BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-01A (2021) 01-12

Characterization of TL and CW-OSL signals of natural Brazilian topaz with different colours

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ABSTRACT

Topaz [$Al_2SiO_4(OH,F)_2$] is usually found in nature and can present different colors. The aim of this paper is to evaluate the Thermoluminescence (TL) and the Optically Stimulated luminescence (OSL) response of five types of topaz collected from three different Brazilian states. The topaz samples studied have a yellow, blue and colorless coloration. The TL results showed that colourless samples from the state of Rio Grande do Norte (RN) present a TL glow curve with the main peak at ~260ºC. The others colourless topaz from Teofilo Otoni and Mato Grosso do Sul. Besides the peak of ~260ºC, they present another peak at 160 ºC. Yellow and blue topaz don't showed a high luminescence signal for the radiation doses studied. The highest TL intensity was observed with the colourless topaz from RN. A linear TL response curve was also observed with these samples from the gamma radiation of ^{60}Co in the range of 0.01 Gy to 3.5 Gy. The Blue Light Stimulation (BSL) showed almost the same intensity response for the three colourless topaz samples. None topaz sample showed response to Optical Infrared Stimulation (IRSL).

Keywords: **Brazilian topaz, thermoluminescence (TL), optically stimulated luminescence (OSL).**

ISSN: 2319-0612
Accepted: 2020-11-22

1. INTRODUCTION

Topaz is an aluminum fluorsilicate with a chemical formula of Al_2SiO_4 (OH,F), that is found as colourless, yellow, orange, red, blue and green colour varieties depending upon origin [1]. It is a class of silicates and a density of about 3.4 ~ 3.6 g/cm^2. Wunder et al. (1993) [2] found that in topaz there is a strong correlation between [OH]/[OH$^+$F] ratio that contributes to its colour type. The substitution of the F ion by the OH group is considered the main defect [3].

In Brazil some types of topaz can be found, such as the imperial topaz that comes from the state of Minas Gerais; blue topazes found also in the states of Minas Gerais, Ceará and Bahia [4]. According Wise *et al.* (1995) [5], the colour of the Brazilian topaz is due to the several impurities presents in the crystal, such as V, Cr, Fe and Mn.

As observed in many type of minerals, natural topaz exhibit luminescence emission, that is of great interest since it could be potentially employed for radiation dosimetry. There are several studies reported in the literature about thermoluminescence (TL) property of topaz from different regions. Moss & Mcklveen (1978) [6] studied the TL characteristics of topaz chips from Utah Mountains (USA) and observed that this topaz offers a TL response to satisfactory radiation in intensity and reproducibility. The saturation value for absorbed dose of gamma radiation up to 10^5 Gy suggests its use as dosimeter for high doses. Azorin *et al.* (1982) [7] studied the TL response of the topaz samples collected from Mexico for gamma radiation of ^{60}Co, and they observed a linear response with doses between 10^{-2} to 10^3 Gy. Souza et al. (1995) [8] studied topaz samples from Brazil and found that topaz is a promising material for dosimetric applications in radiation sources that usually employed high doses of radiation.

As far as we know, there are few studies about the Optically Stimulated Luminescence (OSL) proprieties of natural topaz [9]. The purpose of the present work is to evaluate the TL and OSL responses of five natural topaz samples originated from different deposits in Brazil and that with different colors, in order to obtain a dosimeter to be used in radiotherapy or in industrial applications

2. MATERIALS AND METHODS

2.1. Sample collection and preparation

For this study, we selected five Brazilian topaz samples with different colors and obtained from Brazilian States of Rio Grande do Norte (RN), Mato Grosso do Sul (MS) and Minas Gerais (MG) from different districts as shown in Table 1. Figure 1 shows the image of some of these samples used in this study. Initially the crystals were cleaned to remove superficial encrustations and then the crystals were ground and sieved to select grain size from 75 to 150μm.

Table 1: Origin and colour characteristic of the topaz samples studied in this paper.

Sample	Provenance		Colour	Identification
	State	City		
Number 1	Minas Gerais (MG)	Teofilo Otoni	Colourless	TEO topaz
Number 2		Ouro Preto	Yellow	Imperial topaz
Number 3		Governador Valadares	Blue	Blue topaz
Number 4	Rio Grande do Norte (RN)	NI	Colourless	RN colourless
Number 5	Mato Grosso do Sul (MS)	NI	Colourless	MS colourless

Figure 1: *Samples of natural topaz: (a) Imperial (yellow), (b) Teofilo Otoni (colourless), and (c) Blue Colour*.

(a) **(b)** **(c)**

Source: authors.

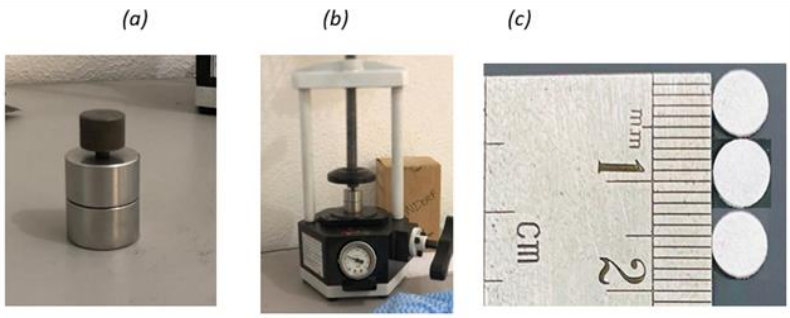
2.2. X-ray diffraction

The X-ray diffraction (XRD) of yellow, blue and colourless topaz powders was analyzed using the Rigaku equipment, model D /Max 2200, Cu-kα radiation. The difractograms were collected in the range of 10° to 70°. The XRD patterns were compared to the reference standard of the American Mineralogist Crystal Structure Database (AMCSD).

2.3. TL and OSL measurements

For the evaluation of the TL and OSL response, The powder samples were heat treated at 400oC for 3 hours. Then, pellets with a diameter of 6 mm and 1 mm in thickness were prepared. It was blending about 40 mg of powder sample with ~10mg of teflon. The powder (sample+teflon) was put inside a compression matrix. And it was applied a pressure of 500 kgf/cm^2 under a hydraulic press. Figure 2 shows the compression matrix, the hydraulic press and the pellet produced. It was produced 10 pellets of each type of topaz. And it was sellected 4 of each one with the closest mass and TL sensitivity are selected. The TL and OSL signals were measured with an automated Lexsyg Smart OSL reader equipped with an internal ^{90}Sr/^{90}Y beta source with a dose rate of 100 mGy/min. The TL glow curves were acquired using a heating rate of 5 °C.s^{-1}, with a wide-band-blue filter pack. The Blue Stimulated Luminescence (BSL) measurements were performed using illumination with blue LEDs with peak emission at 458 nm and power set to 80mW/cm^2. The BSL curves were acquired under constant illumination intensity mode (CW) using a 380 nm filter pack during 60 s and a channel time of 0.1 s. For Infrared Stimulation Luminescence (IRSL), a total reading time of 30 s was selected, with channel time of 0.1 s, LEDs emission peak at 850 nm, Wide-Band-Blue filter pack and power set to 250 mW/cm² .

Figure 2: *Pellets production setup (a) compression matrix, (b) hydraulic press, and (c) pellet*



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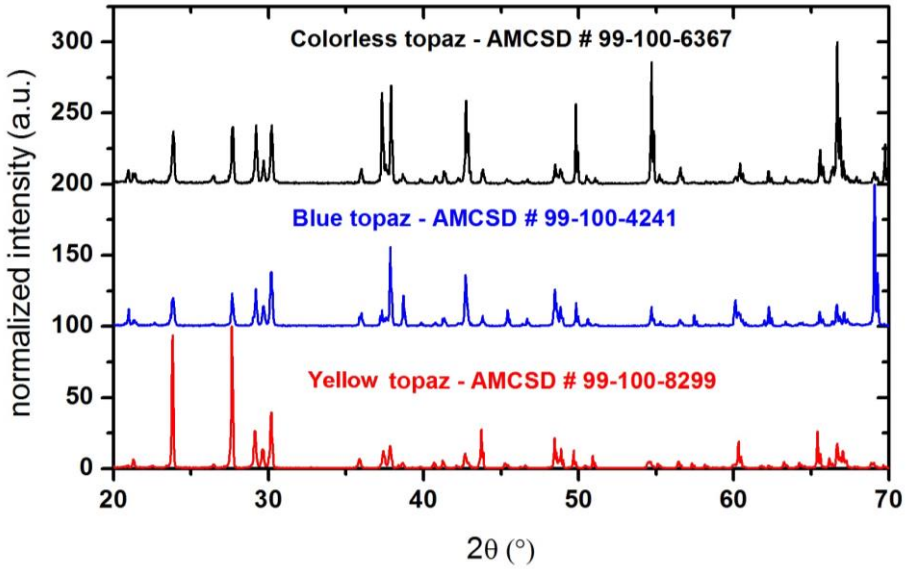
3. RESULTS AND DISCUSSION

3.1. X-ray diffraction

Figure 3 shows the x-ray diffraction pattern of the three topaz samples. The identification of the samples as topaz was confirmed by matching several peak portions with the standards of the American Mineralogist Crystal Structure Database (AMCSD).

Figure 3: *X-ray diffraction patterns of the topaz samples used in this study.*



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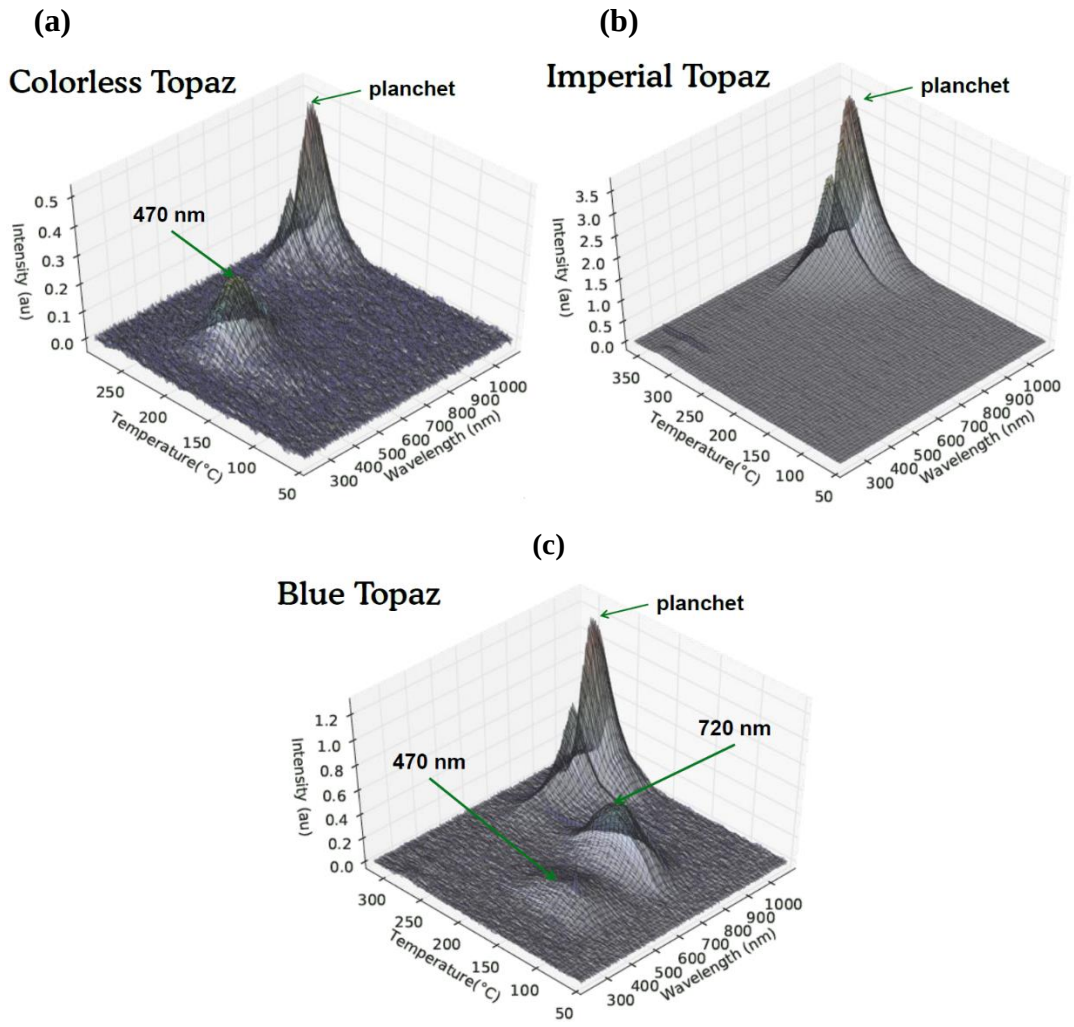
3.2. TL emission spectra

Figure 4 shows the TL emission spectra of three topaz samples. The results show that the colourless topaz samples present an emission spectrum at approximately 470 nm, and the yellow topaz does not exhibit emission spectra in the region evaluated. The blue topaz sample shows a low TL emission intensity at 470 nm and high light emission at 720 nm.

According to Souza et al (2006) [10] the emission at 470 nm can be traced to the $[AlO_4]^0$ defect, a center created when an impurity substitutes the Si^{4+} ion by three H^+ or Al^{3+}. This center $[AlO_4]^0$ was proposed by Mckeever (1991) [11] to explain the emission spectra of natural quartz.

Figure 4: *TL emission spectra of (a) colourless topaz, (b) yellow topaz, and (c) blue topaz. Dose: 4,5 kGy (Co^{60}).*



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3.3. TL Glow curves

Figure 5 shows the TL glow curves of five topaz samples evaluated in this study. The results show that the colourless topaz samples present a TL peak around 260 ^{o}C, being the highest TL sensitivity found for colourless topaz from RN. This sample also present a peak at the region of 350 ^{o}C. The glow curves of colourless samples from MS and from TEO show two peaks, one

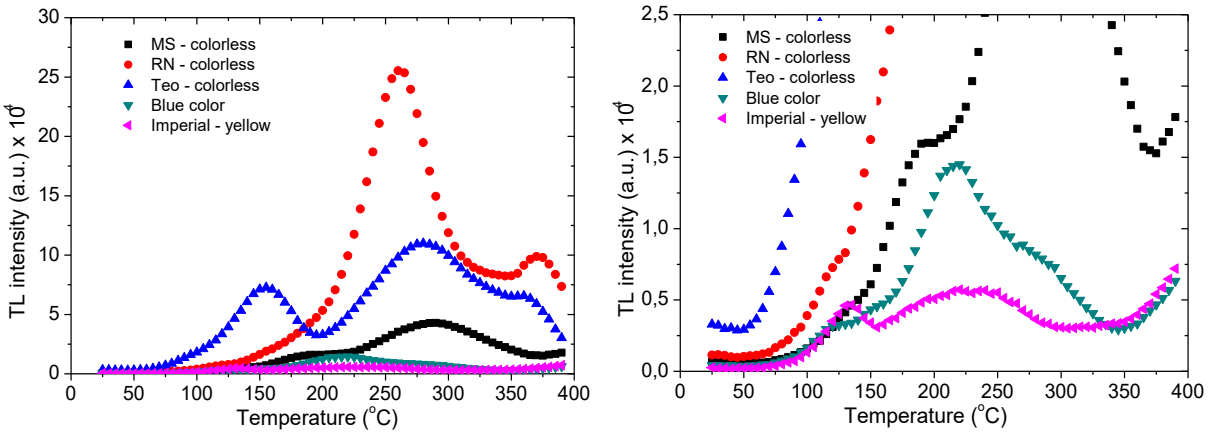
around 150 ^{o}C and the second around 260 ^{o}C, and sample from TEO/MG display a third peak in the region of 350 ^{o}C.

The blue topaz showed a small TL peak at approximately at 200 ^{o}C in the range of doses used in this study. The differences observed in the TL emission of the samples are related to their origin and consequently, to the impurities that can be different from one sample to another.

TL studies of Brazilian colourless and light blue topaz samples performed by Yukihara and Okuno (1998) [12] evidenced that colourless topaz showed a TL peak at 126 ^{o}C and at 192 ^{o}C , while the glow curve of the blue topaz exhibited two prominent peaks at the temperatures of about 122 ^{o}C (Peak 1), 195 ^{o}C (Peak 2).

The TL peaks observed in the glow curves are mainly composed of the emission band centered at ~470 nm, which is the region of the highest efficiency response of the photomultiplier of the TL/OSL reader.

Figure 5: *TL glow curves of five topaz samples. Heating rate of 5 ºC/s. Irradiated with ~500 mGy (Co^{60}).*



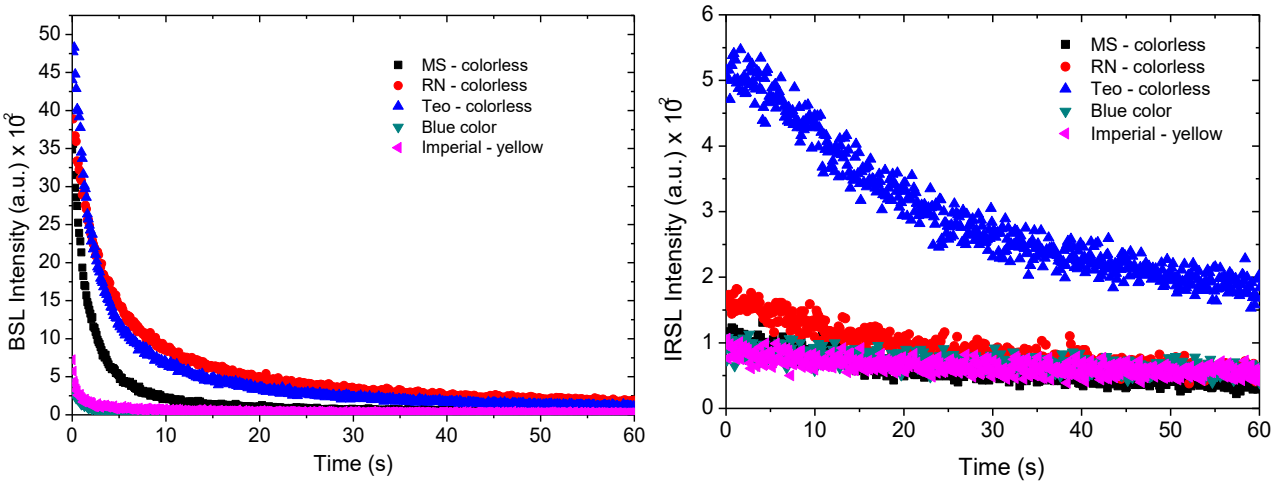
Source: authors.

Optical Stimulated Luminescence (OSL)

Figure 6 shows the OSL curves of the five topaz samples. The results show that the colourless samples show a high luminescence when stimulated by a blue LED. The colourless samples from TEO/MG and MS, despite their low TL response, present high BSL, comparable to that obtained

with RN samples. Both yellow and blue topaz shows a low sensitivity for blue stimulation. All the samples evaluated presented a negligible signal for IRSL stimulation, as can be seen in Fig. 5b.

Figure 6: *Decay OSL samples: a) blue stimulation and b) infrared stimulation. Irradiated with ~500 mGy (Co^{60}).*

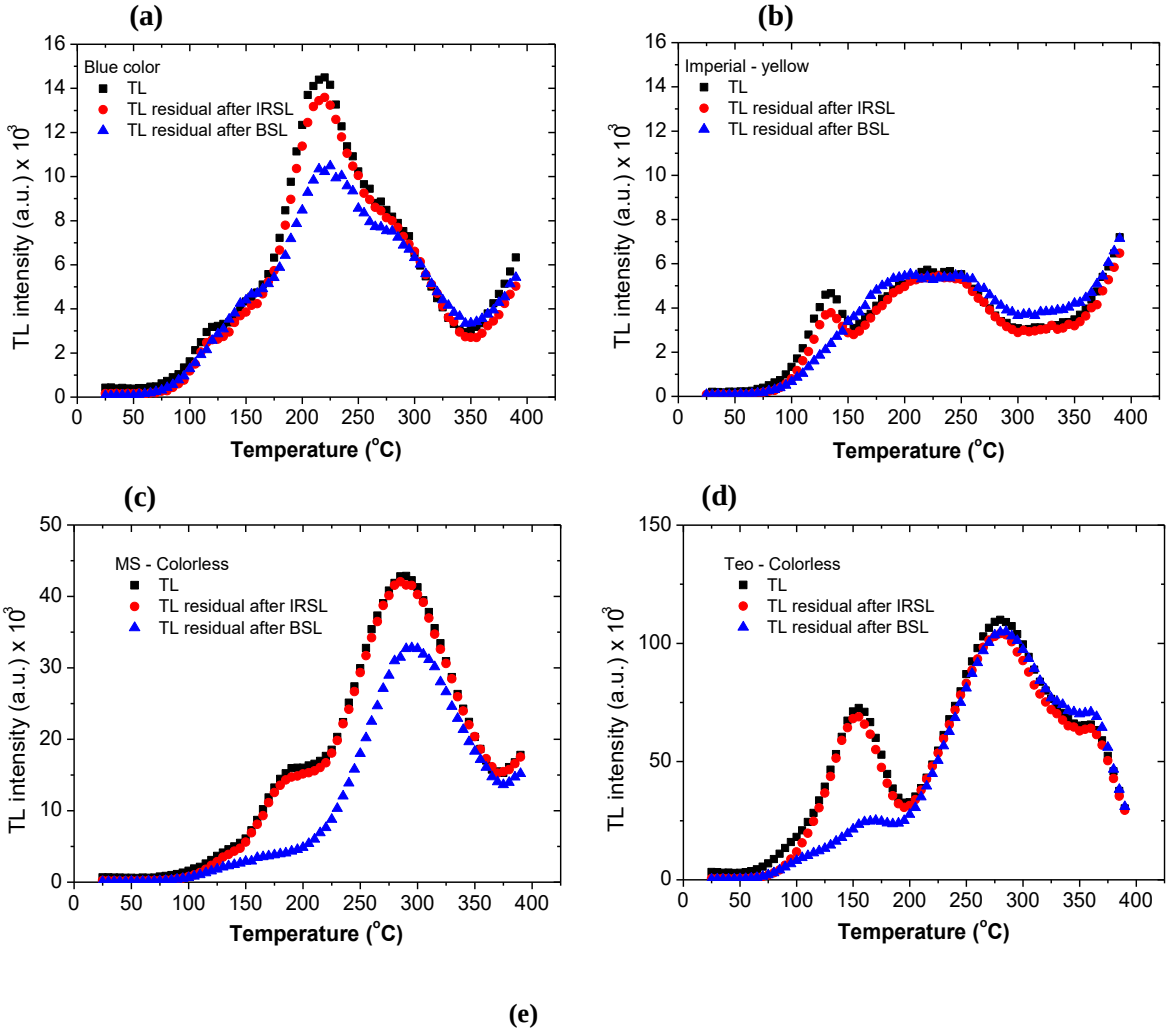


Source: authors.

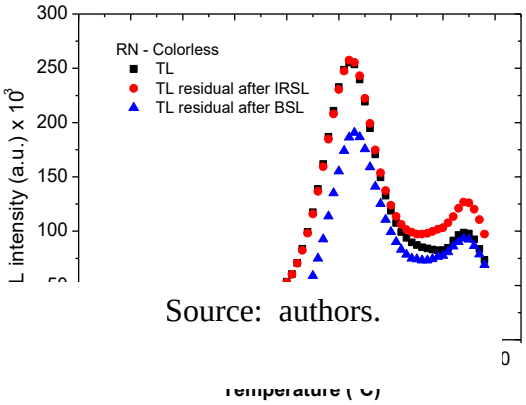
3.4. Residual TL Glow curves

After the OSL readings, TL glow curves were performed to obtain the residual TL showed in Figure 7. The results indicate that, for all the samples, there are no differences between the TL and the residual TL glow curves after stimulation by infrared. The blue samples presented a reduction around 15% in the peak at 260 °C after BSL stimulation. There is no difference for between peak at 150 °C.The two samples (yellow and TEO colourless), presented a TL glow curve with high reduction in the peak at 150 °C and no reduction of the signal at 260 °C. This indicates that their BSL decay curves are related to the superficial trap, and maybe they have a possible fading of the BSL signal. The residual TL glow curves of the colourless samples RN and MS showed a reduction around 30% in the peak at 260 °C, indicating that the traps of these TL regions are the same as BSL stimulation. The results suggest that the BSL responses of RN samples are due to deep traps, and probably they will do not have a significant fading. In any case, studies on OSL fading for these samples remains be performed.

Figure 7: *TL and residual TL Glow curves of topaz after IRSL and BSL stimulation: (a) blue topaz, (b) yellow topaz (imperial), (c) colourless (MS), (d) colourless (TEO) and (e) colourless (RN).*



(e)



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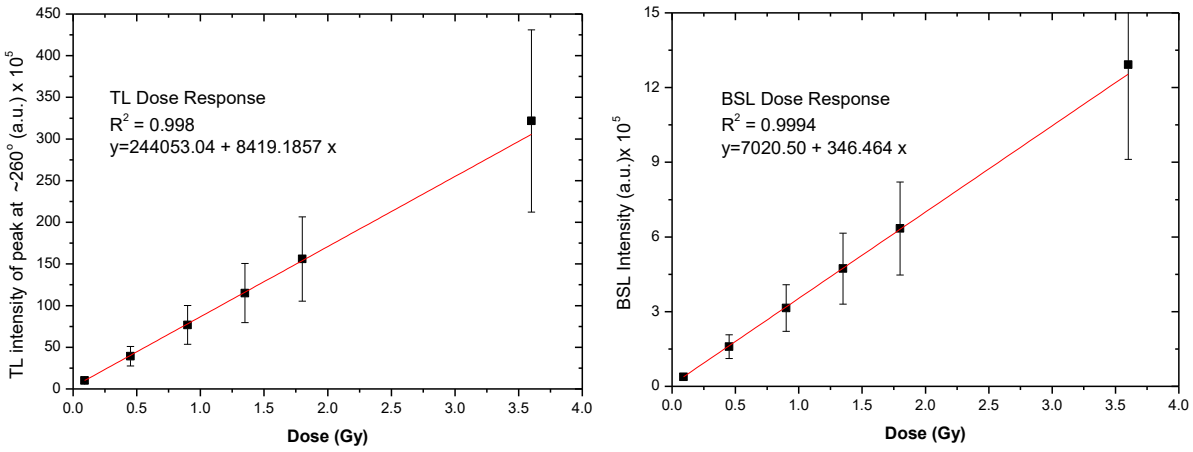
3.5. Dose response

Figure 8 presents the TL and BSL response of the RN topaz samples versus gamma radiation dose of ^{60}Co. The results show a linear TL and BSL responses for radiation doses from 0.1 mGy to 3.6 Gy. Yukihara and Okuno (1998) [12] showed that for the colourless sample that they evaluated, the dose response curve is linear in the low doses region and became supralinear after 20 Gy. Souza et al. (2002) [13] also studied colourless topaz samples from Minas Gerais (Brazil) . They observed a linear response from 0.010 up to 20 Gy, followed by a supralinear response and a saturation around 2 kGy.

Figure 8: *(a) TL and (b) BSL dose response of RN colorless topaz.*



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4. CONCLUSION

It is possible to conclude that the five types of Brazilian topaz samples studied in this paper do not present an IRSL response and the colourless samples from the states of TEO, MS, and RN show a BSL signal. The BSL signal of yellow and blue topaz are negligible for the radiation doses studied. The colourless topaz from RN presented the highest TL response for gamma radiation of ^{60}Co and has a TL peak centered at 260 °C, which is adequate for its use a radiation dosimeter.

ACKNOWLEDGMENT

The authors would like to thank CNPq process 425594/2018-1 and FACEPE, process APW-064-3.09/14 for their financial support.

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