2007 International Nuclear Atlantic Conference - INAC 2007
Santos, SP, Brazil, September 30 to October 5, 2007
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: 978-85-99141-02-1

LEAKED FILTERS FOR ENERGETIC AND ANGULAR DEPENDENCE CORRECTIONS OF THERMOLUMINESCENT RESPONSE

José Eduardo Manzoli[1,2], Vicente de Paulo de Campos[1] and Gabriel Issa Jabra Shammas[1,2]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN-SP)
Av. Professor Lineu Prestes 2242
05508-900 São Paulo, Brasil
vpcampos@ipen.br; jmanzoli@ipen.br

[2] Universidade São Judas Tadeu – USJT
Rua Taquari 546
Móoca, São Paulo, SP

ABSTRACT

Many thermoluminescent materials has been developed and used for photon personal dosimetry but no one has all desired characteristics alone. These characteristics include robustness, high sensitivity, energy photon independence, large range of photon energy detection, good reproductibility and small fading. The phosphors advantages begin to be more required and its disadvantages have became more apparent, in a global market more and more competitive. Calcium Sulfate Dysprosium doped ($CaSO_4$:Dy) and Calcium Fluoride Manganese doped (CaF_2:Mn) phosphor Thermoluminescent Dosimeters (TLDs) have been used by many laboratories. They are used in environmental and area monitoring, once they present more sensibility than other phosphors, like LiF:Mg. Theirs main disadvantage is the strong energetic dependence response, which must be corrected for theirs application in routine, where the kind of photon radiation is unknown *a priori*. An interesting way to make this correction is to interject a leaked filter between the beam and the phosphor, where the beam could strike the phosphor at any angle. In order to reduce the energetic dependence on any incidence angle, this work presents experimental and simulation studies on some filter geometries. It was made TL readings and simulations on TL responses to photon irradiations with Gamma rays of ^{60}Co and X-rays of 33; 48 and 118 keV, on many incidence angles from zero to ninety degrees. The results pointed out the best filter thicknesses and widths, in order to optimize the correction of energetic dependence for the studied geometries.

1. INTRODUCTION

Photon energy dependence of the absorbed dose in dosimetric materials, reflected in its thermoluminescence (TL) emission, is a disadvantage when the TL material is chosen for personal dose evaluations [1,2]. An example is that of $CaSO_4$:Dy shown in Figure 1. For this kind of materials, in order to calculate the dose imparted by an unknown gamma or X-ray source, it is necessary first to determine the photon energy. This is made through non rare complex or of questionable validation algorithms, always been a great source of uncertainty in the measurement of final dose.

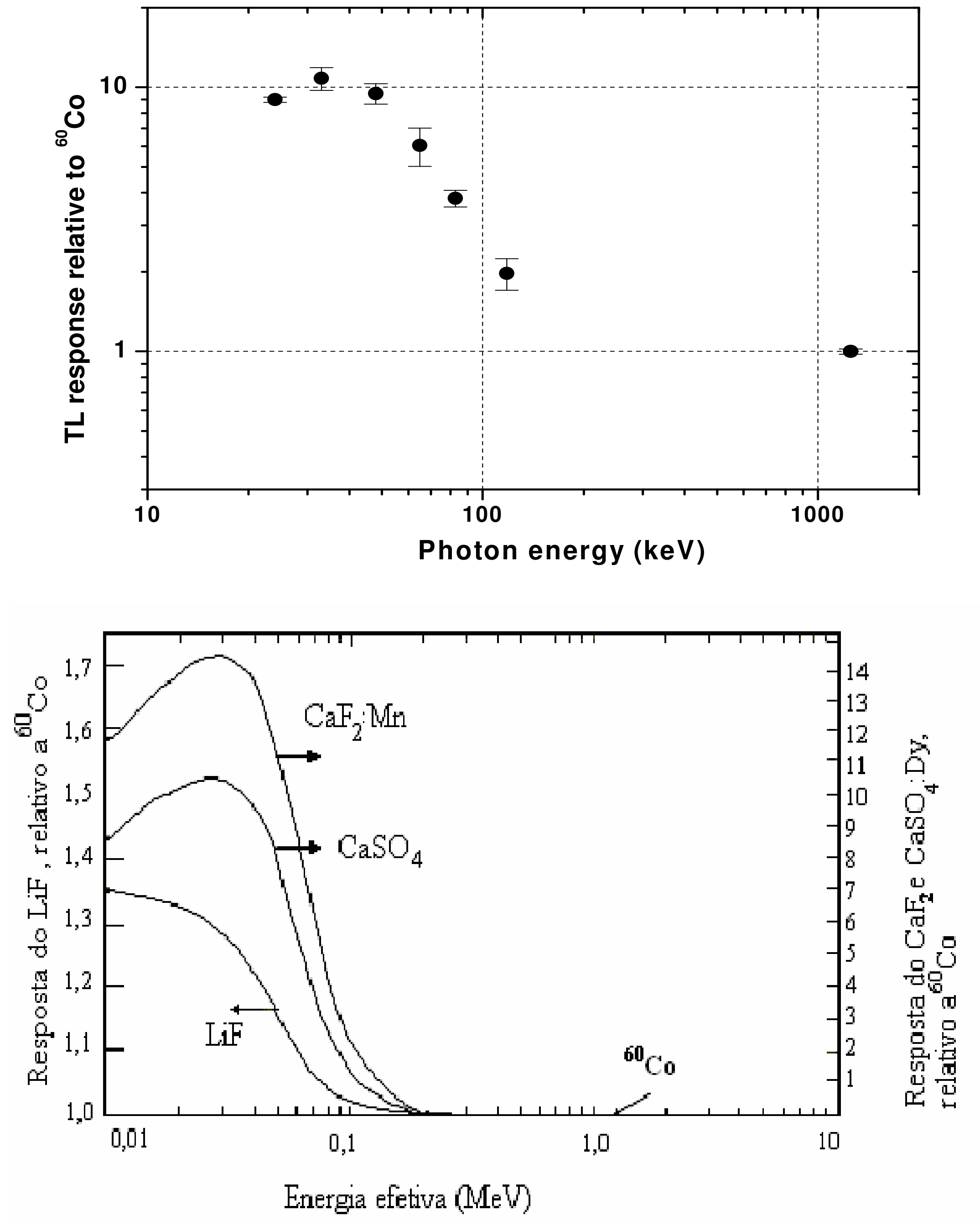

Figure 1. Up: Photon energy dependence of thermoluminescent emission of $CaSO_4$:Dy/PTFE small discs used in personal dosimetry. Down: other materials TL emission dependence with photon energy. Due to its small dependence, beside other qualities, LiF is the most used material in radioprotection dosimetry. 60 Cobalt is a reference because it is used as calibration source for radioprotection dosimetric purposes.

The variation of TL response (or emission) due to different photons could be minimized through interposition of appropriate filters [3-5]. In this work it is shown some geometries of lead filters that diminished this variation. Some geometry configurations were experimentally evaluated and others had their TL response calculated through mathematical simulation.

2. LEAD FILTER GEOMETRIES

The "cross appearance filter" (CAF) shown in Figure 2 was simulated and experimentally tested concerning TL responses [3], for many thickness, widths and radiation incidence angles, beside different photon energy, of course. Only $CaSO_4$:Dy phosphor was studied for this geometry.

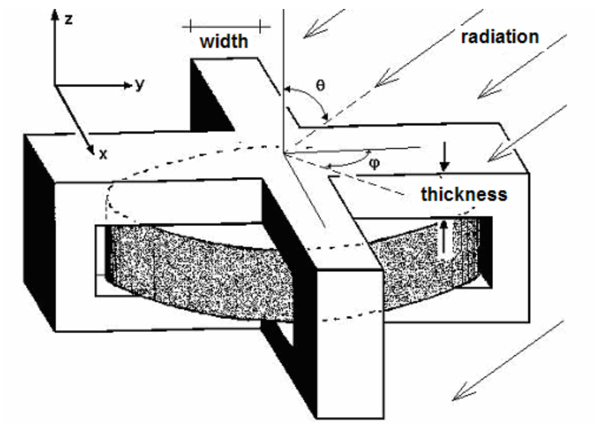

Figure 2. Sketch of lead filter CAF evolving a disc of TL material. After radiation exposition, the disc is evaluated in a TL reader.

Another geometry studied, called "globe appearance filter" (GAF), is shown in Figure 3. Due to its symmetry on radiation incidence, it permitted better results of photon energy TL dependence correction [5]. GAF geometries had their TL response simulated only.

This symmetry permits the use of only two octants of the sphere. The simulation takes into account photons of energies 33, 48, 118 and 1250 keV, with angles $\theta = 45^o$; $67,5^o$; $78,75^o$ and $\phi = 0^o$; 30^o; 45^o; 60^o e 90^o. It was obtained one TL response for each combination of width, thickness and incidence angle. The total of results were writen in databases which permitted to choose the best combination(s) for the response relative to ^{60}Co (used as calibration source) near of the unity.

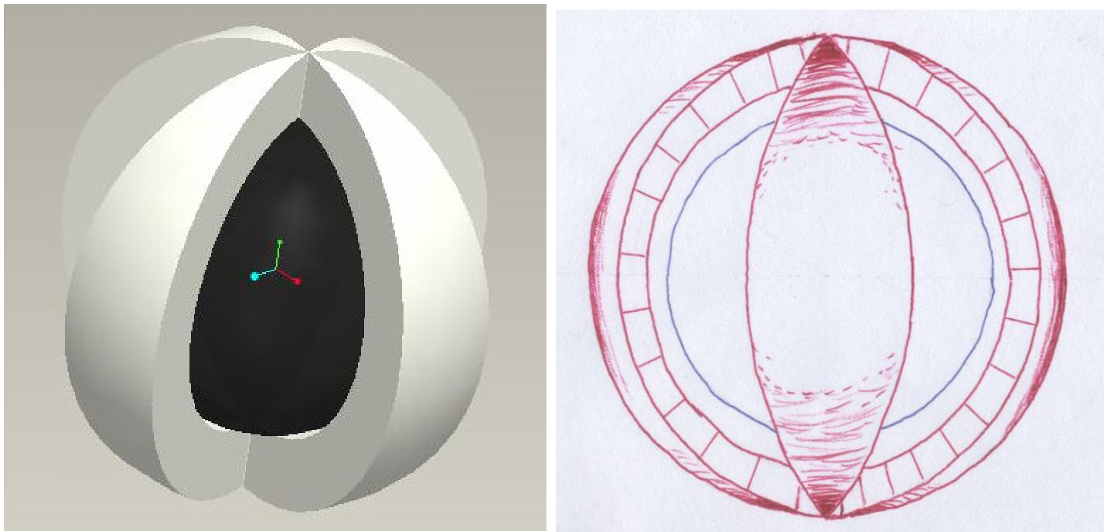

Figure 3. Sketch of lead filter GAF evolving a spherical TL material. Thickness and width were changed in simulation. Width will be measured in angles of covering, where 90 degrees represent phosphor full covering.

3. SIMULATION PROCEDURE

The system lead filter/TL material was discretized in points, in a mesh of orthogonal coordinates for CAF geometry and in spherical coordinates for GAF. A beam of photon radiation is a straight line segment which strikes the TL material. On its trajectory, it is calculated the beam attenuation into the travel medium (air, lead or TL material). Attenuation and photon kind are the most important effects on TL response. Details on this simulation process are in [4,5].

4. RESULTS

In Figure 4 is shown the experimental TL results of $CaSO_4$:Dy with and without CAF geometry under radiation incidence of $\theta = 0^o$ (see sketch of Figure 2).

The simulation of CAF TL response pointed to the values of 3 mm width and 1 mm thickness, as the best choice for energy dependence minimization on normal incidence. So, the CAF was manufactured and tested, with the results shown in Figure 4. Different incidence angles don't have a good energy dependence correction for any thickness-width combination.

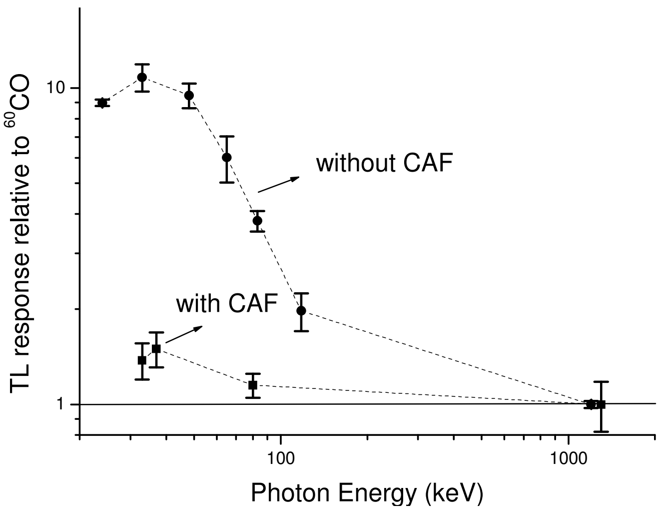

Figure 4: Photon energy dependence of $CaSO_4$:Dy TL response with and without lead filter CAF for a normal incidence of radiation ($\theta = 0^o$ in Fig.2).

The Figure 5 show the results by different angles of CAF dosimeter and commercial dosimeter. Could be see through a gain in response of CAF, primarily for angles of 45º and 90º.

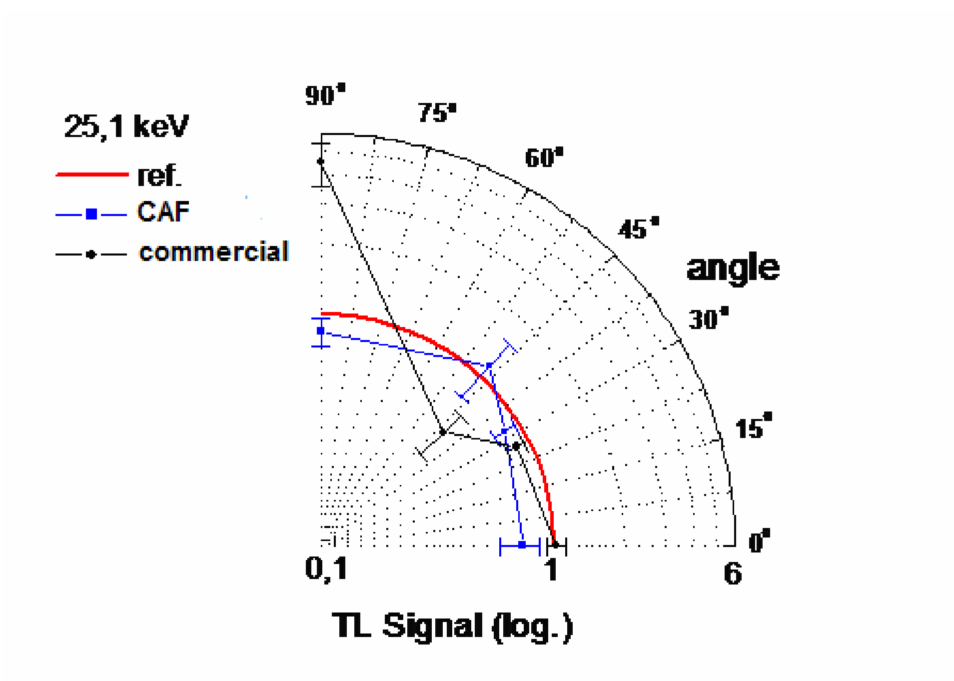

Figure 5: Photon energy dependence of $CaSO_4$:Dy TL response with lead filter CAF for a some incidence angles of radiation for 25,1 keV ($\theta = 0^o$; 30^o; 45^o and 90^o).

For GAF geometry, some results of TL response simulations for $CaSO_4$:Dy are shown in Figure 6.

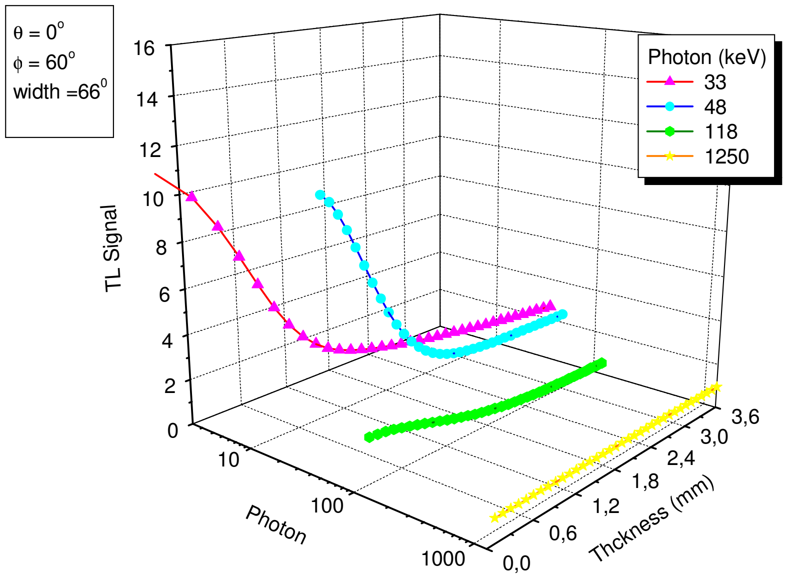

Figura 6: TL signal of $CaSO_4$:Dy simulated as function of thickness and photon energy for the incidence at indicated angles. Width is 66 degrees.

The simulation of GAF TL response of $CaSO_4$:Dy pointed to the values of 66 degrees width and 3 mm thickness, as the best choice for energy dependence minimization. For CaF_2:Mn phosphor, the best choice of GAF was around 70 degrees width and 3,6 mm thickness.

5. CONCLUSIONS

The TL response of detectors under the CAF or GAF filters revealed great reduction of energy dependence for any incidence angle of the radiation beam. Simulations for $CaSO_4$: Dy and CaF_2:Mn phosphors were done and pointed to the best dimensions in theirs manufacturing. Only CAF geometry was made and tested experimentally, due to technical difficulties.

In the research of these filters, the computer simulation demonstrated could be an efficient tool.

REFERENCES

1. Oberhofer M.; Scharmann. A. "*Applied Thermoluminescence Dosimetry*". Published for the Commission of the European Communities. Adam Hilger, Italy.1979.
2. Knoll , G. F. "*Radiation Detection and Measurement*". 2 ed. Michigan. John Wiley&Sons. (1955).

3. Campos, V, "*Desenvolvimento e Avaliação de um Novo Porta Detector/Filtro para Monitoramento Termoluminescente com $CaSO_4$:Dy/PTFE*". Master Degree Dissertation, area Nuclear Techniques and Applications (TNA-IPEN, www.ipen.br), advisor J. E. Manzoli, 2005.
4. Manzoli, J. E.; Campos, V. P. and Shammas, G. I. J."*Estudo da Correção da Dependência Energética e Angular da Resposta Termoluminescente em Dosímetros Pessoais de $CaSO_4$:Dy/PTFE – Medições e Simulação Semi-Empírica*". In: I Jornada Luso-Brasileira de Protecção contra Radiações, 2005, Anais da I Jornada Luso-Brasileira de Protecção contra Radiações. Lisboa, Portugal. CD-ROM. (2005).
5. Shammas, G.I.J., "Simulação Semi-empírica da Resposta Termoluminescente sob Diferentes Geometrias de Filtro". Master Degree Dissertation, area Nuclear Techniques and Applications (TNA-IPEN, www.ipen.br), advisor J. E. Manzoli, 2007.