Characterization of Brazilian Wollastonite for radiation dosimetry

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Abstract

In these work preliminary results of the characterization analyses of Brazilian Wollastonite for radiation dosimetry are presented. Wollastonite is a silicate of calcium, Ca[SiO_3], and it was acquired in the form of rude mineral with Andradite inclusions. The sample was cleaned and prepared for obtained selected grains of Wollastonite. The analyses of chemical and mineralogical compositions were obtained using the neutron activation and X-ray powder diffraction techniques. The thermoluminescent (TL) glow curves of the material shows a prominent peak at about 200°C. TL emission spectra, and photoinduced emission spectra were also obtained.

1. INTRODUCTION

The silicates are essential for life in the earth, because they are present in vegetables, in civil construction, and they are also a source of metals to humanity as aluminum, silicon, nickel, beryl, etc. The silicates represent 92% of the volume of the earth crust minerals, and they represent an abundant source of research for the development of new materials for radiation dosimetry(1). Wollastonite occurs in alkaline igneous rocks, and it can be easily found all over the world, mainly in Csiklova (Romania), Black Forest (Bretagne), Chiapas (Mexico) and Minas Gerais (Brazil)(2). It can also be obtained artificially, for example through coalition of the limestone and silica in electric ovens. Wollastonite is used in the ceramic industry to improve the tenacity and crystallization of the enamels, and to optimize their color stability. In metallurgy, it is used for steel refinement. Commercial glasses(3), silicates and other natural silicates as olivine(4), quartz(5), jade nephrite(6) and recently topaz(7) were investigated as radiation detectors, but works about applications of Wollastonite in radiation dosimetry were not found in literature. In this work characterization analyses of Brazilian Wollastonite for radiation dosimetry were performed.

2. MATERIALS AND METHODS

Wollastonite from Minas Gerais, Brazil, was studied. Wollastonite is a silicate of calcium, $Ca[SiO_3]$, and it was acquired in the form of rude mineral with some Andradite inclusions. In the present work the stones were cleaned, cleaved and triturated to obtain grains with diameter between 0.074 and 0.177 mm. The ferromagnetic minerals presented in the samples were extracted with a Frantz Isodynamic magnetic separator. At that stage, the Frantz separator was adjusted for an angle of 25^o of longitudinal inclination, 10^o of lateral inclination and amperage between 0.5 and 1.5 A. The chemical and mineralogical compositions of the materials were obtained through analyses using neutron activation and X-ray powder diffraction techniques (Siemens D-500). The irradiation of the samples for the obtention of TL glow curves was realized using a Gamma Cell-220 System (^{60}Co), with doses of 10kGy. An EMI 9789QB photomultiplier with associated home-made electronics was utilized for the TL measurements. The TL emission spectra were obtained between 300 and 650nm using a UNICROM 100 monochromator. The photoluminescence measurements were performed using an ISS PC1^{TM} Spectrofluorimeter. The excitation device was equipped with a 300W (Xe lamp) and a holographic grating. The emission was collected in a 25 cm monochromator, equipped with a photomultiplier with a resolution of 0.05 nm in the visible range. The excitation and emission slit widths were 1.0 mm, both monochromators having 1200 grooves/mm. The photoluminescent emission spectra were collected in the ultraviolet range (300 –800 nm) with excitation at 230 nm.

3. RESULTS

3.1 Neutron-activation analysis

Table I presents the results from neutron-activation analyses of natural Wollastonite. There is a significant presence of rare earths: lanthanum (La) with 16.80 ppm and cerium (Ce) with 17.70ppm in mass concentration of the studied Wollastonite samples. Iron (Fe) with 0.18% and sodium (Na) with 0.06% present low percentage values in relation to the mass concentration. In the case of Wollastonite, $CaSiO_3$ can accept considerable amounts of Fe and Mn substituting Ca [2]. The low value of Fe obtained suggests that it does not change ion with the calcium, but it was not possible to determine the mass concentrations of Mn and Ca due to the nuclear parameters as: isotropic fraction, cross section for absorption of neutrons and half-life, among others, and the conditions of measurement in gamma spectroscopy. The optimization of these experimental conditions complete the chemical signature of the studied Wollastonite samples.

Table I – Neutron-activation analysis results of Wollastonite (ppm)

Na (%)	Lu	U	Yb	La	Th	Sc	Fe (%)	Zn	Ce	Co
0.06	0.09	1.30	0.50	16.80	1.40	0.50	0.18	9.70	17.70	2.60

3.2 X-Ray diffractometry

Figure 1 presents the X-ray diffractograms of the studied Wollastonite samples after the use of the magnetic separator Frantz. The results show clearly the standard $CaSiO_3$ lines of a database coinciding in position and height with the lines obtained of the studied sample. This result shows that the diffractogram of the acquired sample is Wollastonite.

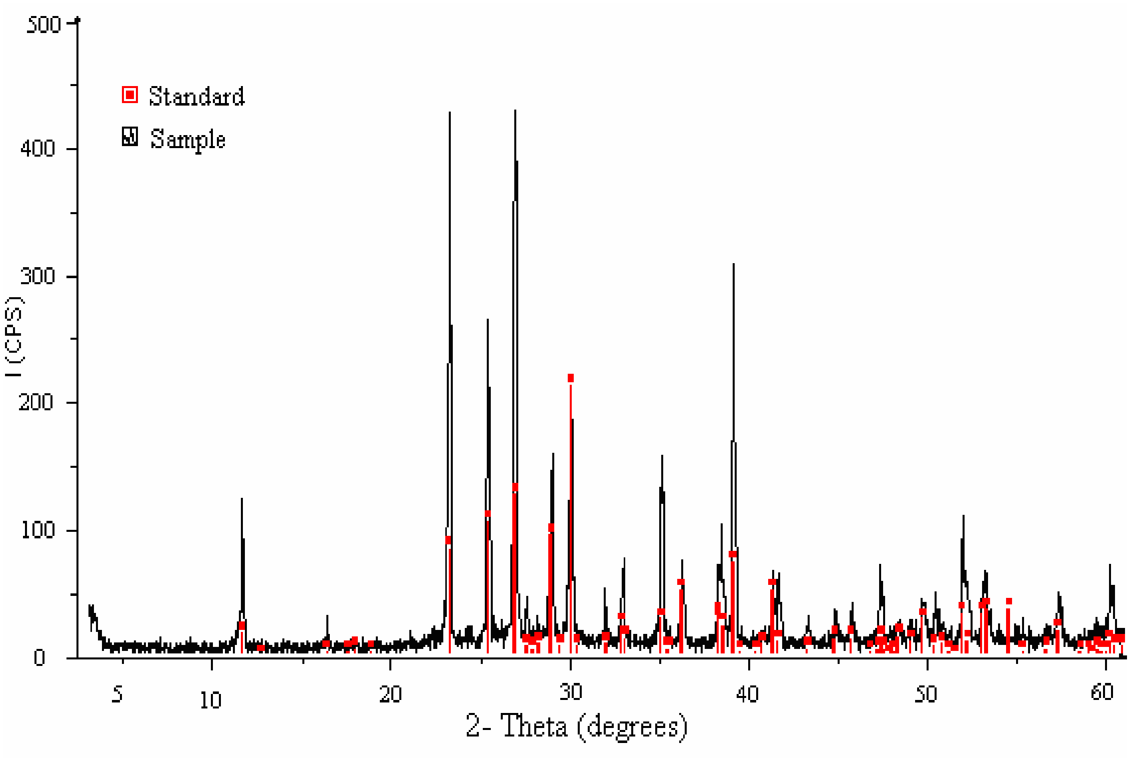

Figure 1. Diffractogram of the Wollastonite sample from Minas Gerais, Brazil. ▣Standard: Wollastonite database. ▣Sample: studied sample.

3.2 TL glow curve

Figure 2 presents the TL glow curves of the unexposed and irradiated (10kGy, ^{60}Co) natural Wollastonite sample. The TL glow curve of the natural Wollastonite samples presents low residual TL signal when compared to the glow curve of the irradiated natural Wollastonite sample. It presents at least three emission peaks around 125°C (peak 1), 200° (peak 2) and 240°C (peak 3). Peak 1 of low TL intensity is distributed between 70°C and 160°C, and it has multicomponent emissions with a maximum around 125°C. Peak 2 presents preliminary interesting properties as a TL peak: It is prominent, isolated and with maximum around 200°C, and it increased with an irradiation. Likely to the TL peak 1, TL peak 3 also presents a TL signal of low intensity and with emission complexity between 225°C and 300°C, and a maximum around 240°C.

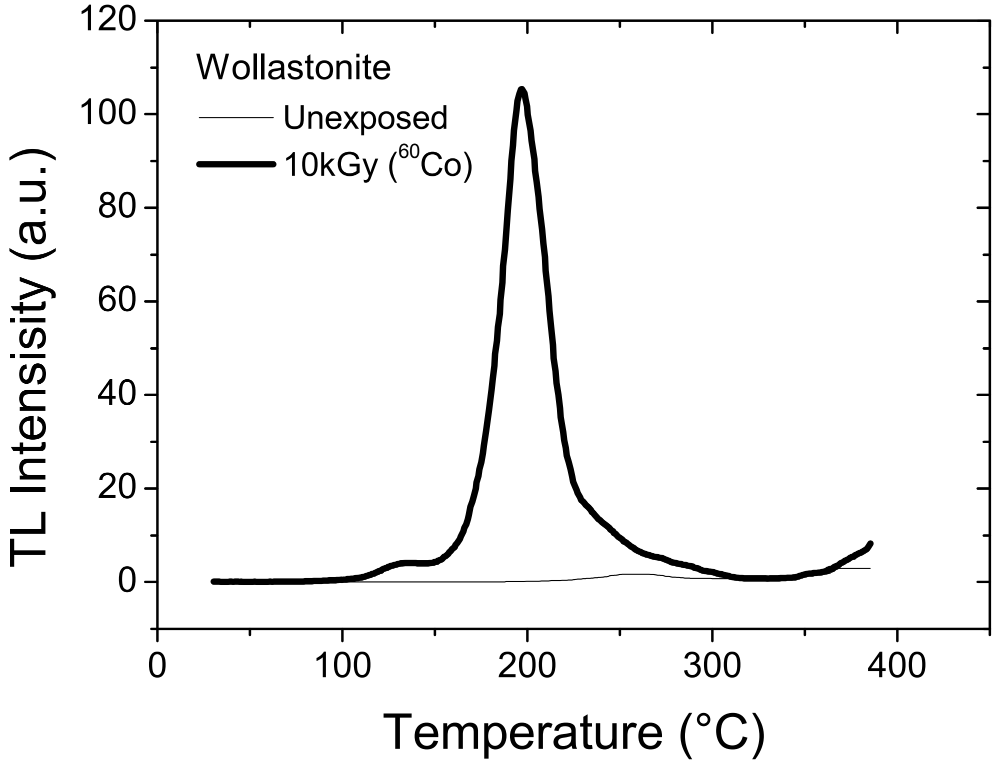

Figure 2. TL glow curves of the unexposed and irradiated with 10kGy (^{60}Co) natural Wollastonite samples from Minas Gerais, Brazil.

3.3 TL emission spectra

The TL emission spectra TL of the natural Wollastonite irradiated with 10kGy (^{60}Co) can be seen in Figure 3. The TL emission spectrum was obtained between 400nm and 650nm, and it presents a complex distribution with several emission peaks of different intensities and positions in the visible spectrum range. TL peak 1 (125°C), distributed between 70° and 150°C, presents a characteristic main emission at 620nm. The intensity of peak 2 (200°C), dosimetric peak, increases with wavelength starting from 440nm up to a maximum around 620nm.The emission spectrum of peak 3 (240°C) presents also a maximum centered at 620nm.

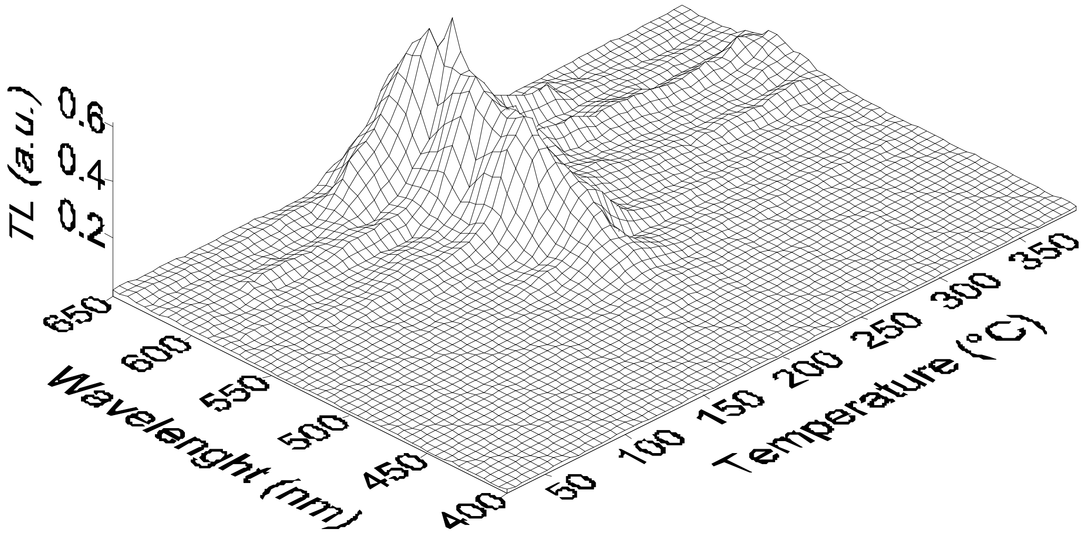

Figure 3. TL emission spectrum of the natural Wollastonite from Minas Gerais, Brazil. The sample was irradiated with 10kGy (^{60}Co).

3.4 Photoluminescence emission spectra

Figure 4 shows photoluminescence emission spectra obtained from Wollastonite samples. The measurement was taken from an unirradiated sample and from another irradiated with 10kGy. The peak observed around 315 nm is an artifact of the excitation monochromator, not related to the emission of the sample. The photoluminescence emission spectra of both samples exhibit three bands containing several emission peaks between 350 and 800 nm. The first band (360-450nm) exhibits the most intense peak at 435 nm; the second band (460-550 nm) shows the most intense peak at 467nm; and the third band (550-700 nm) at 590 nm. This third band presents similarities when compared to the TL emission spectrum in this range. Both spectra exhibit emission bands in the same range, with the most intense emission around 490 nm. The fourth photoinduced band at 700-800nm band is the least intense.

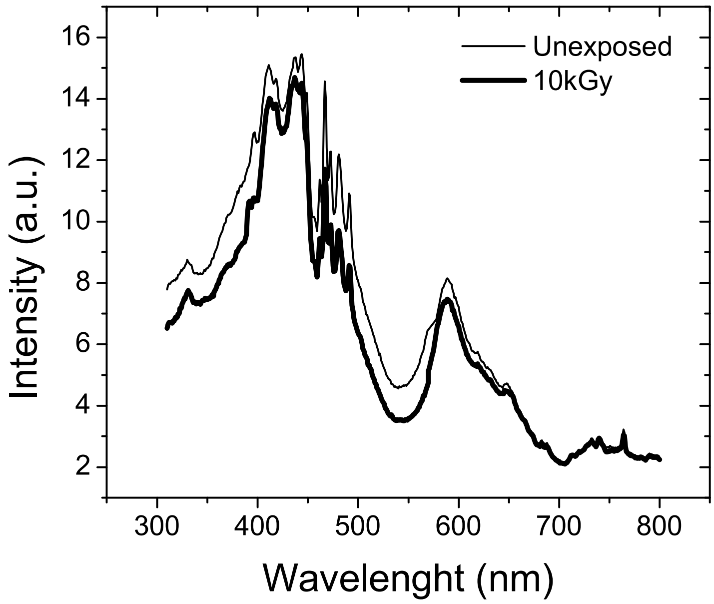

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Figure 4. Photoinduced emission spectra of the unexposed and irradiated with 10kGy (^{60}Co) natural Wollastonite samples from Minas Gerais, Brazil.

4. CONCLUSION

The low value of the Fe concentration obtained from the neutron-activation analysis of the natural Wollastonite samples acquired from Minas Gerais, Brazil, suggests that Fe do not change ions with Ca. The result of X-ray diffractograms show clearly the lines of $CaSiO_3$ of the database coinciding in position and height with the obtained lines of Wollastonite. The TL peaks present different intensities at different temperatures. The TL glow curve show three peaks at 125°C, 200°C and 240°C. Peak 2 presents preliminary interesting dosimetric properties as a TL peak: prominent, isolated and with maximum around 200°C. For TL peaks 1, 2 and 3, the TL emission spectrum obtained between 400nm and 650nm presents only one emission peak at 620nm. The photoinduced emission bands are similar to those of other silicates. Silicates as topaz and quartz exhibit similar bands between 300 and 550 nm, as presented by Dantas et. Al (8). In quartz samples, the luminescence centers responsible by these bands are $[AlO_4]^0$ and $[H_3O_4]^0$. These centers are formed by the ion substitution of Si^{4+} by Al^{3+} or $3H^+$ (9).

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