MEMORY EFFECTS WITH M.B.L.E. CaF_2 THERMOLUMINESCENT DOSIMETERS

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Abstract—The thermoluminescent (TL) dosimetry methods become more and more popular for all applications where personal protection against radiation is needed. For instance, in nuclear installations—civil populations in the case of nuclear accident and military personnel in case of a nuclear conflict. The existing TL systems are very convenient for these applications, as well for low doses as for high doses. However, the principle of TL does not offer theoretically more than one measure of the same dose because of the erasing phenomena caused by the reading process. This erasing characteristic excludes a new reading of the dose in case of an official control or further check.

To fulfil these multireading requirements, we expose three practical methods actually in production giving at the same time with the same dosimeter the total accumulated dose and the reading of the dose received between two measurements. These principles are:

(1) thermal inertia
(2) multipeak reading
(3) light transfer effect in some CaF_2 fluorines.

These three methods are discussed with their respective performances and application field and the conclusion is that they lead from now to a TL dosimeter which combines both properties of photoluminescent and thermoluminescent systems.

INTRODUCTION

Because of the basic principle of thermoluminescence, the reading of a thermoluminescent dosimeter erases the dose information, since it requires emptying the traps. This has the great advantage that it is possible to read any new dose, as low as it may be, without previously recorded doses influencing reading accuracy. On the other hand, in the case of a serious nuclear accident, it may be desirable for medical or legal reasons to check the accidental dose. For this purpose we have created three different types of dosimeters each intended for well defined uses.

1. *Twin-cathode dosimeters with thermal delay memory*

In this system, the cumulated dose may be read above 100 mr. The process is such that the memorized dose is erased. Thus doses can be accumulated with the possibility of reading the total dose; nevertheless once the total dose has been read, the dose and its memory are completely erased. This system is particularly suited to measuring low doses from 100 mR up.

2. *Twin-peak memory dosimeter*

This system is based on the normal reading of dose by emptying trap II of CaF_2 which occurs at about 180°C. The dose accumulation is normally made in peak III which is read at about 375°C. As in the twin-cathode system, the memory is erased by the reading process. The memory facility for this type of dosimeter is designed for doses between 1 and 1000 R.

3. *Memory effect by light transfer*

In this case light is used to transfer a fraction of the energy accumulated in deep traps to traps of lower energy. The memorized doses are read by a normal measurement of these shallow traps after light transfer. The great advantage of this process is that it is possible to transfer only a very small fraction of the stored energy. Thus the process can be repeated and access to the memory can be made several times with good reproducibility. The process is as follows:

(a) Let us suppose that during its use a dosimeter has received in one or several irradiations, doses totalling more than a score of roentgens, and that has been read and thus erased.

(b) If this dosimeter is exposed to a light source for some time, a new reading made in the usual way gives a dose corresponding to a fraction of the total dose received by the dosimeter.

(c) For constant lighting conditions, the dose read in this way is proportional to this total dose, subject to certain threshold limitations.

It has been proved experimentally that after irradiation and reading, the light transfers charge carriers from traps V and VI to trap III. This phenomenon gives a method for checking repetitively the total dose received by a dosimeter. It is indeed possible, by using appropriate light, to transfer only a very small fraction of the energy stored in peaks V and VI and thus to repeat the measurement a great many times with a good reproducibility. These readings may be repeated ten times with a precision of 15% or better, for total doses exceeding several scores of roentgens. Because of this phenomenon of light transfer the M.B.L.E. CaF_2 thermoluminescent dosimeters have a memory and consequently it is possible to read both partial and total dose.

THE PHYSICAL MODEL OF LIGHT TRANSFER

In a thermoluminescent phosphor, the charge carriers created by ionization at the time of irradiation are trapped in sufficiently deep traps not to be released at ambient temperature. When the phosphor is heated the carriers are released in increasing order of trap depth. They then recombine with light emission. It is the measurement of this light which gives the dose reading. In M.B.L.E. CaF_2, the main trap (peak III) is normally measured at a temperature of 265°C. Nevertheless other traps exist in M.B.L.E. CaF_2, including deeper traps, e.g. peak V, at about 500°C. During manufacturing, all the traps of a new dosimeter are emptied, including those corresponding to peak V. On the other hand, when the dosimeter is used, the reading or erasing heatings do not produce the temperature required to empty peak V traps. Thus traps of peak V fill up progressively at each irradiation, and the amplitude of peak V corresponds to the total dose accumulated by the dosimeter since its manufacture. Because of the high temperatures involved it is difficult to read the amplitude of peak V directly without strongly disturbing the dosimeter characteristics. On the other hand, it is possible to make this measurement indirectly, but with precision, by using the light transfer phenomenon.

OPERATIONAL USE OF LIGHT TRANSFER

The dosimeter is exposed to U.V. light (about 3300 Å) of such an intensity and for such a time (about 5 min) that a new reading of the dosimeter gives a dose exactly equal to 1/400 of the total dose received by the dosimeter. Under these conditions, the measurement may be made ten times with very good reproducibility.

RANGE OF USE AND ACCURACY

At the present stage of development there is a lower limit (about 2R) to the dose which can be read by light transfer. The accuracy of the transfer measurement is 15% of the total dose, and the reproducibility of several transfers is a few per cent.

CONCLUSION

There exist today several possible memory techniques associated with the thermoluminescence phenomenon. The first two processes listed require specially designed dosimeters and permit only one measurement of the memorized dose, while the third process (light transfer) has the great advantage that the total dose can be reread a number of times.

Further research may well reduce the present threshold level of 20 R.

At the present time all M.B.L.E. standard CaF_2 dosimeters can make use of this effect and hence the partial doses can be read by thermoluminescence, and the total dose can be reread as with photoluminescent glass.