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Film Dosimetry and Spatial Dose Distribution of Electron Beam

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1. Introduction

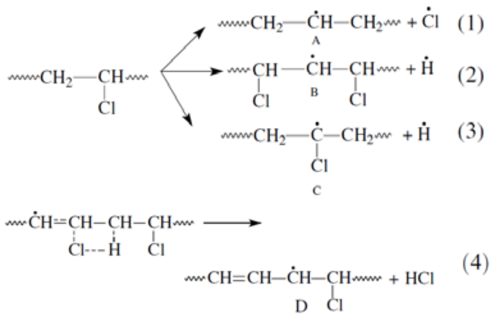
In radiation dosimetry there are numerous problems associated with the measurement of iso-dose curves and depth-dose distributions in high-gradient regions of beams using conventional measuring systems such as ionization chambers, semiconductors, thermo-luminescent detectors (TLDs), and radiographic films. Ionization chambers and semiconductors do not provide sufficient spatial resolution for many treatment planning needs. Thermo-luminescent dosimeters, even with small dimensions, are cumbersome and time consuming when one- or two-dimensional dose distributions are required. Dosimetric data cannot be stored for archival purposes by using conventional TLD readout procedures. The evaluation of an ionizing beam is difficult by using silver-halide radiographic film, because of large differences in sensitivity to radiation energies in the 10–200keV region, even though its relatively high spatial resolution offers an advantage over most other radiation measuring systems. Energy absorption and transfer properties of radiographic films do not match those of biological tissues. Radiographic films also have the disadvantages of being sensitive to room light and requiring wet chemical processing. These difficulties have resulted in a search for a radiation dosimeter with high spatial resolution which does not require a special developmental procedure and gives permanent absolute values of absorbed dose with an acceptable accuracy and precision and ease of handling and data analysis. Some of these features have been achieved with the introduction of radio-chromic dosimeters. These dosimeters, with very high spatial resolution and relatively low spectral sensitivity variation, are insensitive to visible light, thus offering ease of handling and preparation in room light. Radio-chromic dosimeters color directly and do not require chemical processing—a color change (colorless to blue, red, green, etc.) indicates exposure to radiation. Image formation occurs as a dye-forming or a polymerization process, in which energy is transferred from an energetic photon or particle to the receptive part of the leuko-dye or colorless photo-monomer molecule, initiating color formation through chemical changes.

2. Methods and Results

When a film is irradiated with an electron beam, a color change is observed. The degree of change in color is digitized as a digital value when scanned. Especially the dose and red values are linearly proportional. Using this fact, the unknown dose irradiated on the film is predictable. However, the main advantage of using a film is that it can analyze spatial distribution rather than dose measurement. This chapter describes the principles of color change, experimentation, and results.

2.1 Principle

The PVC's radiation interaction gives rise to macro-radicals deriving from C–Cl or C–H bond scission reactions. During this interaction, the following reactions can take place:



Obviously, C–C bond scission cannot be excluded, but probably the two macro-radicals recombine with each other due to the restricted mobility of the macro-radicals in the solid state. Among the three radiation induced polymeric radicals, ‘‘B’’ continues the reaction by way of a four center reaction, in which HCl is formed and acts as a catalyst. Eq. (4) is a chain reaction which can proceed until the occurrence of a termination step. As a result of Raman analysis, post-irradiation PVC shows carbon's G-peak which means pristine PVC becomes more carbonaceous as electron beam is irradiated. Thus, the transmission rate of light is getting low and we could figure out the relationship between the amount of fluence and light transmittance.

2.2 Experiments

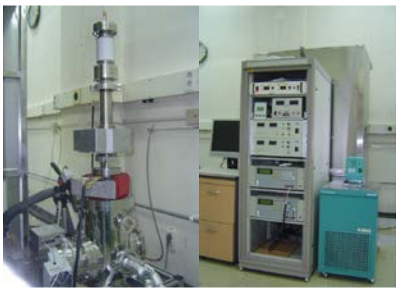


Figure 1. Electron beam generator

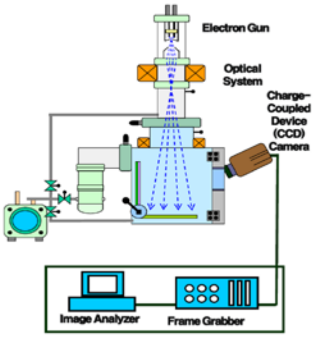


Figure 2. Diagram of the electron beam generator

If the radiation is irradiated to the film it takes place visually observable change of color. When scanning a post-irradiated film, color is converted to an RGB value meaning red, green, and blue values. Here, the R value shows a better linear relationship with fluence than G or B. After obtaining the relationship between R and fluence, the fitting function can be derived by irradiating various fleunces using an electron beam irradiator on uPVC film.

2.3 Results

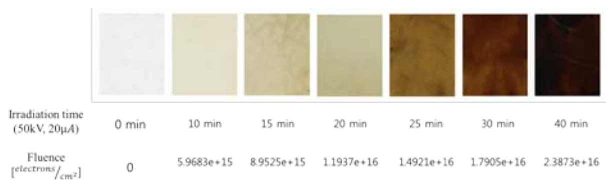


Figure 3. Color changes of uPVC films

Figure 3 shows the change of film color according to the amount of electron beam irradiation. The color gradually changes to black depending on the irradiated time.

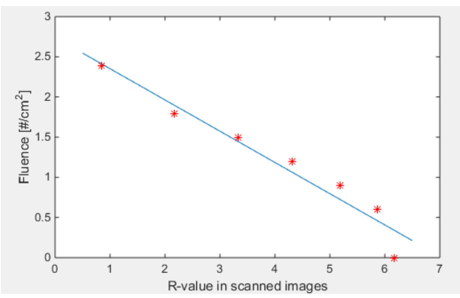


Figure 4. Correlation between r value and fluence

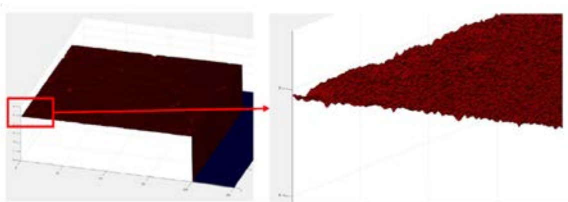


Figure 5. Spatial distribution using matlab

$$flatness = \frac{fluence_{max} - fluence_{min}}{fluence_{max} + fluence_{min}} \quad (5)$$

When the electron beam is irradiated on the uPVC film, the result as shown in figure 3 can be obtained. From Figure 4, we can obtain the correlation between R value and fluence value. If the R values of the film pixels are converted into fluence values by using the conversion formula, the spatial distribution can be analyzed as shown in Fig. 5 and the flatness can be calculated. The flatness is defined as Equation (5) and it provides a measure of the uniformity of the electron beam in the electron beam generator.

3. Conclusions

Radiographic film serves several important functions in electron gun calibration, radiation therapy, and radiation protection. It can serve as a radiation detector, relative dosimeter, display device, and an archival medium. Film gives excellent 2D spatial resolution and, in a single exposure, provides information about the spatial distribution of radiation in the area of interest or the attenuation of radiation by objects. It is essential to consider the error of the fitting function as it should be minimized to better optimize the veracity of the film analysis. Furthermore, rather than considering a pure uPVC film, a heterogeneous polymer mix primarily composed of uPVC can be used in the future to potentially enhance the performance in terms of reliability and accuracy.

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