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DIFFERENCES IN TLD 600 AND TLD 700 GLOW CURVES DERIVED FROM DISTICT MIXED GAMMA/NEUTRON FIELD IRRADIATIONS

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ABSTRACT

In Neutron Capture Therapy, a thermal neutron beam shall impinge on a specific nuclide, such as ^{10}B, to promote a nuclear reaction which releases the useful therapeutic energy. A nuclear reactor is usually used as the neutron source, and therefore field contaminants such as gamma and high energy neutrons are also present in the field. However, mixed field dosimetry still stands as a challenge in some cases, due to the difficulty to experimentally discriminate the dose from each field component. For the mixed field dosimetry, the International Commission on Radiation & Units (ICRU) recommends the use of detector pairs with different responses for each beam component. The TLD 600/700 pair meets this need, because these LiF detectors have different Li isotopes concentration, with distinct thermal neutron responses because ^{6}Li presents a much higher neutron capture cross section than does ^{7}Li for low energy neutrons. TLD 600 is ^{6}Li enriched while TLD 700 is ^{7}Li enriched. However, depending on the neutron spectrum presented in the mixed field, TLD 700 response to thermal neutrons cannot be disregarded. This work aims to study the difference in TLD 600 and TLD 700 glow curves when these TLDs are submitted to mixed fields of different energy spectra and components balance. The TLDs were irradiated in a pure gamma source, and in mixed fields from an AmBe sealed source and from the IPEN/MB-01 reactor. These TLDs were read and had their two main dosimetric regions analyzed to observe the differences in the glow curves of these TLDs in each irradiation. Field components discrimination was achieved through Monte Carlo simulations run with MCNP radiation transport code.

1. INTRODUCTION

The Boron Neutron Capture Therapy (BNCT) is based on a capture reaction which occurs when thermal neutrons focus on ^{10}B atoms. Therefore, the useful energy of this therapy does not come from radiation beam; it comes from the capture reaction which produces two particles with high LET.

To produce the thermal neutrons that will be used in BNCT, a nuclear reactor is usually used as neutron source. But the beam comes from reactor is contaminated with gammas and high energy neutrons. So it is necessary a mixed gamma/neutron dosimetry to use in this situations. The mixed gamma/neutron dosimetry still stands as a challenge in some cases, due to the difficulty to experimentally discriminate the dose from each field component.

For the mixed field dosimetry, the International Commission on Radiation & Units (ICRU) recommends the use of detector pairs with different responses for each beam component [1]. Therefore the use of LiF TLDs pair – TLD 600 and TLD 700 – is an alternative, because they meet these recommendations due to difference composition of Lithium isotopes in their composition.

Some methods that use the pair TLD 600/TLD 700 utilize these TLDs as the TLD 600 is sensitive to thermal neutron and gamma radiation, while TLD 700 is only sensitive to gamma radiation.
But some studies showed that depending of the field that TLDs were exposed, the TLD 700 sensibility for neutrons cannot be neglected [2], Fig.1. And if this sensitivity was disregard in these cases, the response of neutrons will be underestimating and the response of gamma will be overestimate.

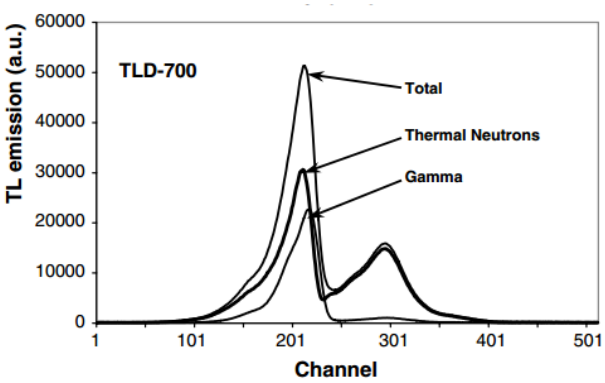

Figure 2 : Glow curve of TLD 700 exposed in the reactor thermal column [2]

This work realized experiments in different radiations fields with increment complexity to analyze the difference in glow curves of these TLD in each case.

2. MATERIALS AND METHODS

The LiF:Mg,Ti TLDs – TLD 600 and TLD 700 – in chip form with 3.2 x 3.2 x 0.9 mm produced by Harshaw was utilized in this work. The difference between these TLDs is in the difference of Lithium isotope composition in these TLDs. Where the TLD 600 is enriched with ^{6}Li, containing 95.62%. Already the TLD 700 is enriched with ^{7}Li, 99.99%.
The ^{6}Li has a high cross section for neutron than ^{7}Li, Fig. 1. And because of that the TLD 600 is more sensitive to neutron than TLD 700. But the TLD 700 sensibility to neutrons cannot be discarded depending of the field that these TLDs were irradiated.

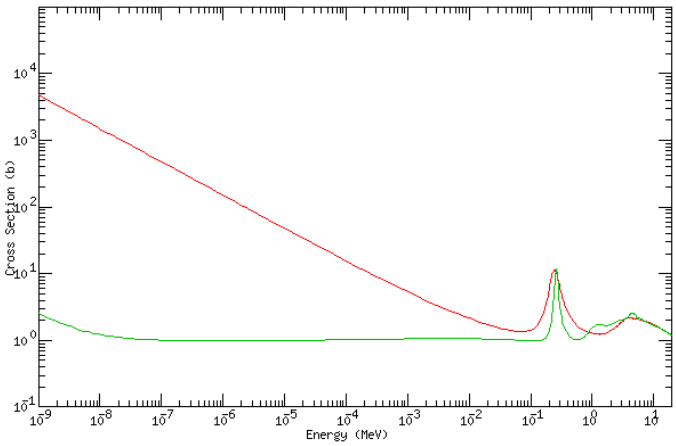

Figure 2 : Total neutron cross section for ^{6}Li (red) and ^{7}Li (green) [3]

These both TLDs have two region of interest, which are formed by more stables peaks. The first region is around 195°C, and de second region is around 250°C, Fig. 3.

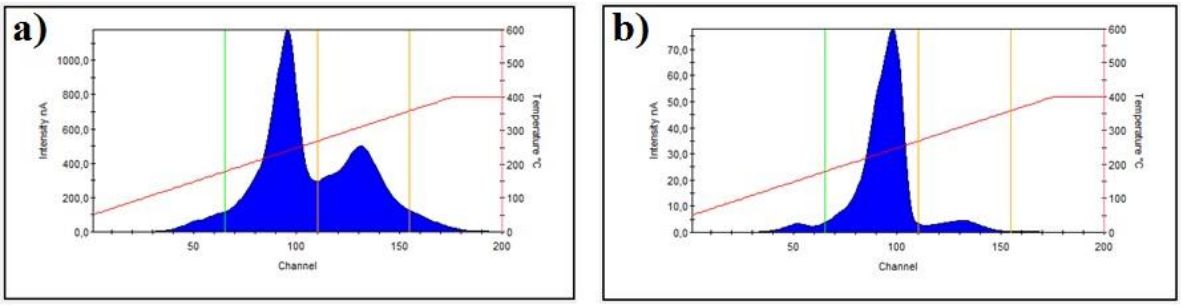

Figure 3 : Glow curves of TLD 600 (a) and TLD 700 (b) when they are irradiated at BNCT research facility at IPEN/CNEN - SP

In all experiments realized with these TLDs the same sequence of steps were made. This sequence corresponded a three days where: in the first day the TLDs were thermal treatment; in the second day occurred the irradiations; and in the third day the TLDs were read.
The thermal treatment of both TLD is the same: one hour at 400°C, and after more two hours in 100°C.
This same sequence was realized to minimize possible difference in response of TLDs due to fading of the dosimetric peaks of these TLDs.
In these work these TLDs were irradiated in three different fields with increasing complexity to study the difference at TLD response in each case. In all these irradiations simulations with Monte Carlo code (MCNP5) were realized to calculate the dose deposited in TLDs by different components of field.
This work divided the experiments in two steps. The first was compared the glow curves and the response of these TLDs when they are irradiated in a pure gamma source, ^{60}Co, and in a mixed neutron/gamma field of low flux from a system with an AmBe source. In the second step, the TLDs were irradiated in six different positions inside a zero power reactor. These different positions provided different field composition, so it was studied the relation between the responses of different region of interest of these TLDs when they are irradiated in fields with different field composition.

2.1. Comparison of the glow curves and response of TLDs when they are irradiated in a pure gamma field and in a low flux mixed neutron/gamma field

In these experiments the TLDs were first irradiated in panoramic ^{60}Co source, which gives 20 mGy of gamma air kerma in the irradiation position. For this irradiation the TLDs were placed inside acrylic supports which have a 3 x 3 matrix to place the TLDs.
The irradiation in a low flux mixed neutron/gamma field was realized in a system with a polyethylene cylinder with a AmBe source of 2 Ci inside it. And the TLDs were placed in a Styrofoam supports that were placed around the polyethylene cylinder.
This polyethylene cylinder was necessary because the AmBe source emits preferable fast neutrons, and the TLD is more sensitive to low energies neutrons. So the polyethylene was used to decrease the energies of emitted neutrons.
Simulations with MCNP5 were realized to calculate the air kerma and the deposited dose in each TLD in each irradiation. These results are showed in Tab.1.

Table 1 : Calculated values of air kerma and deposited dose in each TLD in the irradiations with ^{60}Co source and with the system with AmBe source

	^{60}Co			AmBe		
	Air kerma	**Dose**		**Air kerma**	**Dose**	
[mGy]		**TLD 600**	**TLD 700**		**TLD 600**	**TLD 700**
Gamma	20	18.5 (1)	18.5 (1)	80.3 (1.4)	75.6 (2.1)	75.6 (2.1)
Neutrons	---	---	---	35.68 (64)	9.6 (2)E+03	290 (7)

2.2. Irradiations in a zero power reactor

It was utilized the IPEN/MB-01 reactor, that is a zero power reactor that allows the simulation of all nuclear characteristic of large-size reactor. This reactor allows the researches research not only the theoretical calculation, but with experimental measurements too [4].
For these irradiations, it was chosen six positions in one the reactor faces to place the TLDs. These positions were chosen because their differences in the components of the field.
The TLDs were shielded with plastic film and arrested in an acrylic plaque, Fig. 4. The TLDs were shielded for the TLDs did not get wetting when they were placed inside the water tank of reactor.

Figure 4 : Assembly of the plaque with TLDs to irradiated inside IPEN/MB-01 reactor

It was performed simulation with MCNP5 to calculate the flux in each six positions which TLDs will be. In Fig. 5 it is presented the normalized calculated flux for each region.

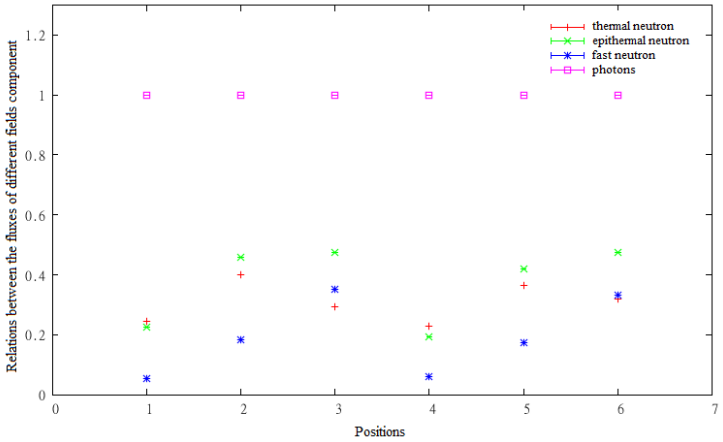

Figure 5 : Calculated normalized flux for each position of each field component in the six positions inside IPEN/MB-01 reactor

3. RESULTS AND DISCUSSIONS

3.1. Comparison of the glow curves and response of TLDs when they are irradiated in a pure gamma field and in a low flux mixed neutron/gamma field

First was realized the analyses of the difference of glow curves of these TLDs when they were irradiated in a pure gamma source, ^{60}Co, and in low flux of mixed neutron/gamma field derived from the system with the AmBe source. These differences could be seen at Fig. 6 and Fig. 7.

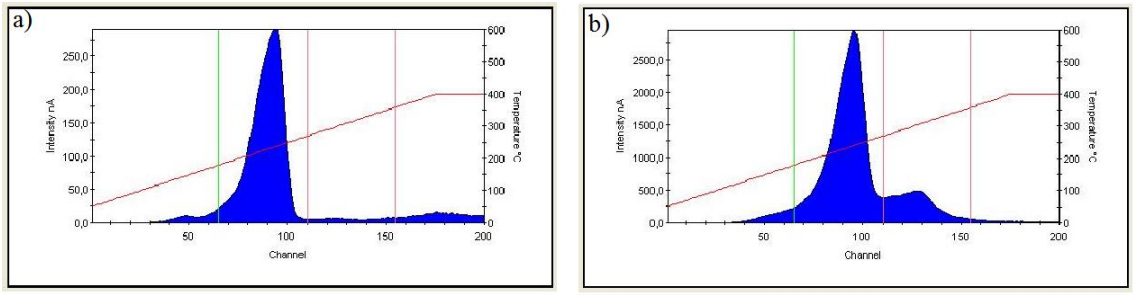

Figure 6 : Glow curves of TLD 600 when they are irradiated in a pure gamma source of ^{60}Co source (a) and at system with AmBe source (b)

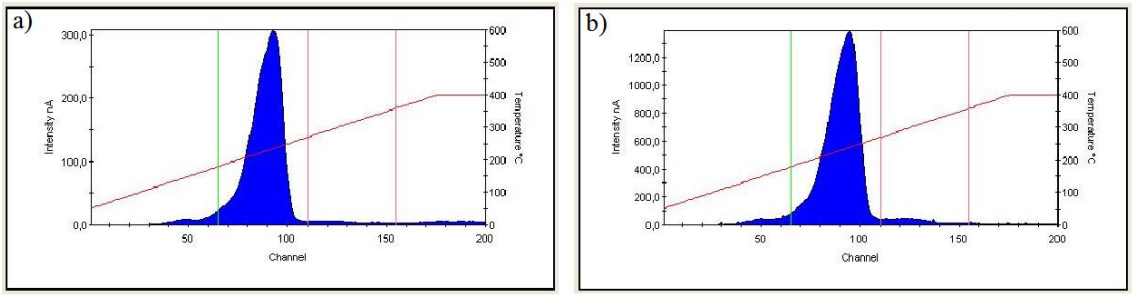

Figure 7 : Glow curves of TLD 700 when they are irradiated in a pure gamma source of ^{60}Co source (a) and at system with AmBe source (b)

From the Fig. 6 and Fig. 7 it is possible to see the emergence of the picks of second region of interest when TLD 600 is irradiated by a mixed neutron/gamma source. For TLD 700 is possible to see a little peak in second region of interest, but nothing very considerable.
From Tab 1., it is possible to see that the deposited gamma dose in both TLDs is the same, once the TLDs have the same chemistry composition. It is possible to see too that TLD 600 absorbed much more neutron dose than TLD 700. But nonetheless the dose deposited in TLD 700 by neutrons is greater than the dose deposited by gamma radiation.
It was analyzed the response of both region of interest of these TLDs in these irradiations, and the results are showed at Tab. 2.

Table 2 : Response the two region of interest of TLD 600 and TLD 700 when they were irradiated in a ^{60}Co and in the system with AmBe source

[uC]	TLD 600		TLD 700	
	ROI 1	ROI 2	ROI 1	ROI 2
^{60}Co	1.15 (10)	0.05 (1)	1.11 (8)	0.01 (2)
AmBe	10.3 (7)	2.34 (5)	4.88 (31)	0.27 (2)

For the irradiation in a ^{60}Co source, the both TLDs response similarly, what is in agreement with the expected. The TLD 600 presented a greater response in its two region of interest than TLD 700, what is in agreement too because TLD 600 is more sensitive to neutrons.
Comparing the increases of the response of the TLDs when they are irradiated in ^{60}Co source and at a system with AmBe source (Tab. 2), and the calculated deposited dose in each TLD (Tab. 1) it is possible to see that the increasing in the response of TLD 700 first region of interest has approximately the same growth rate than the calculated deposited dose. It

suggests that for this low flux field of a system with the AmBe source the TLD 700 does not present significantly sensibility for neutrons. Even the deposited neutron dose in TLD 700 was greater than gamma dose.
So how the both TLDs respond in the same way for gamma, it can be considered that the difference between the first region of interest of TLD 600 by the first region of interest of TLD 700 gives the neutron response.
So for low neutron fields, the TLD 700 could be considered sensitive only for gamma radiation, and the simples subtraction of the first region of interest of TLD 600 and TLD 700 can be used to evaluate the neutron response of these TLDs.

3.2. Irradiations in a zero power reactor

In this irradiation, the fluxes that TLDs were exposed were shown in Fig. 5. Four TLDs of each type were irradiated in each position, and the response of each region of interest of each TLD for each position is showed in Fig. 8 for TLD 600 and in Fig. 9 for TLD 700.

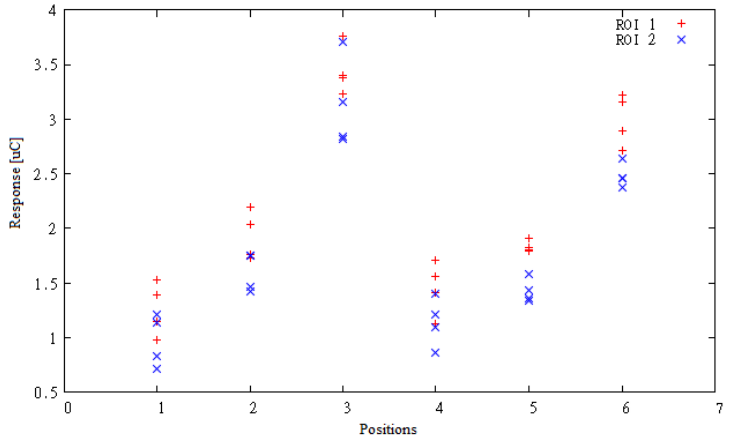

Figure 8 : Response of each region of interest of TLD 600 for each of six positions in irradiation inside de IPEN/MB-01 reactor

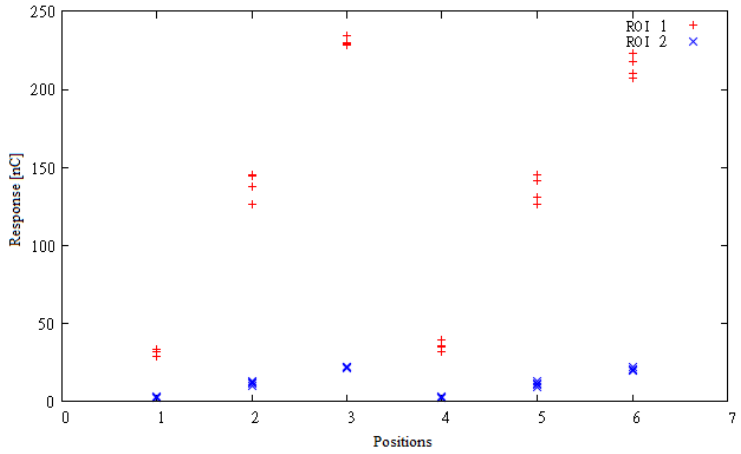

Figure 9 : Response of each region of interest of TLD 700 for each of six positions in irradiation inside de IPEN/MB-01 reactor

The response of TLD 600 is higher than the response of TLD 700. It was expected due to major sensibility to neutrons of TLD 600. But the TLD 700 response for neutron is not more neglected, once that the second region of interest of these TLD starts to increase when it is in a irradiation position with higher neutron flux.
It was calculated the rate between the second region of interest by the first region of interest of each position for each TLD. These calculations are shown in Tab. 3.

Table 3 : Rate between second and first region of interest for each position inside IPEN/MB-01 reactor for each TLD

Position	TLD 600		TLD 700	
	Rate [ROI2/ROI1]	Uncertanty [%]	Rate [ROI2/ROI1]	Uncertanty [%]
1	0.76	6	0.077	4
2	0.82	3	0.084	6
3	0.84	2	0.095	3
4	0.79	3	0.074	4
5	0.81	6	0.083	10
6	0.83	5	0.096	5

It is possible to see certain similarity with rate between positions 1 and 4; 2 and 5; 3 and 6. And analyzing the Fig. 5, with the fluxes of each field component for each position, it is possible to see certain similarity with these relative fluxes for these positions. Therefore this relation between the region of interests of TLD 600 and TLD 700 can be used to identify the relative composition that these TLDs were exposed.

4. CONCLUSIONS

The study of the difference in glow curves of TLD 600 and TLD 700 was the objective of this work. In the experiments in ^{60}Co source and in the system with AmBe source, the comparison between the responses of these TLDs for these cases showed the higher sensibility of TLD 600 for neutron than TLD 700. However TLD 700 showed a greater deposited dose for neutrons than for gamma, but it does not convert in response of this TLD, which show the low sensibility for neutron of this TLD.
So for low neutron field, the simple subtraction between the responses of TLD 600 and TLD 700 can be used as methodology to obtain the response due to neutrons.
The experiments in zero power reactor, IPEN/MB-01, showed that the TLD 700 presents a response in its glow curve due to neutrons. So the gamma dose will be overestimate if the all response of TLD 700 is considered due to gamma radiation.
This experiment in IPEN/MB-01 reactor showed too that the relation between the response of the two region of interests of these TLD can be used to obtain the relative relation between the neutron and gamma fluxes.

ACKNOWLEDGMENTS

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