# A COMBINED MONITOR-DOSIMETER FOR NON-IONIZING RADIATION

G. E. Fanslow
Associate Professor of Electrical Engineering

R. A. Hendrickson
Associate Professor of Nuclear Engineering

A. M. Fanslow
Associate Professor of Home Economics Education

Iowa State University, Ames, Iowa 50011

## Abstract

The temperature-dependent light-scattering properties of cholesteric liquid crystals and the thermal fade characteristics of pre-irradiated thermoluminescence dosimetry tags are combined in a differential calorimeter configuration to provide measures of present, average and accumulated exposures to non-ionizing electromagnetic radiation.

## Introduction

Although there are instruments and methods that can be used to provide radiation monitoring and measures of radiation exposure over extended periods, they tend to be rather expensive. This fact limits the availability of these services, increases the possibilities of people being exposed to hazardous amounts of radiation and leaves unknown the degree of extended exposure to radiation. The purpose of this paper is to describe a less expensive approach to these problems. It uses special properties of cholesteric liquid crystals and thermoluminescence dosimetry (TLD) tags to provide measures of present and accumulated radiation.

## Liquid Crystals

The property of liquid crystals used for radiation monitoring is their temperature-dependent ability to scatter light selectively. In operation, a number of liquid crystals that show color at different temperatures are applied to the blackened surface of the material whose temperature is to be measured. Those liquid crystals that are responsive to the temperature of the material will show color and the remainder of the surface will be black. Temperature is determined by knowing which liquid crystal is providing color play.

## Thermoluminescence

Thermoluminescence (TL) theory assumes that when TL phosphors are exposed to ionizing radiation, electrons are excited from the valence to the conduction band. These charge carriers move through the crystal until they recombine or lodge in traps within the crystal lattice. Heating the crystals releases trapped carriers and allows them to give up their excess energy in the form of light (thermoluminescence). The ionizing radiation dosage is determined by a reader that provides controlled heating and a measure of the light output. Crystals that are stored at a given temperature after they have been irradiated and before they are read have some traps emptied and the TL signal reduced. For measurements of ionizing radiation this "fade" is a disadvantage. However, because it is temperature dependent, it has potential for other applications such as the measurement of temperature exposure [1,2]* and microwave dosimetry [3].

## The Monitor-Dosimeter

The monitor-dosimeter is illustrated in Figure 1. It utilizes two plastic temperature sensing strips, one with metal coating and one without. The temperatures of both strips follow general changes in ambient temperature; however, when non-ionizing radiation is present the metallized strip absorbs energy and its temperature rises. Liquid crystals are used both to sense and to indicate the temperatures of the strips and the difference between them is a measure of the non-ionizing radiation [4]. The TL fade associated with the TLD tags also depends on these temperatures, and the difference between the TL readings is a measure of the average and total non-ionizing radiation exposure.

## Experiments

Radiation measurements were made at 2.45 GHz using 200 ohm per square metallized plastic as the "active" element. Because the thermal responses were found to be essentially the same as those reported earlier [4], radiation conditions were simulated by subjecting the TLD tags to selected water bath controlled temperatures. The TLD tags used for this application had the phosphor, 4% $CaSO_4$:Mn by weight, incorporated in Teflon.® Tags were 1 mm in diameter and 10 mm long. Groups of twelve were annealed at 300 °C for 30 minutes, placed in a glass vial and exposed to $^{60}$Co gamma photons at room temperature; absorbed dose was approximately 150 rads. The TL reading for four of these tags was obtained right after the ionizing radiation treatment and the remaining tags, two sets of four each, were placed in envelopes to shield them from light and exposed to simulated ambient temperature and non-ionizing radiation conditions. Typical examples are: 1. for an ambient temperature of 22 °C (71.6 °F) and a radiation of 10 mW/cm$^2$ for 7 days the difference in mean values of the TL readings was 57.5 (arbitrary units); 2. for an ambient temperature of 24 °C (75.2 °F) and radiation of 7 mW/cm$^2$ the difference in mean values of the TL

*Numbers in brackets denote references at the end of this paper.

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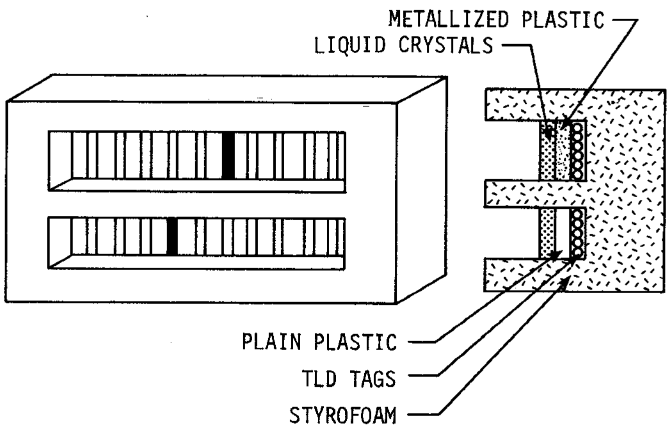


Figure 1. The monitor-dosimeter

readings was 42. Standard errors of the means ran from 2 to 4 percent of the means.

Similar experiments using $CaF_2$:Dy-Teflon discs (12 mm diameter by 0.4 mm thick) as the TLD tags have been initiated; however, they have been rather limited and, for the temperature range investigated, there were no apparent differences in TL readings.

## Discussion

Additional studies are under way to refine the ionizing radiation and annealing pre-treatments of the TLD tags. Moran [2] has shown that, by proper choice of these parameters, the use of TL fade for thermal dose monitoring can be tailored for a wide range of temperatures. Other areas to be investigated are the possible use of more than one phosphor to more accurately define exposures and, for signals that would not provide sufficient heating of a metallized plastic, antenna-detector probes and electronics packages that would provide $I^2R$ heating of the TLD tags. In a sense the latter approach would be making instruments presently on the market into dosimeters.

The monitor dosimeter described is a unique device for providing information on exposures to non-ionizing radiation. It does not require a power supply, electronics or a meter and it has potential for being relatively inexpensive. Its availability would make it easier to obtain monitoring and dosage measurements in communications centers, industries, homes, laboratories and other places that are presently seldom, if ever, checked for radiation.

## References

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