A NEW APPROACH TO SCREENING ABNORMAL GLOW CURVES

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ABSTRACT

A simple computer program specifically developed to electronically screen abnormal LiF:Mg,Ti glow curves in routine dosimetry is presented. The method identifies glow curves with abnormal patterns by examining a few key features from which information about background and thermoluminescent (TL) signals can be extracted. The underlying criteria for glow curve acceptance/rejection are discussed. By analyzing the records of Quality Control (QC) cards that are in the same group as the field cards, the dosimeter- and reader-dictated parameters (such as the peak location) are automatically determined, thus eliminating the need for any prior knowledge of those conditions required for reference determination. The program performance was evaluated by using actual glow curve data provided by users of commercially available readers and dosimeters in routinely high-throughput operations. The initial tests showed a near 100% success rate in identifying abnormal glow curves (no false positive results) and a minimal rate of rejection of normal glow curves. Results have shown that this method is applicable for dose levels down to 50 μSv.

INTRODUCTION

As radiation monitoring and protection becomes an increasingly important issue, the growth in the scale of routine dosimetry is inevitable. A well established and widely employed dosimetry technique is thermoluminescence dosimetry (TLD) using LiF as the host material[1,2]. Dose information is generally extracted from the integral area under the glow curve or part of the glow curve. Errors in such measurements are inevitable due mainly to the existence of background and to the complex nature of the fast-fading glow peaks. Much effort has been devoted to improving the accuracy of dose measurement by subtracting background signal and by eliminating contributions from the fast-fading glow peaks[3-5].

In routine dosimetry where accuracy is not a critical issue, dosimetric information is approximated by the total area under the glow curve. The validity of such practice is ensured by carefully examining each individual glow curve and eliminating spurious readings before they can be used in dose algorithms[6]. Currently glow curve screening is done manually. This is not only time consuming, but the pass/fail decision making is highly subjective. The existing analysis programs cannot help change this situation because many features of these methods are not compatible with the practical requirements of routine dosimetry.

For the now-apparent reasons we have developed a simple program for routine personnel dosimetry to electronically analyze the shape of LiF:Mg,Ti glow curves. Rather than separating individual glow peaks, this method automatically recognizes irregular glow curves by identifying a few key glow curve features and testing them against a set of empirical criteria. Emphasis is placed on complete rejection of faulty glow curves and minimal rejection of good glow curves. Some specific faulty features in glow curve shape are:

1) saturation of readout
2) spikes caused by electrical interference
3) lack of a glow peak
4) glow peak occurs at unexpected temperature
5) distortion caused by non-radiation induced signal
6) high IR tail or high residual signal
7) end of acquisition before completion of glow curve.

GLOW CURVE STANDARDS

The intrinsic glow curve characteristics — the location and width of the main glow peak — are adversely affected by a host of factors such as the chip thickness, electronics of the card-reading instrument, and the heating profile used for readout. If all cards in a group are of the same type and are read in a relatively short time frame (say, one day) by the same reader, we can reasonably expect these glow curves to exhibit close similarity in shape. The established values of these parameters are defined as 'glow curve standards'.

Because the standards are largely determined by factors that are different from user to user, it is impossible to arrive at a universal set of parameters that are applicable to all users. This difficulty, however, can be overcome by utilizing the Quality Control (QC) cards that were interspersed in groups of field cards during card reading. The values of the intrinsic parameters (with reasonable tolerances) for field glow curves can be predicted from the corresponding aspects of the QC curves. This approach enables the determination of glow curve standards without any prior knowledge of the aforementioned conditions.

GLOW CURVE ASSESSMENT STEPS

The glow curve screening program proceeds through the following logical decision tree to determine which glow curves are likely to have faulty features and need visual inspection.

1. Saturation Test. Check for readout saturation by testing for a flat top in the TL spectrum.

2. Curve smoothing. Outlier points must first be removed from the initial spectrum. An outlier is a discrete point on the curve which, judging from its amplitude, is likely to arise from instrument malfunction rather than from statistical fluctuation. Specifically, an outlier y_i satisfies the condition:

$$\frac{|y_i - y^0_i|}{y_{max}} > 0.1$$

where

$$y^0_i = 0.5*(y_{i-1} + y_{i+1})$$

is the corresponding average of the immediate neighboring channels. An outlier is removed by replacing y_i with y^0_i. The weighted averaging method is used to filter out glow curve noise caused by the dosimeter and by instrument electronics. The weighting factors are chosen such that a respectable smoothing is achieved without altering the original features of the glow curve.

3. Glow curve noise level. The noise level of a glow curve is characterized by the number of outlier points and by the extent of the TL scatter. The latter is estimated by comparing the spectra before and after smoothing. If the estimated noise level exceeds a pre-set threshold, the glow curve is rejected.

4. Peak finding and Peak 5 identification. Peaks are automatically found by searching for local maximum, which is defined as the highest points in a region of ± 10 channels from a putative apex. The main dosimetric peak — peak 5 — is identified as the one closest to the expected peak location (as defined by the standard) and lies within a certain tolerance window.

5. Estimate various regions of interest. The glow curve from an irradiated dosimeter upon linear heating can be divided into three regions, where background and dosimetric information can be extracted.

   Region I: Low temperature region (peaks 1 and 2). In routine personnel dosimetry, peaks 1 and 2 are generally invisible due to long fade time. Consequently, this region should be dominated by the photomultiplier tube dark current. Excess signal in this region indicates the possibility of non-radiation induced signal, in which case the glow curve should be rejected.

   Region II: Main dosimetric peak region. This is the region of dosimetric interest and usually includes peaks 3, 4 and 5.

   Region III: High temperature region. This region is dominated by the temperature-dependent background, due mainly to infrared radiation (IR) by hot TL element and detector parts. The relative size of the IR radiation to the actual dosimetric signal is estimated by the ratio of the area under the curve for the last few channels over the area of Region II. An internal upper limit for this ratio has been set to reject those glow curves with high IR tails.

6. Determine the inflection point on the high-temperature side of Peak 5. This point is found either by searching for a local minimum immediately to the right of Peak 5, or by utilizing the curve slope information. If this point cannot be found, the glow curve should be rejected as incomplete.

7. Baseline fitting and background subtraction. For a complete glow curve, the baseline is fitted to an exponential function:

$$y = \exp(a + bx),$$

   where x is the channel number, y is the background level at channel x, a and b are parameters to be extracted from the fit. The sampling points used in the fit are the first N channels with constant background and the points in Region III. Figure 1 shows a smoothed glow curve and a superimposed background curve. The background signal can be calculated by integrating the area under the fitted background curve. If the ratio of background signal to the total signal is greater than the limit pre-specified by the user, the glow curve will be rejected.

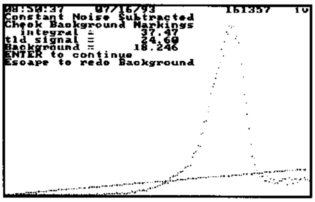

Figure 1. Background Subtraction

8. Estimate the width of the main glow peak. The glow peak width is measured by its full width at half maximum (FWHM) height. A maximum acceptable value of FWHM is determined based on the information obtained from the QC card records in the same group. A very wide glow curve structure usually indicates poor heat transfer and hence should be rejected.

PROGRAM OUTPUT

If a glow curve is rejected by the algorithm as a result of a failure from the evaluation criteria, an online message is displayed stating the dosimeter ID and reason for rejection. Upon completion of the program a summary report is created including the user-specified values of glow curve acceptance criteria, the number of dosimeters processed and a list of all glow curves rejected along with reasons for rejection.

PERFORMANCE EVALUATION

The method described herein has been tested with some 2000 glow curves provided by users of Harshaw/Bicron Model 8800 Automatic TLD Readers. The current algorithms demonstrated a success rate of nearly 100% in rejecting problematic glow curves. While having certain irregularities, a small fraction of the rejected glow curves may be deemed by some users as acceptable for dose evaluation. Figures 2 through 4 show some of the glow curves rejected by this program.

Naturally this method is more effective for high doses than for low doses. Nonetheless, it is effective down to the level of 50 μSv. Bearing in mind that the purpose of this program is to avoid erroneous evaluation and reporting of radiation received by the dosimeter wearer, the significance of this program is of less concern in analyzing glow curves that reflect only background radiation.

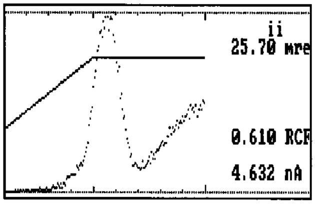

Figure 2. High IR Signal

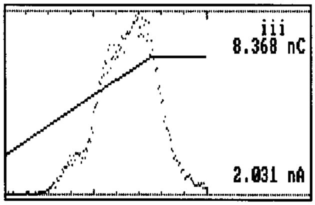

Figure 3. Wide Glow Curve

CONCLUSION

A simple computer program has been developed to screen abnormal LiF:Mg,Ti glow curves in routine dosimetry. Extremely encouraging results were obtained from the initial tests. More careful and extensive tests are suggested to thoroughly evaluate the current algorithms. Continuous efforts are anticipated to improve the program's functionality. It is worth pointing out that although this method was developed specifically for analyzing LiF glow curves, it can be modified with reasonable ease to extend its scope to include glow curves from other types of TL materials.

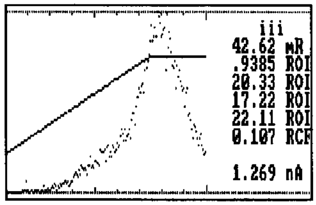

Figure 4. Incomplete Glow Curve

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