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RADIATION DOSIMETRY USING DECREASING TL INTENSITY IN A FEW VARIETY OF SILICATE MINERALS

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ABSTRACT

When the TLD is used for Radiation Dosimetry, the calibration curve is produced by plotting increasing TL intensity as function of dose. There are cases where the TL intensity decreases as dose increases and can be used in radiation dosimetry. Such behavior can be found in green quartz, three varieties of beryl and pink tourmaline. In all these silicate crystals we can show that if we irradiate with increasing γ-dose there is a dose D_m for which the TL intensity is maximum. Of course, D_m varies depending on the crystal and irradiated crystal with the dose D_m is stable. If we take one of these crystals and irradiate with dose D_m and we irradiate with doses from low values up to 400-500 Gy we obtain a curve of decreasing TL intensity, such curve can be used as calibration curve.

1. INTRODUCTION

The Radiation Dosimetry based on some ionic crystal had a considerable progress since LiF:Mg,Ti was introduced successfully for that purpose around 1950. Many other crystals have been tested some of them with very good result, particularly for routine dosimetry. In the last two decades we investigated natural silicate minerals and found many of them with high sensitivity. The physical properties that were used are thermoluminescence and electron paramagnetic resonance. In few cases optical absorption was used. In the usual TL or EPR dosimetry, the TL or EPR intensity is measured as function of radiation dose. The common feature is that the TL or EPR intensity increases with the dose, linearly for low doses, but different kind of dependence can be observed at high doses as reported by Watanabe et al. [1]. In quartz it is usual to deal with E'_1-cnter, which is formed in the following way. In quartz it is known that stable oxygen vacancies are formed even at RT. When the crystal is irradiated with gamma-rays electrons from liberated electron-hole pairs can be captured by oxygen vacancies. One electron captured by oxygen vacancy constitutes an E'_1-center, which can be detected by EPR.

2. MATERIALS AND EXPERIMENTAL

Green quartz, three varieties of beryl (uncoloured-goshenite, aquamarine-blue/green, morganite-pink) and pink tourmaline have been investigated in this work. We tested also non-silicate crystal, namely, LiF:Mg,Cu,P (MCP).

Electron Spin Resonance experiments were carried out using a Bruker EMX ESR spectrometer operating at X-band frequency with 100 kHz modulation frequency. The g factor of signals were determined using a reference sample of Diphenyl Picryl Hydrazyl (DPPH).

The TL measurements were carried out in a nitrogen atmosphere with a Daybreak model 1100 reader and a model 4500 Harshaw TL reader. The heating rate used in the TL measurements was 4 °C/s. Each point in the glow curve represents an average of five readings.

For irradiation, Institute for Energy and Nuclear Researches Radiation Center's ^{60}Co source was used for γ-doses below 50 kGy. Higher dose irradiation was carried out at CBE-EMBRARAD.

3. RESULTS AND DISCUSSION

To begin with we started EPR measurement of green quartz irradiated with gamma-rays with low doses up to 200-300 Gy. Fig.1(a) shows the result of this measurement. As already commented the main signal is that of E'$_1$-center. Note that the EPR intensity increases, reaching maximum between 200 and 300 Gy. Of course, this result can be used in radiation dosimetry for doses between low and about 200 Gy. Subsequently we did the following; we irradiated green quartz sample with 300 Gy and then with doses from low to 300 Gy. Fig. 1(b) shows the behavior of the EPR intensity with the dose. This result has shown that 300 Gy irradiated green quartz, which is stable, can be used for radiation dosimetry in the range 0 - 300 Gy. The experimental points follow the equation:

$$I = I_R + I_0 exp(-\beta D) \quad (1)$$

I_R is the residual value for large D value and I_R+I_0 is the value at D=0. In the present case of the green quartz we obtained I_R = 1005 (a.u.), I_0 = 857 (a.u.) and β = 0.005/Gy.

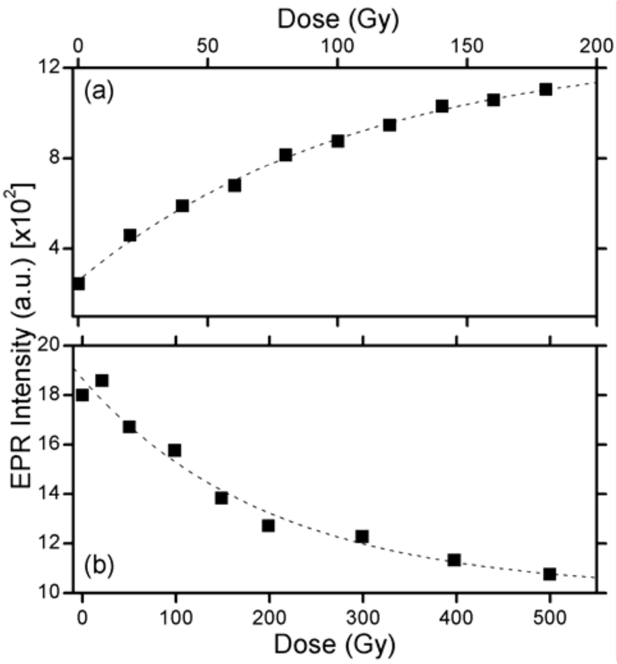

Figura 1. (a) EPR intensity of E′$_1$-center as function of dose. (b) EPR intensity of E′$_1$-center in 500 Gy irradiated green quartz.

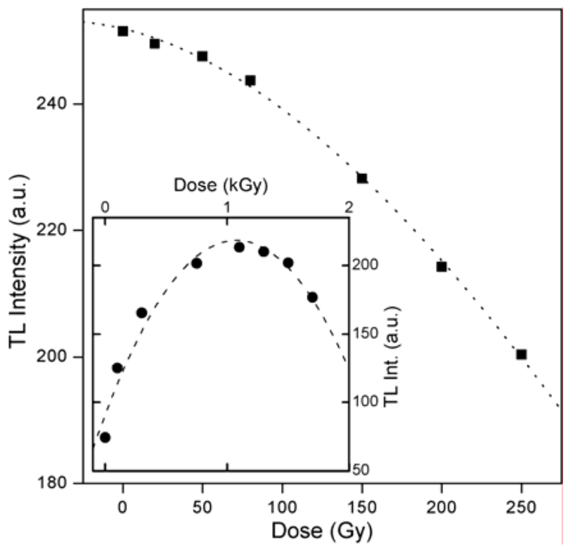

Figura 2. TL vs. dose curve of a 1100 Gy irradiated Green quartz subsequently irradiated with low to 250 Gy γ-rays. Inset: TL response curve of green quartz in the interval 0 to 2000 Gy**.**

We carried out similar measurements on three varieties of beryl and on pink tourmaline, however now we used TL measurements. We included green quartz again. We started again with green quartz and like in the EPR case, first we measured TL of the sample irradiated with doses up to 1600 Gy. The inset of Fig. 2 shows that the resulting curve is a parabola with a maximum around 1100 Gy, using, therefore, the sample irradiated with 1100 Gy and then irradiating it with doses up to 250 Gy a curve shown in Fig. 2 results.

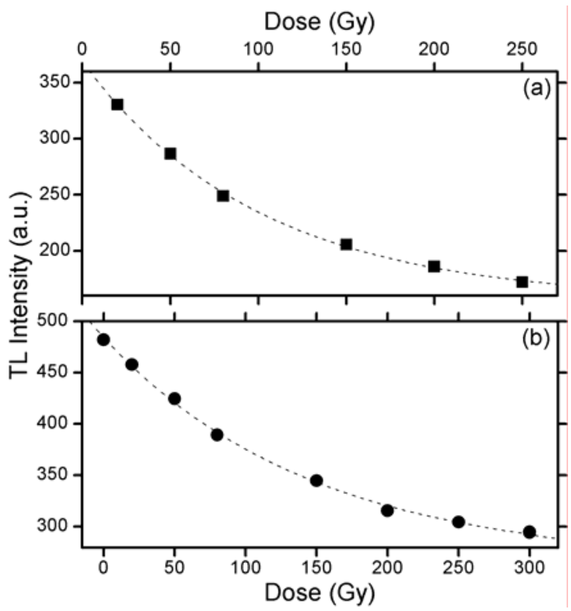

Figura 3. (a) Aquamarine irradiated with 45 kGy γ-ray and then irradiated with low up to 250 Gy γ-ray. (b) For goshenite previously irradiated with 1100 kGy and then to low up to 300 Gy γ-ray.

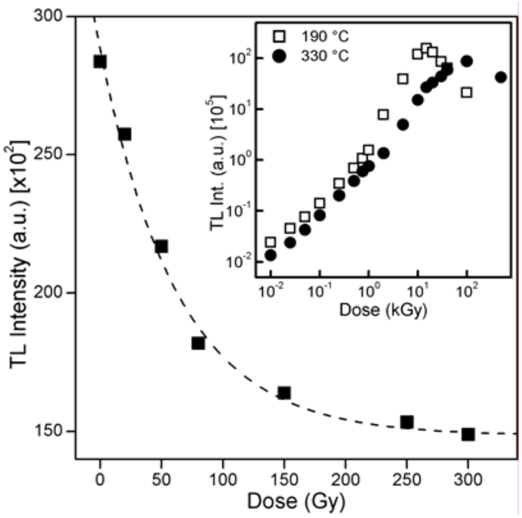

Figura 4. TL vs. dose curve of Pink tourmaline pré-irradiated with 100 kGy and then irradiated with low to 300 Gy γ-ray. Inset: TL response of 190 °C and 330 °C TL peak of pink tourmaline in the range of 10^{-2} to 10^{2} kGy.

Watanabe et al. [1] have shown that TL intensity in morganite grows linearly up about few thousand Gy and then saturates, therefore we did not carry out the experiment of irradiating the morganite irradiated with, say, 1000 Gy. We did, however, such experiment with aquamarine irradiated with 45 kGy and goshenite irradiated with 1250 kGy. Fig. 3(a) shows the result for aquamarine and Fig. 3(b) for goshenite. The inset of Fig. 4 shows the TL intensity vs. dose curve of TL peak at 190 ° C and at 330° C of pink tourmaline sample, we consider only the second peak. Then irradiating such sample with 100 kGy and subsequently with doses up to 300 Gy we obtain the curve shown in Fig. 4. We then took a MCP sample irradiated with 50 kGy which irradiated subsequently with doses up to 500 Gy a curve shown in Fig. 5 is obtained.

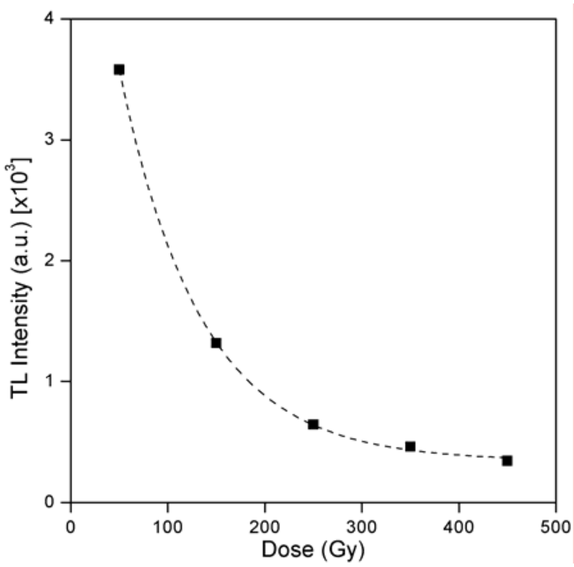

Figura 5. TL vs. dose curve of LiF-MCP-N pre-irradiated with 50 kGy γ-ray and then irradiated with low up to 500 Gy γ-ray.

4. CONCLUSIONS

This work shows that many TL materials have TL response in function of radiation dose that has a maximum at some dose Dm. If such material is pre-irradiated with the dose Dm, being subsequently irradiated with g-dose with dose from low values up to 300-500 Gy present a decreasing TL response, however in a regular way. Here we investigated green quartz, aquamarine, goshenite, pink tourmaline (all are silicate mineral) and MCP-LiF:Mg,Cu,P (an alkaline halode). Such decaying TL as function of dose can be used in radiation dosimetry.

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5. REFERENCE

1. Watanabe, S., Cano, N.F., Carmo, L.S., Barbosa, R.F., Chubaci, J.F.D., “High- and very-high-dose dosimetry using silicate minerals”, *Radiation Measurements*, **72**, pp.66-69 (2015).