4].The glow peak at 235 °C grows up to 30 kGy and then starts to decrease when higher doses are applied.

Table 1 show the mass measured after sintering. A mass loss is observed for all dosimeters. The mean value is 29.2 ± 4.11.

Table 1 Mass after sintering

Pellet Id	Mass (mg)
P-1	29.0
P-2	32.5
P-4	27.2
P-5	31.1
P-6	23.1
P-7	29.5

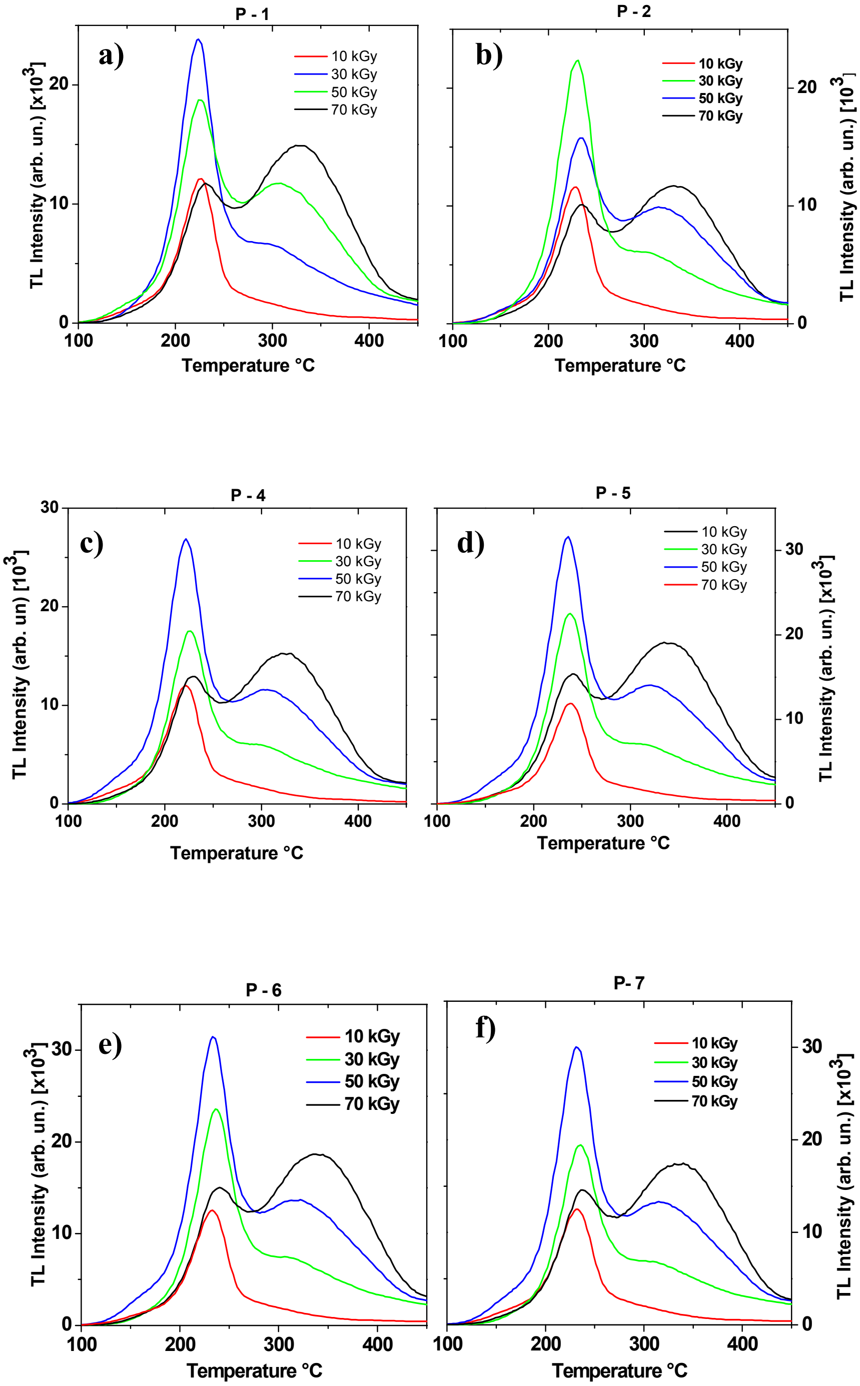

Figura 1:TL glow curves of each dosimeter irradiated showing the dosimetric peak at 310-340 °C and the lower temperature peak at 230 °C

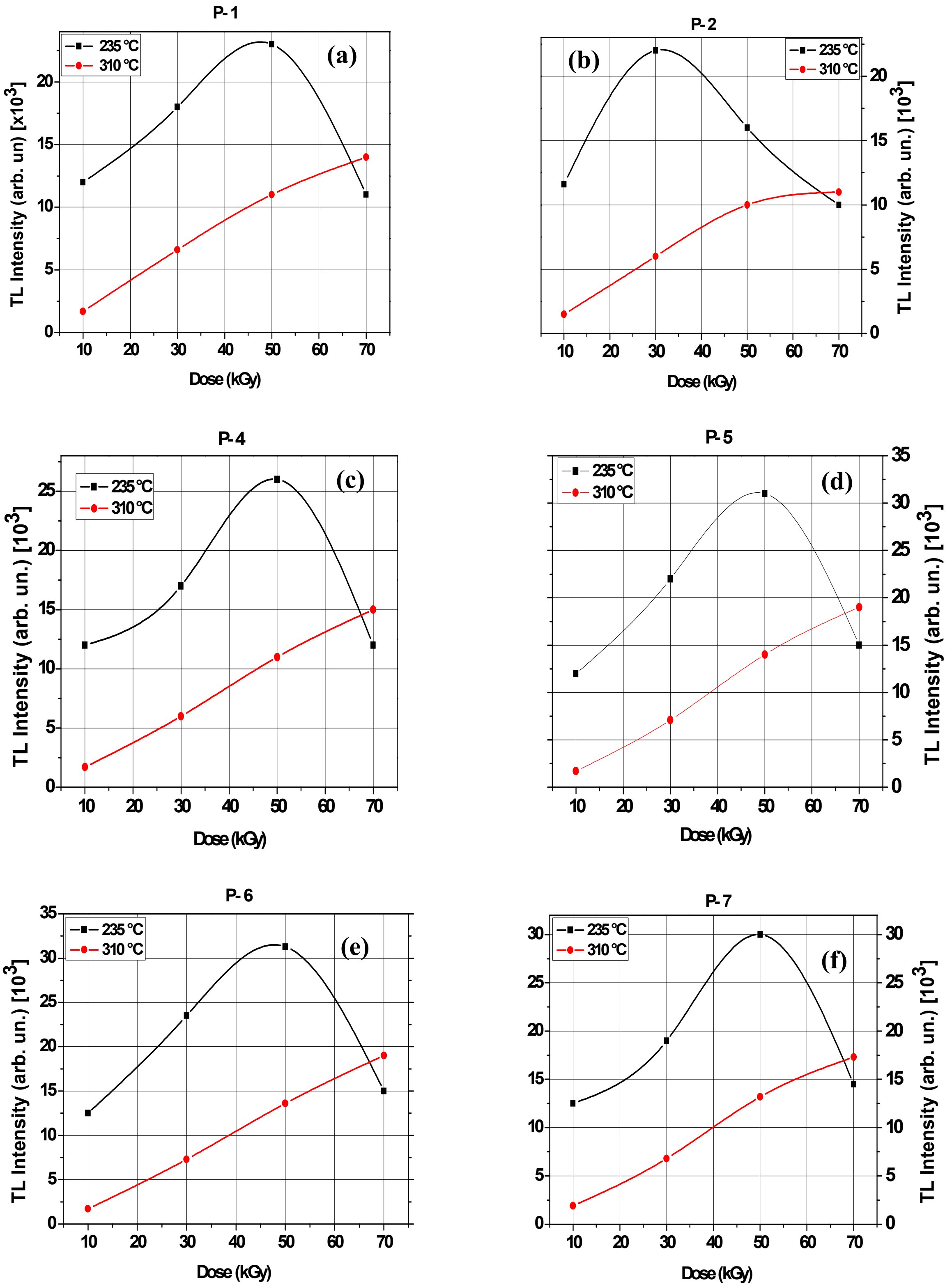

Figura 2:TL response as function of dose for each dosimeter irradiated showing the behavior of both peaks presented by blue beryl pellets

4. COMMENTS AND CONCLUSIONS

Silicate minerals have a good TL emission indicating a high sensitivity for ionizing radiation. The usage of such mineral in radiation dosimetry has been evaluated for some authors and some of them agree in that a high-dose dosimetry can be performed using silicate minerals.

The glow curve from all dosimeters have shown two main peaks, one at 230 °C and another at 310 °C that shifts to 340 °C while dose increases. The dose-dependent TL response is seen in fig. 2 and shows that the 230 °C peak decreases in intensity when doses higher than 30 kGy are applied. The 310 °C peak grows almost linearly for all dosimeters which is a desirable behavior for radiation dosimetry.

In this way we can say that blue beryl pellets can be used for high dose dosimetry of beta rays using the 310 °C glow peak. Further experiments are being carried out in order to measure high doses of gamma rays from an industrial irradiator, proton beams and heavy charged particles from a particle accelerator at Physics Institute of USP.

ACKNOWLEDGMENTS

The authors wish to thank Ms. E. Somessari and Mr. C. Gaia, IPEN, Brazil, for kindly carrying out the irradiation of the samples. This work was performed with the financial support of the FAPESP and CAPES.

REFERENCES

1. D.T.BARTLETT, “100 years of solid state dosimetry and radiation protection dosimetry”, *Radiation Measurements,* **v.43**, pg. 133-138 (2008)
2. P. BILSKI, B. OBRYK, Z. STUGLIK. “Behaviour of LiF:Mg,Cu,P and LiF:Mg,Ti thermoluminescent detectors for electron doses up to 1 MGy”, *Radiation Measurements*, **V. 45**, Issues 3–6, P. 576–578 (2010)
3. V. KORTOV, Y. USTYANTSEV. “Advantages and challenges of high-dose thermoluminescent detectors”, *Radiation Measurements*, **v.56**, pg. 299-302, (2013)
4. B. OBRYK, P. BILSKI, P. OLKO. “Method of thermoluminescent measurement of radiation doses from micrograys up to a megagray with a single LiF: Mg, Cu, P detector”, *Radiation Protection Dosimetry*, **vol. 144**, No 1 – 4, pp. 543 – 547, (2011)
5. B. OBRYK, P. BILSKI,P. OLKO. “Method of thermoluminescent measurement of radiation doses from micrograys up to a megagray with a single LiF: Mg, Cu, P detector”, *Radiation Protection Dosimetry*, **vol. 144**, No 1 – 4, pp. 543 – 547, (2011)
6. D.N. SOUZA, J.F. LIMA, M.E.G. VALERIO, L.V.E. CALDAS. “Performance of Pellets and Composites of Natural Colourless Topaz as Radiation Dosemeters”, *Radiation Protection Dosimetry*, **Vol. 100**, Nos 1–4, pp. 413–416, Nuclear Technology Publishing, (2002)
7. S. WATANABE, N.F. CANO, L.S. CARMO, R.F. BARBOSA, J.F.D. CHUBACI. High- and very-high-dose dosimetry using silicate minerals, *Radiation Measurements,* **V. 75**, pg. 66-69, (2015)