MAKROFOL AS A HIGH EXPOSURE GAMMA RAY DOSIMETER

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ABSTRACT

Dosimetric studies were carried out using Makrofol polycarbonate plastic (195 μm thick) as the radiation sensitive material. It was found that it could be utilized in measuring absorbed doses in the range of 10^6 to 10^7 rads using optical density measurement method and in the range of 10^7 to $2 \cdot 5 \times 10^8$ rads using chemical etch rate measurement method.

INTRODUCTION

THE various fields, where application of Solid State Track Detectors (SSTD) have played an important role, also include the branch of radiation dosimetry. This is because SSTD fulfil the basic requirements of a dosimeter[1] such as low cost, simplicity and high degree of reproducibility.

Day and Stein[2] have suggested the use of changes in optical density of plastics, due to irradiation (absorbed dose) as a means of dosimetry. Such changes in optical density have been observed for polycarbonate films[3] due to gamma irradiation and should serve the purpose of dosimetry.

Benton[4] has suggested the possibility of using track detecting plastics as high exposure gamma ray detectors based on the dependence of chemical etch rate on absorbed dose and has shown that cellulose nitrate plastic can be utilized in the range of about 10^6 to 10^8 rads. Frank and Benton[3] have investigated Lexan polycarbonate plastic and have found that this can be utilized in measuring absorbed doses in the range of about 10^7 to 10^9 rads.

In the present work, dosimetric characteristics of Makrofol N (195 μm thick) film have been studied for gamma radiation, using both optical density and bulk etch rate measurement methods. These methods were found to supplement each other and thus enhance the range over which dosimeter could be employed.

EXPERIMENTAL

The plastic pieces used in the investigation were successively washed with detergent, tap water and distilled water, dried on filter paper and subsequently handled with tweezers. Irradiation of plastic pieces to different doses was carried out in a Co^{60} gamma chamber having a dose rate of $1 \cdot 2 \times 10^5$ rads per hour.

(A) *Radiation Dosimetry by Optical Density Method*

For the measurement of optical densities, Carry Recording Spectrophotometer model-14 was used. *This is capable of measuring optical densities in the* range of 0·01 to 2·00.

Makrofol film squares were cut to a standard size of 1″ × 1″ in order to fit conveniently into sample and control carriers of the spectrophotometer.

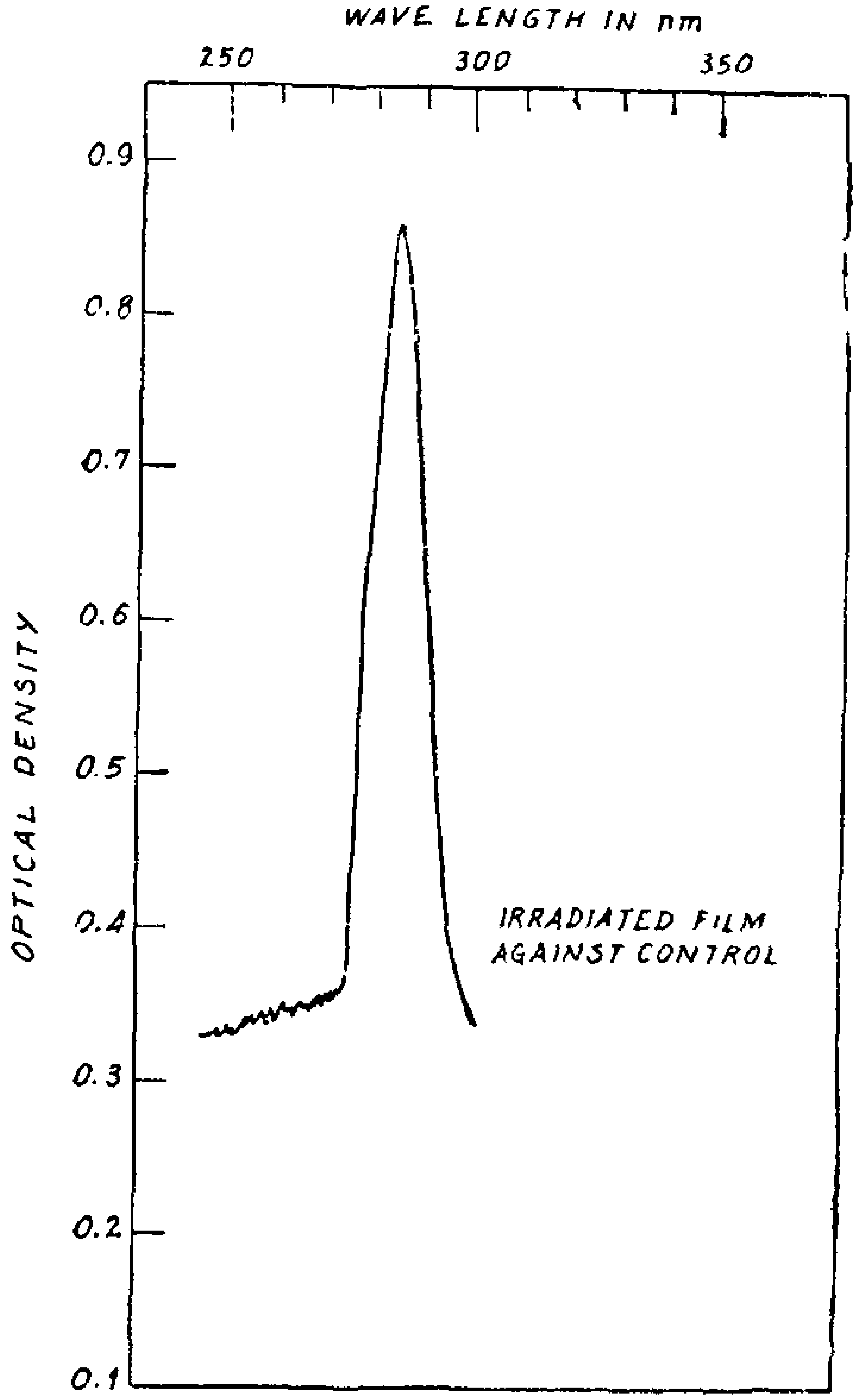

FIG. 1. Radiation induced ultraviolet absorption in makrofol (195 μm thick).

Figure 1 shows the absorption spectrum of an irradiated Makrofol piece against an unirradiated piece as reference. A clear peak is found to exist at about 284 nm. *This peak optical density value was found to* increase with absorbed dose. All the subsequent measurements of optical density were carried out at the wavelengths, corresponding to the peak region. This not only gives the maximum value for a given dose but also minimises the effect of errors due to wavelength shift or slit-width. The enhanced UV-*absorption is a direct consequence of the new chemical* species formed as a result of energy deposition by the incident gamma rays. These species differ from the bulk polymer in that they possess electronic configurations that strongly absorb the *UV*-radiation at that wavelength.

The background optical densities of the plastic *films* (195 μm *thick) to be irradiated were measured* at wavelengths corresponding to the peak region, *i.e., around* 284 nm. *They were then irradiated to different* doses in a Co^{60} gamma chamber and their optical densities were measured at the same wavelengths. The increase in optical density is a measure of the induced absorption. The dose range covered was from $0 \cdot 6 \times 10^6$ to $1 \cdot 08 \times 10^7$ rads.

When the maximum optical density values were plotted against the corresponding absorbed doses, a linear relationship was found to exist, which can be expressed *by the equation* $y = 0 \cdot 1714\,x$ where $y =$ O.D. of the irradiated piece and $x =$ Absorbed dose in Megarads.

The above equation can be used to find out the absorbed doses if the optical densities of the irradiated Makrofol films are measured at the peak region. No fading in optical density values was noticed even after a period of two months. *By this method*, it is convenient to carry out number of dose measurements within a short time.

In the present investigation, Makrofol plastic of 195 μm thickness was used. If it is desired to measure smaller radiation doses, measurable optical density can be obtained by using thick films. When large doses are to be measured, one can employ thinner films, *e.g.*, 40 μm thick film can cover the range up to about $4 \cdot 0 \times 10^7$ rads.

(*B*) *Radiation Dosimetry by Etch Rate Method*

Makrofol film circles of about 1″ dia. were individually weighed on a balance capable of reading thousandth of a mg. *The plastic circles were exposed to* Co^{60} gamma rays *in* a gamma chamber in the dose range of 10^7 to $2 \cdot 5 \times 10^8$ rads. At high doses in the range studied, the plastic films were found to become sticky. Therefore aluminium *foils* were used as spacers between the plastic circles during irradiation. Above this dose range, Makrofol plastic was found to become brittle and difficult to handle. Hence the *study could* not be extended to higher doses.

The plastic circles were weighed, after different doses of gamma *irradiation but before etching*, to check whether there was any weight loss because of irradiation. It was observed that at doses of $5 \cdot 0 \times 10^7$ rads and above there were measurable weight losses which are assumed to be due to escaping gases.

Four Makrofol circles were irradiated for each gamma dose. In the present investigation etchings were carried out at 80° C in 6N NaOH. Eleven circles comprising one from each irradiation and one control were etched simultaneously in an etching set-up in which each circle was held in a small separate compartment *formed by interconnecting perspex rings* and stainless steel wiremesh. The weight losses due to etching were measured for etching periods of 1, 2, 3 and 3·5 hours. From these values, the thickness losses from a single surface of films were calculated. When the average thickness losses (for four films) were plotted against various etching periods of each dose, straight lines were obtained. This indicated *that the etch rate remained constant for various etching* periods, *i.e.*, the etch rate did not change with depth in the film.

Similarly when the average thickness losses from a single surface for various etching periods were plotted against the corresponding absorbed doses on a semi-log paper, parallel straight lines were obtained. This, therefore, indicates that the average thickness loss of an irradiated film is an exponential function of the absorbed dose. These parallel straight lines (on semi-log paper) are represented by the general equation $y = 0 \cdot 00246\,x + C$, where $y =$ Average thickness loss *in* μm *from a single surface* (on log scale), $x =$ *Absorbed dose in Megarads (linear scale) and* C *has* values of 0·524, 0·808, 0·960 and 1·028 for etching periods of 1, 2, 3 and 3·5 hrs *respectively*.

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1. Moe, H. J., Lasuk, S. R. and Shumacher, M. C., *Radiation Safety Technician Training Course*, ANL–7291, Rev–1, 1972, p. 336.
2. Day and Stein, *Nature*, 1951, **168**, 644.
3. Boag, J. W., Dolphin, G. W. and Rotblat, J., *Radiation Research*, 1958, **9**, 589.
4. Frank, A. L. and Benton, E. V., *Radiation Effects*, 1970, **2**, 269.
5. Benton, E. V., *A Study of Charged Particle Tracks in Cellulose Nitrate*, NRDL–TR–68–14, 1968.