A COMPARATIVE STUDY ON PIEZO AND THERMOLUMINESCENCE OF LiF

A.M. Eid, A. Moussa*, E.H. El-Adl*, and K.V. Ettinger**

National Centre for Radiation Research and Technology
* National Institute for Standards
** Dept. of Bio-Medical Phys. Aberdeen Univ. U.K.

Abstract:

In the present work the pieze- and thermoluminescence yield of LiF irradiated with γ-radiation is experimentally determined. Natural and thermally activated fading properties are also studied for both phenomena. For comparative purposes, the piezoluminescence assumes linear relation as a function of dose similar to that of thermoluminescence. An attempt to throw some light on piezo-luminescence mechanism is made.

Introduction:

Evidently, light is emitted as a result of applying stresses on some alkali halide crystals being irradiated with X- or γ-radiation. Quantitative and qualitative analysis of this phenomenon, piezoluminescence (PL), have been reported by many authors; among them Metz (1957), Buther (1966), Chandra (1981), Atary (1982) and Manam (1985). Although, no suitable model has been established for its mechanism, however, Atary (1982) suggested that the mechanism associated with both phenomena (TL and PL) is mainly due to recombination process between electrons and holes set free as a result of thermal - or mechanical activation. Also, he added that, using PL-phenomenon, it is capable of measuring γ-radiation with minimum detectable dose of 0.40 mGy. Neverthless, Manam (1985) showed that deformation does not appreciably alter the mechanism and the site of recombination in the TL-emission but may cause a preferential redistribution of traps by changing of relative intensities of these emission.

In the present work, luminescence of LiF resulting from mechanical as well as thermal activation is investigated, for the sake of intercomparison between the two phenomena (TL & PL) of the same material. Fading characteristics under certain experimental conditions are also presented.

Experimental:

LiF polycrystalline chips (TLD-100) with dimensions (3x3x0.87 mm^3) are used. The samples are γ-irradiated from Co^{60}-source at dose rate 74 Gy/hr. For each test dose four chips are assigned, two beeing used for PL-measuring and the other two for TL.

Fig. (1) illustrates the experimental set up for PL-determination in which sufficient care is taken to reduce undesirable experimental difficulties (Dept of Biomed. Phys., Aberdeen Univ.). The pressure applied on the samples is generated by a material testing machine fitted with an electronically controlled cross-head. The cross-head speed can be adjusted between 0.5 mm/min. to 10 mm/min.

For TL-measurements a Harshow 3000-A with X-Y recorder is used (National Institute for Standards - Cairo).

Results:

For a test dose of 70 Gy the integrated PL-yield is examined against the applied pressure, Fig. (2). It can be seen, for the first approximation, that the relation is straight line with varying slope in which the yield increases as the pressure increases. This indicates that the PL-yield pressure relationship being not a first order relation. Also, it should be mentioned that no appreciable change in the PL-yield is noticed upon changing the speed of the cross-head (increase of pressure) from 0.5 to 5 mm/min.

Fig. (3) illustrates the variation of compression curve (a) together with that of PL-glow curve (b); both relative to the sweeping time in seconds. Whence, apart from the sweeping time, it can be seen that PL-signal assumes the same variational features as that of the compression curve; particularly, in the growth stage. However, upon keeping the compression constant, at its maximum value (~100 bar) for about 100 seconds, the PL-signal drops sharply down to ground-state signal. Then, upon pressure releasing a peak formation starts reaching its maximum at about 150 bar.

The effect of compression upon TL-intensity is shown, Fig. (4). So, no significant change is noticed except a 10% rise in the relative intensity at the peak position leaving the area under curve about the same. Nevertheless, the down-shift of the rise part of the curve stands for preferential redistribution of the traps without altering the position of the recombination process (peak), which is in good agreement with the previous work of Manam.

Fading characteristics of PL-signal, naturally (a) and thermally-activated (b), are illustrated in Fig. (5) included with the thermally-activated fading curve of the TL-signal (c). In case of TL the natural fading is known to be 5% per year at room temperature while thermally activated TL-fading goes very faster which appears clear from curve (c), Fig. (5). On the conterary the PL-natural fading, curve (a) Fig. (5), experiences a peak after about 60 h from the time of irradiation. In other words, the PL-yield increased by 25% of its original value as the time naturally run 60 h. This may indicate that, as far as PL is concerned, radiation

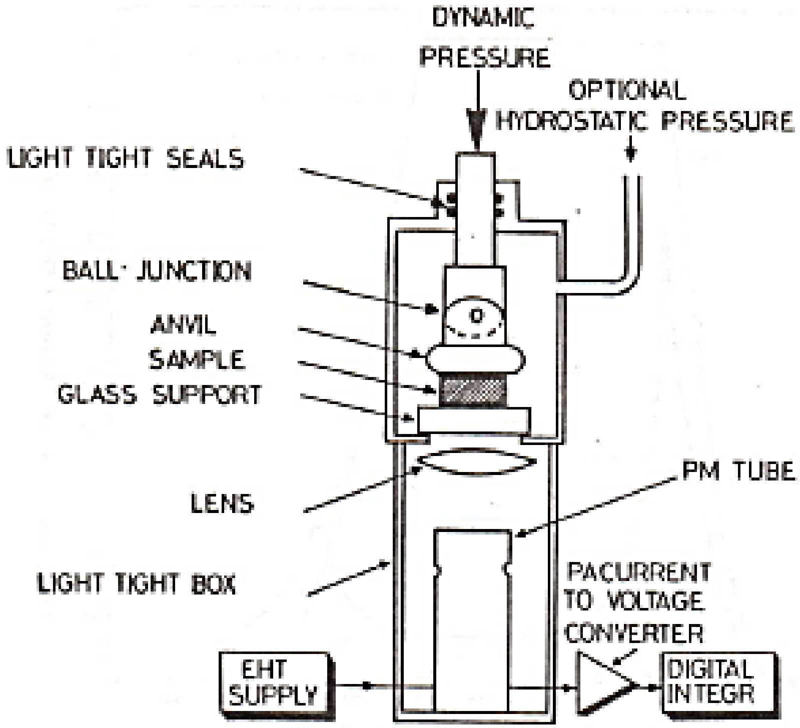

Fig.(1): Schematic diagram of piezoluminescence experimental ste up

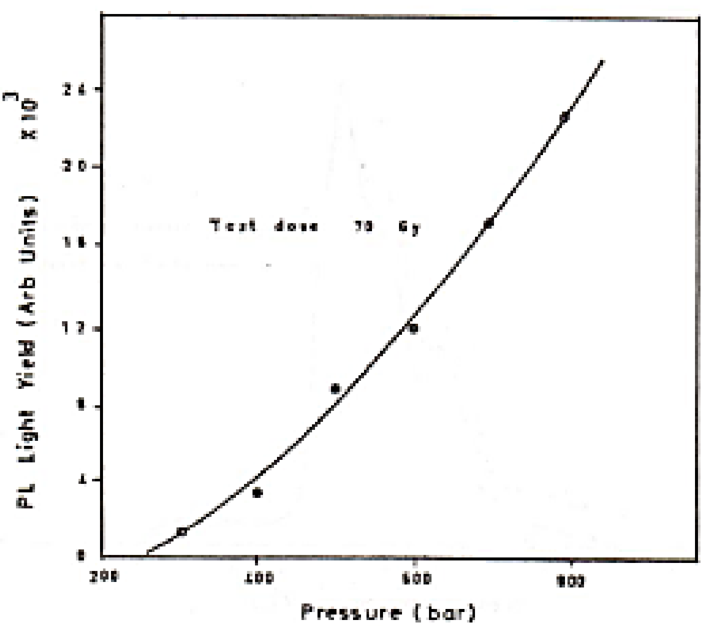

Fig.(2): Piezoluminescence yield of LiF vs the applied Pressure.

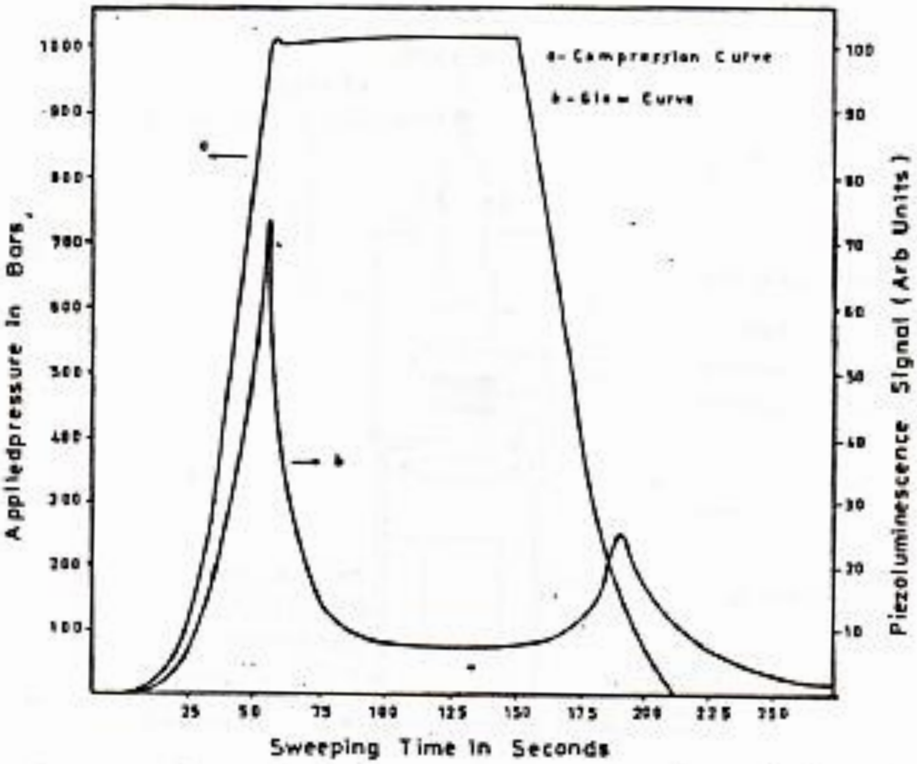

Fig.(3): Piezoluminescence glow curve of irradiated LiF during application and release of pressure.

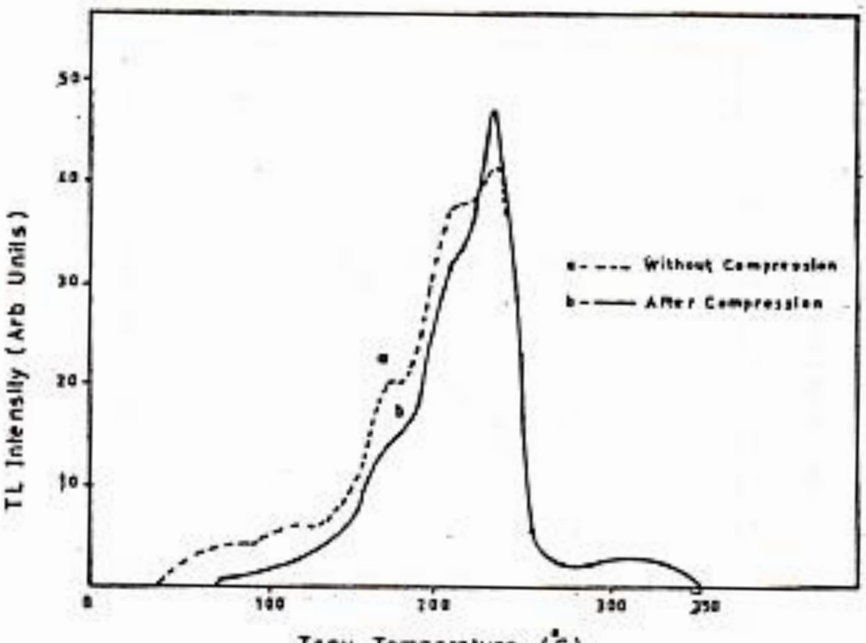

Fig.(4): Typical TL glow curve of LiF exposed to gamma-ray, a -before compression, b-after compression.

induced defects have certain stimulation time which should be elapsed to obtain the maximum PL-yield. Moreover, annealing induces no appreciable variation, particularly in the first stage, on the fading properties of PL as compared with natural fading. Nevertheless, the PL-signal naturally reaches to about 40% of its original value upon storage for twelve days whereas annealing at 170°C cleans up the chips down to PL-background.

Eventually, PL-and TL-signals are plotted as a function of dose, Fig. (6). It appears from the figure, although different scales, that the response in both cases being of similar feature. Also, as far as PL is concerned, it covers a big range of dose with a reasonable sensitivity.

Discussion and Conclusion

The fact that the energy imparted to the cloud of charge in crystal array upon heating to 500 K (the peak position of LiF under investigation) is given to be 4.3×10^{-2} eV. This amount of energy is responsible for the excitation of the radiation induced point defects to giving rise to TL-emission as a result of recombination between charges of different signs. In the same manner, the energy imparted as a result of applying 1000 bar pressure is 1.8×10^{-3} eV, Shurmak (1967). Therefore, the energy required for thermally activated emission is about 24 times larger than that required for mechanically activated emission. Thus, one can safely state that PL-emission does not arise from the recombination of the untrapped charges since the energy imparted in the mechanical activation process is so small compared with that required to set the charges free from a trap position.

In so far, the TL-emission remains unchanged after post-irradiation compression, Fig. (4), which properly indicates that radiation induced defects (mainly trapped charges) are actually not quantitatively influenced by the premechanical treatment. This, and in view of the above mentioned, emphasizes that we should basically differentiate between radiation induced defects responsible for TL-emission and those responsible for PL-emission. Furthermore, the appearance of a PL-glow peak upon release of force, Fig. (3), suggests that PL-mechanism depends to a great extent on the defects arises from the elastic deformation of the continuum rather than point defects.

In view of Fig. (6) where TL- and PL- is illustrated as a function of radiation dose, it can be concluded that the proportionality between dose and both yields (TL,PL) is rather linear. However, PL- to be used as indicative phenomenon has no significant advantage compared with the TL-phenomenon as a well established criterion for precise identification of radiation dose. In addition, specimens may practically suffer from fracture and damages as a result of mechanically applied pressure which may possibly makes their results irreproducible.

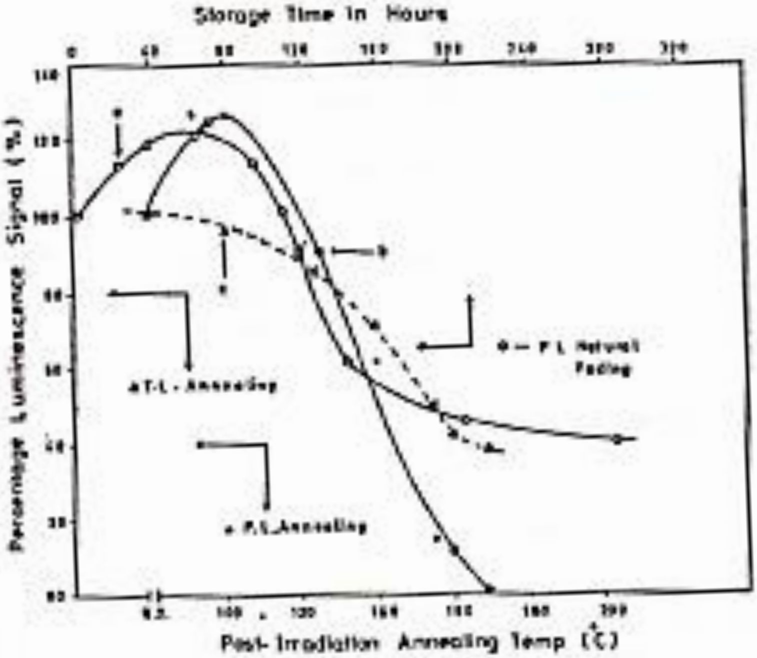

Fig.(5): Post-irradiation heating and natural fading of piezoluminescence and thermoluminescence signals of LiF.

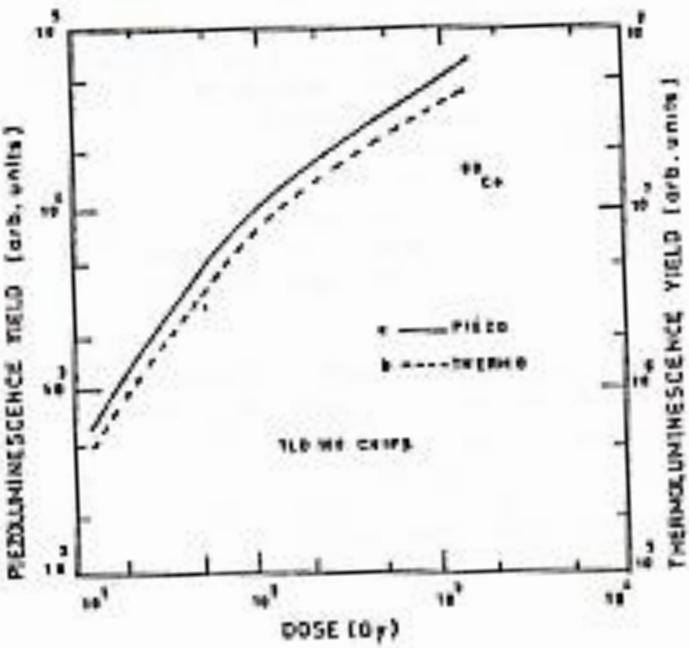

Fig.(6): Dose response Curve for piezoluminescence and thermoluminescence of LiF exposed to different gamma-ray doses.

References

1. Atari, N.A., Phys. Letters, Vol. 90 A, No. 1, 2, (1982) 93.

2. Buther, C.T.; Phys. Rev. 141 (1966) 750.

3. Chandra, V.P. and Zink J., 1 (b) J. Phys. Chem., Solids, 42 (1981) 529.

4. Manam, J., and Ratman, V.V., Nucl Tracks, Vol. 10, Nos 1/2, pp. 97-100, (1985).

5. Metz, F.J., et al., J. Phys. Chem. 61. (1957) 86.

6. Shmurak, S.Z. and Eliasberg, M.B., Fiz. Tver. Tela, 9 (1967), 1818.