COO--1105-226

TL RESPONSE TO 1-30 kV ELECTRONS OF TLD-100 AND TLD-100 DIFFUSED WITH VARIOUS ELEMENTS

Technical Report COO-1105-226

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Abstract

The TL response of LiF TLD-100 has been examined as a function of diffusional dopings of the dosimeter surface layers. The glow curve shapes and TL response for irradiations with Cs γ-rays compared with electrons in the 1-30 kV energy range provides a good diagnostic and suggests some interesting practical applications.

TL Response to 1-30 kV Electrons of TLD-100 and TLD-100 Diffused with Various Elements

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The TL response of TLD-100 single crystals irradiated with 1-30 kV electrons is being investigated. We have found that the glow curve shape is the same as that obtained when irradiated with Cs^{137} gamma rays. This is true only if all annealings are done in vacuum. If the annealing is done in air the glow curve produced by low energy electrons is greatly different from the glow curve produced by irradiation with x-rays. Experiments are in progress to isolate the elements which diffuse into TLD-100 during annealing and alter its glow curve. Since the depth of penetration of these elements can be limited to a few microns the TL resulting from radiation which deposits its energy in this region can be distinguished from radiation which deposits its energy in the bulk. One example is distinguishing the dose due to tritium β rays from the dose due to a background x-ray field.

Samples measuring 1/8" x 1/8" x .040" were cleaved from a large single crystal of TLD-100 purchased from the Harshaw Chemical Co. (Cleveland, Ohio) in 1975. These were annealed for one hour at 400°C in a vacuum of 5×10^{-6} torr and allowed to cool in the vacuum to room temperature. The samples were read out once prior to irradiation to remove the effect of their slow cooling to room temperature.

Irradiations were carried out in an evacuated pyrex chamber. A vacuum of 10^{-5} torr was sufficient to prevent ionic currents. The source of electrons is a tungsten filament held at 0 to minus 50 kV. The electrons pass through two aligned 1 mm holes in stainless steel discs and strike the sample. (See Fig. 1). The first disc is grounded and the second disc is at minus 45 volts. The samples rest in shallow wells drilled in a rotatable stainless steel disc. These wells may

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be precisely positioned under the irradiation port. The sample disc is grounded through a Kiethly 610C electrometer which measures the total charge striking the sample. A fine tungsten mesh has been spot welded over the irradiation hole in the second disc to minimize pertibation by this hole of the electric field seen at the crystal. Geometrically all electrons which pass through the irradiation port must strike the sample. Secondary electrons produced at the sample are repelled by the second stainless steel disc and are collected by the sample disc.[1] All secondary electrons produced at the top of the first disc are repelled by the second disc and do not reach the collecting sample disc.

The samples were read out in a helium atmosphere in a modified Harshaw 2000 A reader. A linear heating rate of 7°C/sec. was used. Fig. 2 shows a typical response to 5, 10, 30 KeV electrons and to cesium gamma rays. Annealing in vacuum for as long as 150 hours resulted in no change in the glow curve shape or sensitivity of the crystals. Figure 3 shows the results of measurement of the height of peak 5 as a function of dose delivered to the sample for several different electron energies. The relative response to Cs in Fig. 3 was calculated by measuring the response per erg deposited at one Rad and multiplying by the superlinearity factor[9] at the stated dose.

The onset of saturation at 10^5 rad agrees with the findings of Suntharalingam for 50 KeV electrons and supports his model for the onset of saturation occurring at the dose where the concentration of ion pairs is approximately equal to the concentration of Mg impurities.[2] The monotonically decreasing TL sensitivity with increasing L.E.T. (the L.E.I.) of 30, 20, 10, 5, 2.5 KeV electrons are 4.9, 6.7, 11.1, 15.2 and 19.2 KeV/ respectively[3]) is qualitatively in agreement with the findings of Jahnert[4] and Suntharalingan.[5] These data will be extended into the low dose regions

where the TL sensitivity to these different L.E.T. electrons can be studied without the complicating effect of saturation.

The effect of annealing samples in air at 400°C for one and twenty four hours is shown in Figures 4 and 5. Their responses to x-rays remains unaffected. It is evident that the impurity responsible for the change in the glow curve has diffused about the range of a 20 kV electron, 3 microns, in one hour and more than the range of a 30 kV electron, 6.1 micron[6], in 24 hours: The area under the glow curve of a crystal annealed in air at 400°C for 24 hours and irradiated with low energy electrons is 50% less than for a crystal annealed in vacuum. Several authors have noted the decreased sensitivity of TLD-100 to low energy electrons.[7,8] In their experiments the effect of annealing in air was apparently not considered.

Stoebe and DeWerd[10] have reported a similar change in the glow curve for the x-ray response of TLD-100 diffused with hydroxyl ions. To see if hydroxyl ions are responsible for the change in the glow curve obtained from the surface, samples were sealed in a thoroughly cleaned evacuated quartz tube along with ice made from deionized water. The result of diffusion at 700°C for four hours are shown in Figure 6. The changes produced are similar to those produced by annealing in air and to DeWerd's findings for the OH diffused TLD-100. This suggests that we may predict the bulk glow curve which will be produced by doping with various elements by diffusing these elements into the surface and examining its response to low energy electrons.

During the course of these experiments samples were annealed at 700°C in continuously flowing commercial grade argon and nitrogen. The low energy electron response of the resulting crystals is shown in Figure 7. Since both crystals produce identical glow curves it is believed an impurity in these commercial grade gases is responsible for the change. Furthermore,

samples annealed in reagent grade argon at 700°C for several days show no change in their glow curve. The presence of a peak at 290°C, where there is no response in an untreated sample, suggests the use of this sample to discriminate between radiation which deposits its energy in the top treated layer and radiation which deposits its energy in the bulk. Figure 7 shows these sample's response to tritium and cesium gamma rays. We plan to isolate the impurity responsible for the 290°C peak.

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Fig. 1 Irradiation chamber

Fig. 2 Response of TLD-100 single crystals to 10^{-10} coulomb 5, 10, and 30 kV electrons and 230 mRad cs^{137} x-rays. Scales are multiplied by indicated factors.

Fig. 3 Height of peak 5, for vigin single crystal TLD-100, as a function of dose delivered to the sample.

Fig. 4 Response of TLD-100 to 5, 10, 20 and 30 kV electrons. Scales are multiplied by indicated factors.

Fig. 5 Response of TLD-100 single crystals annealed in air for 24 hours at 400°C to 5, 10, 20 and 30 kV electrons. Scales are multiplied by indicated factors.

Fig. 6 Response of TLD-100 single crystals diffused with OH at 700°C for 4 hours. Scales are multiplied by indicated factors.

Fig. 7 Response of single crystal TLD-100 annealed in commercial grade argone at 700°C for 75 minutes to low energy electrons. Annealing in commercial grade nitrogen gave the same response. Scales are multiplied by indicated factors.

Fig. 8 Response of treated samples to tritium (A) and cesium gamma rays (B).

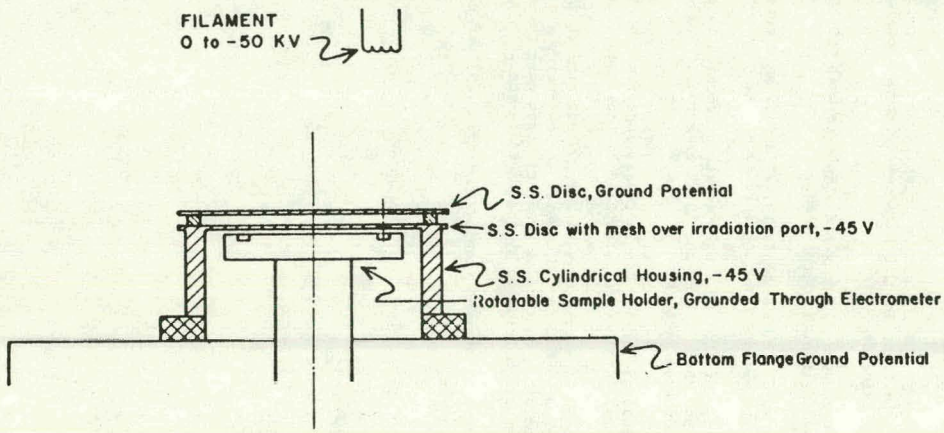
FILAMENT
0 to -50 KV
S.S. Disc, Ground Potential
S.S. Disc with mesh over irradiation port, -45 V
S.S. Cylindrical Housing, -45 V
Rotatable Sample Holder, Grounded Through Electrometer
Bottom Flange Ground Potential

Fig. 1

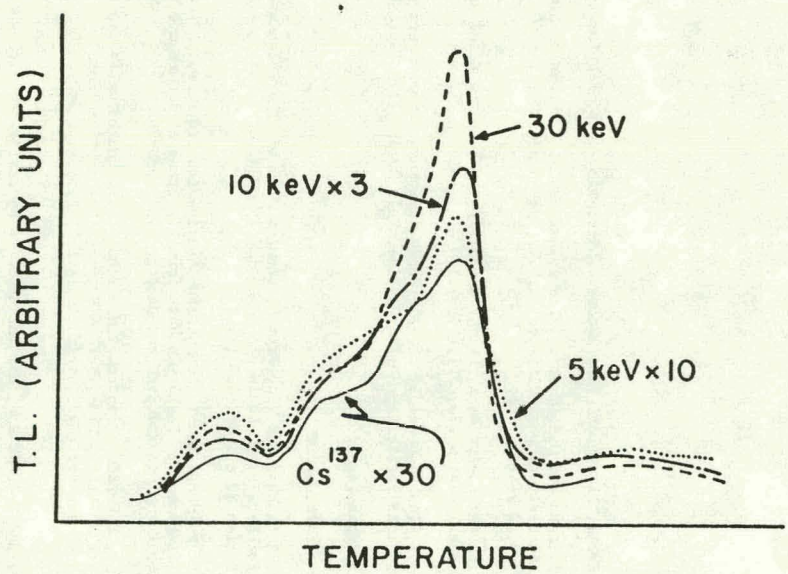
T.L. (ARBITRARY UNITS)
30 keV
10 keV×3
5 keV×10
Cs 137 ×30
TEMPERATURE

Fig 2

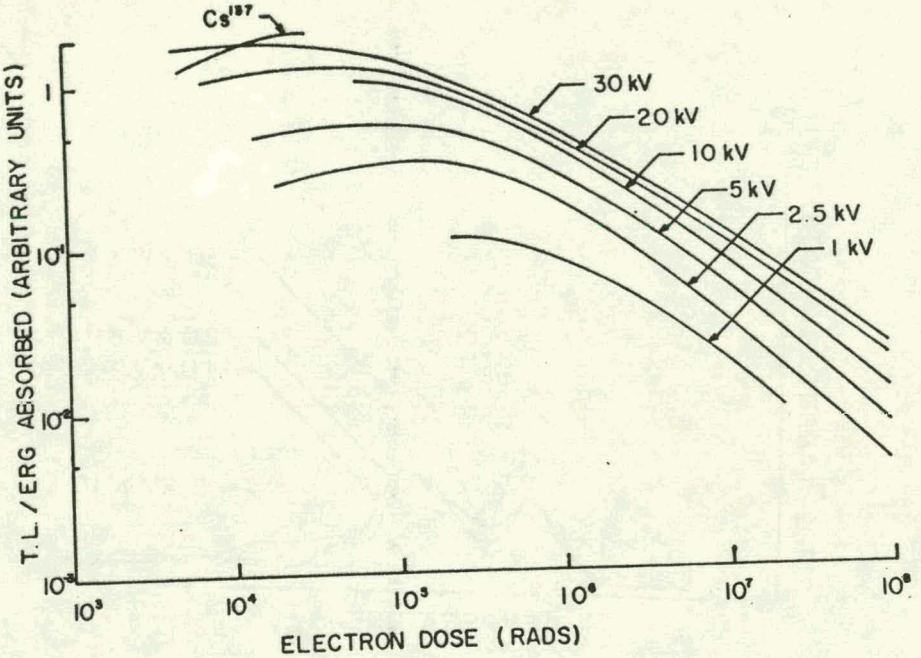
Cs137
30 kV
20 kV
10 kV
5 kV
2.5 kV
1 kV
T.L. / ERG ABSORBED (ARBITRARY UNITS)
10³
10⁴
10⁵
10⁶
10⁷
10⁸
ELECTRON DOSE (RADS)

Fig. 3

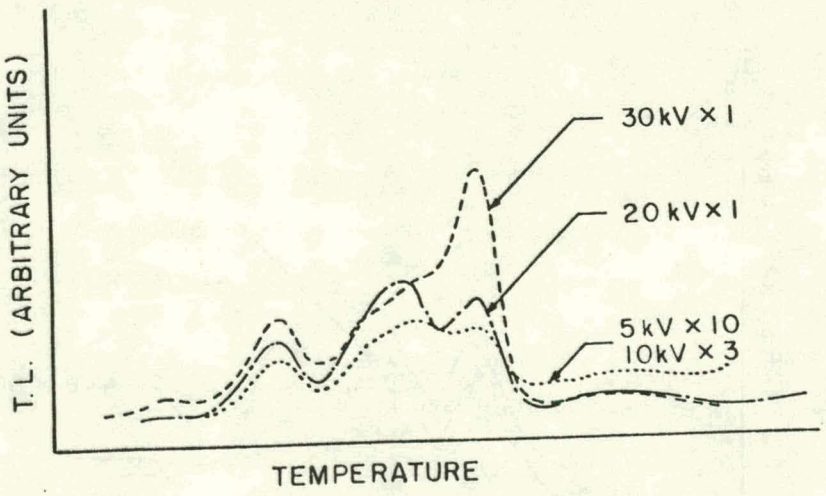
T.L. (ARBITRARY UNITS)
30kV × 1
20 kV × 1
5 kV × 10
10kV × 3
TEMPERATURE

Fig. 4

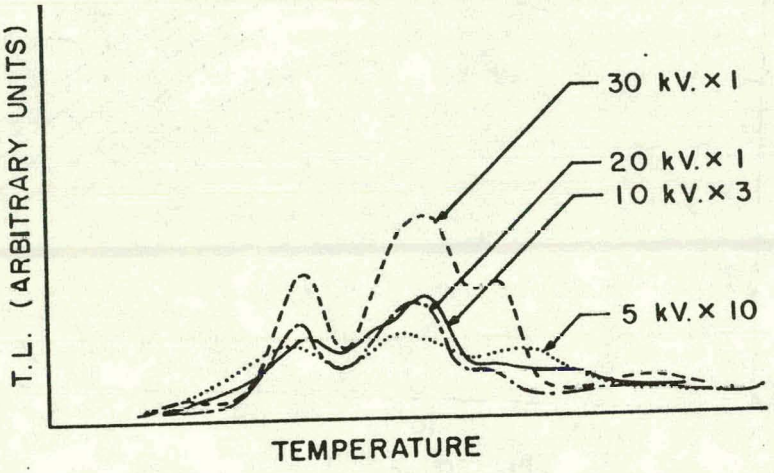
T.L. (ARBITRARY UNITS)
30 kV. × 1
20 kV. × 1
10 kV. × 3
5 kV. × 10
TEMPERATURE

Fig.5

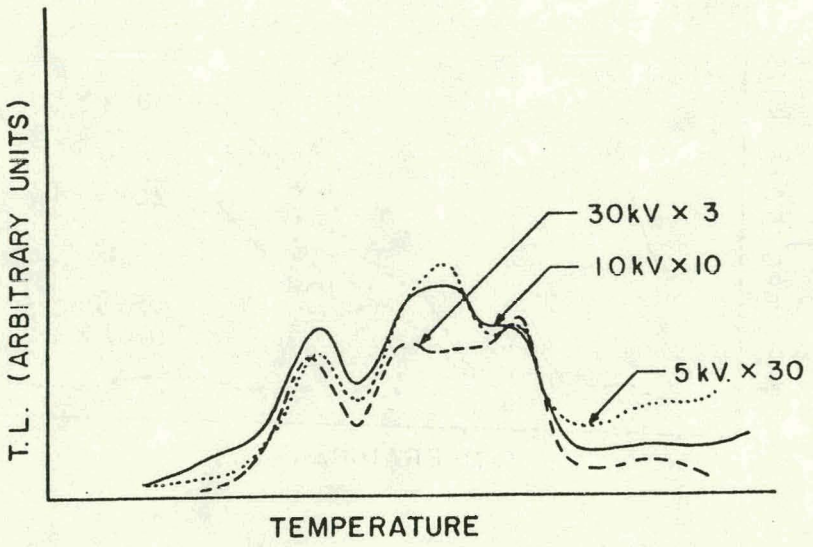
T.L. (ARBITRARY UNITS)
30kV × 3
10kV × 10
5 kV. × 30
TEMPERATURE

Fig. 6

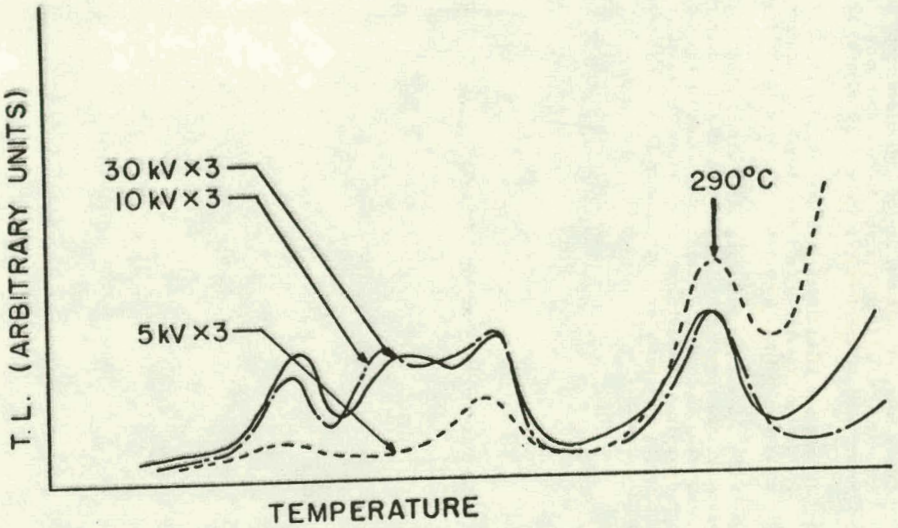
30 kV×3
10 kV×3
5 kV×3
290°C
T.L. (ARBITRARY UNITS)
TEMPERATURE

Fig. 7

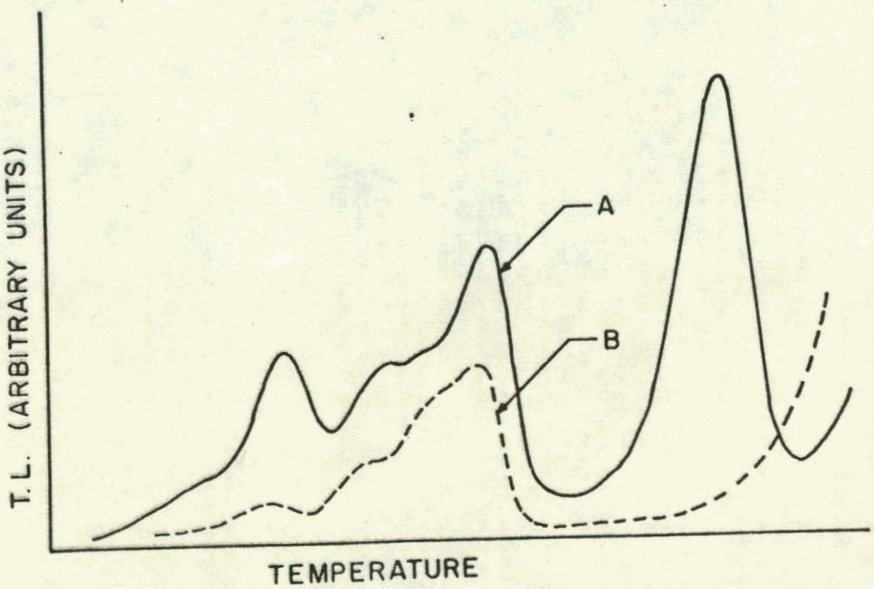
A
B
T.L. (ARBITRARY UNITS)
TEMPERATURE

Fig. 8

FAST NEUTRON ACTIVATION DOSIMETRY WITH TLD

Technical COO-1105-227

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Abstract

Gas neutron activation using threshold reactions is the only neutron dosimetry method which offers some neutron energy information and complete discrimination against gamma-rays. Conventional activation foil technique requires sensitive radiation detectors to count the decay of the neutron induced activity. For extensive measurements at low level neutron fluences, vast outlays of counting equipment are required. TL dosimeters are inexpensive, extremely sensitive radiation detectors. The work of Mayhugh et.al. (Proc. Third Int. Conf. on Luminescence Dosimetry, Risø Report 249, 1040, (1971)) showed that $CaSO_4$:Dy TLDs could be used to measure the integrated dose from the decay of the radioactivity produced in the dosimeters by exposure to thermal neutrons. This neatly combines the activation detector and counter functions in one solid state device. This work has been extended to fast neutron exposures and other TL phosphors. The reactions $^{19}F(n,2n)^{18}F$, $^{32}S(n,p)^{32}P$, $^{24}Mg(n,p)^{24}Na$ and $^{64}(n,p)^{64}Ca$ were found to be useful for fast neutron activation in commercial TLDs. As each TLD is its own integrating decay particle counter, many activation measurements can be made at the same time. The subsequent readings of the TL signals can be done serially after the induced radioactivity has decayed using only one TL reader. The neutron detection sensitivity is limited by the number of statistics of the neutron activations. The neutron measurement precision is within a factor of 2 of conventional foil activation techniques for equivalent numbers of activating atoms. Commercially available TLDs can measure 14 MeV neutron fluences of $10^9 n/cm^2$ with 10% precision.

The bulk of this report constitutes a Ph.D. dissertation by Dave W. Pearson which will be transmitted separately under the same report number after its completion.