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Extensive Fade Study Of Harshaw LiF TLD Materials

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Abstract

A Comprehensive and extensive fade study was conducted for Thermo Scientific™ Harshaw™ LiF TLD materials. This study covers the well established LiF:Mg,Ti and LiF:Mg,Cu,P materials in their different isotopes, sizes, forms and time-temperature readout schemes. Two parts of the fade study on the signal loss and the sensitivity loss were carried out in a long-term period of 500+ days at temperatures of 0˚C, 20˚C and 40˚C using more than 3500 dosemeters. Detailed results are presented and a summary is provided.

Introduction

Fade is the process of gradually reducing the capability of producing the response due to the radiation exposure. It has two components. One is the signal loss (post-fade: the reduction of the response signal after the material has been irradiated), another is the sensitivity loss (pre-fade: the reduction of the capability to produce the response before the material is irradiated).

Study and Setup

The details of each type of dosemeter are described as following:

LiF:Mg,Ti Card (TLD-1776):

	Detector 1	Detector 2	Detector 3	Detector 4
Mat'l	TLD-100	TLD-700	TLD-700	TLD-600
Size	0.32 x 0.32 x 0.4 mm	0.32 x 0.32 x 0.4 mm	0.32 x 0.32 x 0.15 mm	0.32 x 0.32 x 0.4 mm

LiF:Mg,Cu,P Card (TLD-1776H):

	Detector 1	Detector 2	Detector 3	Detector 4
Mat'l	TLD-100H	TLD-700H	TLD-700H	TLD-600H
Size	Φ3 x 0.4 mm	Φ3 x 0.4 mm	Φ3 x 0.25 mm	Φ3 x 0.4 mm

Extremity

	LiF:Mg,Ti EXTRAD XD-700	*LiF:Mg,Ti DXTRAD DXT-100*	*LiF:Mg,Cu,P EXTRAD XD-707H*	*LiF:Mg,Cu,P DXTRAD DXT-707H*
Mat'l	TLD-700	TLD-100	TLD-700H	TLD-700H
Size	0.32 x 0.32 x 0.4 mm	Φ3 x 0.4 mm	Powder	Powder

The study is conducted on:

- Signal loss and Sensitivity loss.
- Three storage temperatures: 0 C, 20 C and 40 C.
- There are about 3000 cards and 650 extremities. 18 permutations in cards and 8 permutations in extremities for each type of detector.
- Standard Harshaw TLD Time-Temperature Profiles.
- All dosemeters annealed at the beginning.
- Half irradiated 2 days later (Signal loss); Another half irradiated a week before readout (Sensitivity loss).
- Controls are read at the same time.
- Harshaw Model 8800 TLD reader.
- Delivered dose = 3 mSv using a $^{90}Sr/^{90}Y$ beta source.

Results

In this study, the baseline is defined as 2-day fade: one day Signal loss and one day Sensitivity loss. Figures 1-5 show the detailed glow curves changes. Figures 6-10 show the TL response change compared to the baseline versus the fade time.

At the storing temperature 20˚C, in the first 30 days, the signal loss out weighs the sensitivity loss. Beyond 60-80 days, the sensitivity loss increases at a faster rate. This 'flip' is illustrated clearly in figures 9 and 11. However, this is not notable for LiF:Mg,Cu,P (figure 7c).

When the TLD is preheated to the temperature that eliminates the fast faded peaks in its readout, the fade should be reduced. This can be observed in figure 8c at 20˚C storing temperature where there is no significant fade. However, at 0˚C storing temperature, the response appears to increase, figure 8a. It cannot be explained in the present work. At 40˚C, more sensitivity loss than signal loss is noticed, see figure 8b.

The basic fade function form, based on these data, is: $F=a*\ln(T)+b$ where F is the fade factor and T is the time period from anneal to readout in days. Parameters and of each type are provided in table below.

Currently used function: $F = e^{-0.00331*(\frac{T}{2}-8)}$

This fade function is based on an 8-day Signal loss and an 8-day Sensitivity loss. It has been used for years for LiF:Mg,Ti material, in all forms, with the limit of no more than 120 days. From figures 9 and 11, one can see that these two fade functions are comparable between 20 to 120 days

LiF:Mg,Ti Card	0°C Signal Loss	0°C Sensitivity Loss	0°C Average	20°C Signal Loss	20°C Sensitivity Loss	20°C Average	40°C Signal Loss	40°C Sensitivity Loss	40°C Average
a	-0.0425	-0.0333	-0.0379	-0.0524	-0.0736	-0.063	-0.0569	-0.0726	-0.0647
b	1.0531	1.0568	1.055	1.0018	1.0832	1.0425	1.003	1.0075	1.0053
LiF:Mg,Ti Extremity									
a				-0.0464	-0.0878	-0.0671			
b				0.9749	1.1332	1.0541			
LiF:Mg,Cu,P Card									
a	-0.0153	-0.006	-0.0107	-0.0187	-0.0249	-0.0218	-0.0225	-0.0315	-0.027
b	1.0256	1.0111	1.0183	1.0032	1.0339	1.0186	1.0073	1.024	1.0156
LiF:Mg,Cu,P Card									
a	0.0056	0.0043	0.0049	-0.0065	-0.0139	-0.0102	-0.0165	-0.0292	-0.0228
b	0.9992	1.0033	1.0012	1.0243	1.0513	1.0378	1.0122	1.0343	1.0233
LiF:Mg,Cu,P Extremity									
a				-0.0118	-0.006	-0.0062			
b				1.0663	1.029	1.0476			

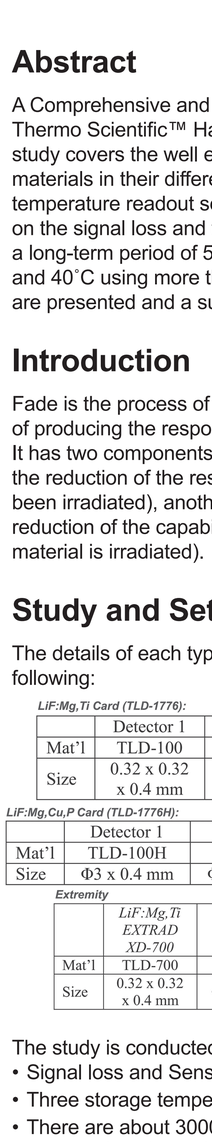

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fig. 1a LiF:Mg,Ti (TLD-100, 0.4mm) 0°C

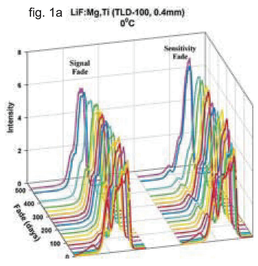

fig. 2a LiF:Mg,Cu,P (TLD-100H, 0.4mm) 0°C

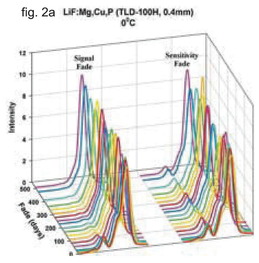

fig. 1b LiF:Mg,Ti (TLD-100, 0.4mm) 20°C

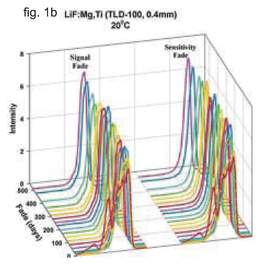

fig. 2b LiF:Mg,Cu,P (TLD-100H, 0.4mm) 20°C

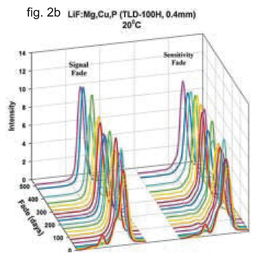

fig. 1c LiF:Mg,Ti (TLD-100, 0.4mm) 40°C

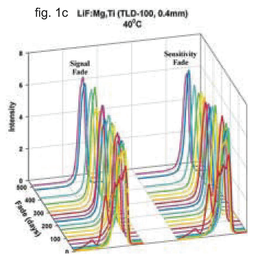

fig. 2c LiF:Mg,Cu,P (TLD-100H, 0.4mm) 40°C

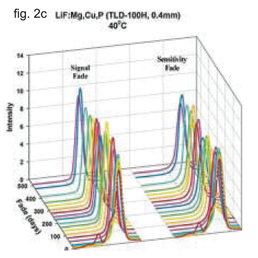

Figure 1: Illustration in glow curve changes for the Signal loss and Sensitivity loss of LiF:Mg,Ti Card (TLD-1776) at storage temperatures of: a. 0 C; b. 20 C and c. 40 C in a period of 17 months. The readout temperature ramped from 50˚Cto 300˚C.

Figure 2: Illustration of glow curve changes for the Signal loss and Sensitivity loss of LiF:Mg,Cu,P Card (TLD-1776H) at storage temperatures of: a. 0 C; b. 20 C and c. 40 C in a period of 17 months. The readout temperature ramped from 50˚Cto 260˚C.

fig. 3a LiF:Mg,Cu,P (TLD-100H, 0.4mm) 0°C

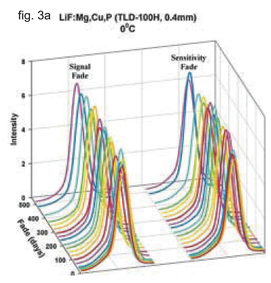

fig. 3b LiF:Mg,Cu,P (TLD-100H, 0.4mm) 20°C

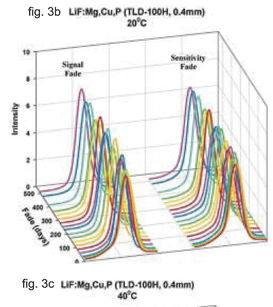

fig. 3c LiF:Mg,Cu,P (TLD-100H, 0.4mm) 40°C

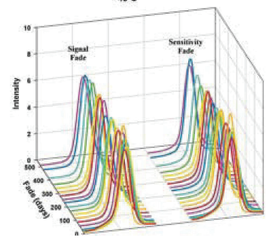

fig. 4 LiF:Mg,Ti (TLD-100, 0.4mm) DXTRAD 20°

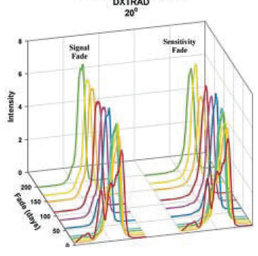

fig. 5 LiF:Mg,Cu,P (TLD-707H, 0.07mg/cm²) EXTRAD 20°

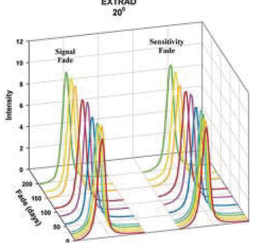

Figure 3: Illustration in glow curve changes for the Signal loss and Sensitivity loss of LiF:Mg,Cu,P Card (TLD-1776H) at storage temperature of: a. 0 C; b. 20 C and c. 40 C in a period of 17 months. The readout temperature ramped from 165 Cto 260 C.

Figure 4: Illustration in glow curve changes for the Signal loss and Sensitivity loss of LiF:Mg,Ti Extremities (XD-700 and DXT-100) at storage temperatures of 20 C in a period of 6 months. The readout temperature ramped from 50 Cto 300 C.

Figure 5: Illustration in glow curve changes for the Signal loss and Sensitivity loss of LiF:Mg,Cu,P Extremities (XD-707H and DXT- 707H) at storage temperature of 20 C in a period of 6 months. The readout temperature ramped from 165 Cto 255 C.

fig. 6a Harshaw TLD LiF:Mg,Ti Heating Range 50° - 300°C Signal Fade and Sensitivity Fade at 0°C

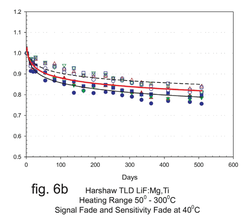

fig. 6b Harshaw TLD LiF:Mg,Ti Heating Range 50° - 300°C Signal Fade and Sensitivity Fade at 40°C

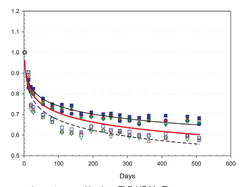

fig. 6c Harshaw TLD LiF:Mg,Ti Heating Range 50° - 300°C Signal Fade and Sensitivity Fade at 20°C

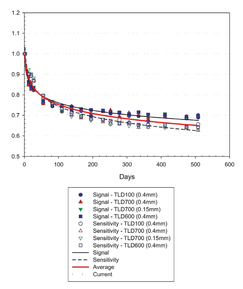

fig. 7a Harshaw TLD LiF:Mg,Cu,P Heating Range 50° - 260°C Signal Fade and Sensitivity Fade at 0°C

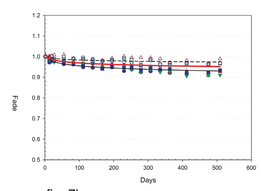

fig. 7b Harshaw TLD LiF:Mg,Cu,P Heating Range 50° - 260°C Signal Fade and Sensitivity Fade at 40°C

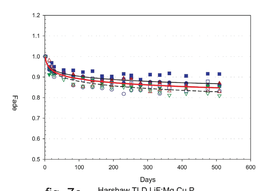

fig. 7c Harshaw TLD LiF:Mg,Cu,P Heating Range 50° - 260°C Signal Fade and Sensitivity Fade at 20°C

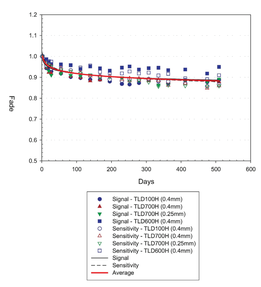

Figure 6: Relative Signal loss and Sensitivity loss, based on 2-day fade, of LiF:Mg,Ti Card (TLD-1776) at storage temperatures of: a. 0˚C; b. 40˚C and c. 20˚C in a period of 17 months. The readout temperature ramped from 50˚Cto 300˚C.

Figure 7: Relative Signal loss and Sensitivity loss, based on 2-day fade, of LiF:Mg,Cu,P Card (TLD-1776H) at storage temperatures of: a. 0˚C; b. 40˚C and c. 20˚C in a period of 17 months. The readout temperature ramped from 50˚Cto 260˚C.

fig. 8a Harshaw TLD LiF:Mg,Cu,P Heating Range 165° - 260°C Signal Fade and Sensitivity Fade at 0°C

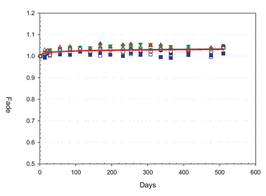

fig. 8b Harshaw TLD LiF:Mg,Cu,P Heating Range 165° - 260°C Signal Fade and Sensitivity Fade at 40°C

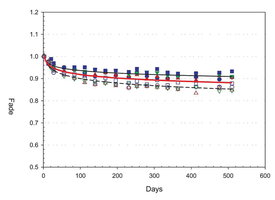

fig. 8c Harshaw TLD LiF:Mg,Cu,P Heating Range 165° - 260°C Signal Fade and Sensitivity Fade at 20°C

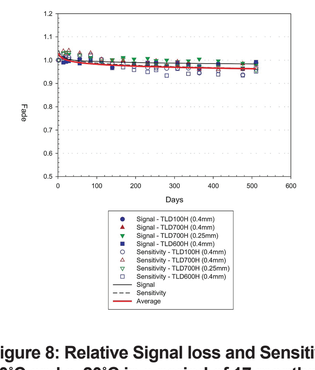

fig. 9 Harshaw TLD LiF:Mg,Ti - Extremity Heating Range 50° - 300°C Signal Fade and Sensitivity Fade at 20°C

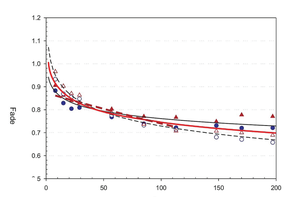

fig. 10 Harshaw TLD LiF:Mg,Cu,P - Extremity Heating Range 165° - 255°C Signal Fade and Sensitivity Fade at 20°C

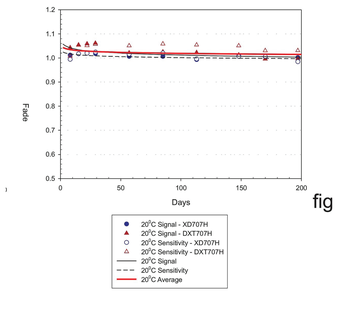

fig. 11 Harshaw TLD LiF:Mg,Ti Heating Range 50° - 300°C Signal Fade and Sensitivity Fade at 20°C

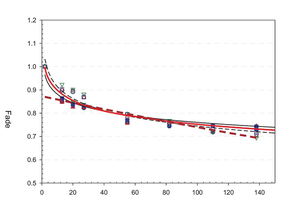

Figure 8: Relative Signal loss and Sensitivity loss, based on 2-day fade, of LiF:Mg,Cu,P Card (TLD-1776H) at storage temperatures of: a. 0˚C; b. 40˚C and c. 20˚C in a period of 17 months. The readout temperature ramped from 165˚Cto 260˚C.

Figure 9: Relative Signal loss and Sensitivity loss, based on 2-day fade, of LiF:Mg,Ti Extremities (XD-700 and DXT-100) at storage temperatures of 20˚C in a period of 6 months. The readout temperature ramped from 50˚C to 260˚C.

Figure 10: Relative Signal loss and Sensitivity loss, based on 2-day fade, of LiF:Mg,Cu,P Extremities (XD-707H and DXT-707H) at a storing temperature of 20˚C in a period of 6 months. The readout temperature ramped from 165˚C to 255˚C.

Figure 11: Rescale of figure 6c for 150 days.

Summary

An extensive long term fade study of Harshaw LiF based TLD has performed. The results are highlighted below:

1. The Signal loss and the Sensitivity loss do not fade at the same rate and are dependant on the storage temperature.
2. At the low temperature, Signal loss is faster than the Sensitivity loss due to the preservation of low temperature peak 2.
3. There is a transition period, when peak 2 is completely faded. At this point, the sensitivity starts to fade faster than the signal.
4. The readout TTP, with preheat, reduces the fade. There is no significant fade for LiF:Mg,Cu,P during the 17 months period.
5. Different material isotopes, sizes and forms have insignificant effect on fade.
6. The currently used fade function is valid within its limits.

Further work to quantify each peak and to better understand the fade is planned.

Acknowledgement

The author would like to acknowledge her co-workers for their support.

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