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Estimation of uncertainty for sulfonated grafted low density polyethylene dosimeter using thermoluminescent dosimeter

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ABSTRACT

In this work, one type of thermoluminescence dosimeter low density polyethylene grafted by acrylic acid acrylamide, acrylic acid actinamide polymer film (LDPE-g-p (AAm/AAc)) was irradiated by ^{60}Co therapeutic gamma ray dose. This work deals with the case of sulfonated grafted film which has good properties such as thermal stability, and good dosimetric properties. The various sources of uncertainty for this type of thermoluminescence dosimeter under study were analyzed. The uncertainty budget tables for radiation measurements were declared. For the used procedure, these uncertainties multiply the coverage factor equal 2 to obtain the expanded uncertainty at 95% confidence level. The combined uncertainty does not exceed 6.3%. The results suggested that, the expanded uncertainty at 95% confidence level should be added to the value of measurements to obtain the accurate dose.

1. Introduction

The thermoluminescent (TL) properties of films have been previously reported [1–3] and the grafted polymer is considered as a candidate material for radiation dosimetry in off-line measurements. It seems to be insensible to radiation damage [4] and exhibits high sensitivity, allowing the use of samples tailored in very small sizes when a high spatial resolution is required. This is the case in radiotherapy, when small irradiation fields are employed or when high spatial gradients of doses are present. Moreover, grafted polymers can be used for ‘in vivo’ and in phantom measurements. It has been reported that [4] some preliminary results have been reported on the dosimetric characteristics of different diamond samples. After irradiation with a gamma beam from a cobalt machine, they showed a good TL sensitivity, of the same order of TLD100 dosimeters, the dose response for both were linear until 3 Gy, but the reproducibility was not satisfactory because of the presence of low temperature peaks in the glow curves, which resulted in a high thermal fading. This led us to look for new samples with different kind of defects. A set of high-quality, recently produced, grafted polymers samples; cut from the same disk was studied in order to determine their TL response. The dosimetric characterization includes the reproducibility, the TL response as a function of the dose and the dependence of the TL response on the radiation energy [5]. From [1,2] the use of thermoluminescence for dosimetry in individual monitoring of photons and electrons from external sources, one can derive a list of commonly encountered sources of errors that can affect the precision and accuracy in determining the dose under certain geometrical conditions [6]. Recently, some studies achieved for uses of solar cells in dosimetry monocrystalline silicon solar cell of the construction $n^{+}pp^{++}$ Passivated Emitter Solar Cell (PESC) was irradiated by ^{60}Co gamma ray dose the various sources of uncertainty were analyzed [7]. The expanded uncertainty at 95% confidence level should be added to the value of measurements to obtain accurate doses. The TL enhancement response to gamma radiation makes the monocrys-

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talline silicon solar cell system a promising material for gamma detection dosimetry. These properties may have important applications in developing selective detectors and dosimeter suitable to study the biological effects of ionizing radiation exposure [7].

Also, dosimetric properties of the quaternary tellurite glasses have been measured as a function of different compositions of the glassy system in different rare earth oxides concentration by using thermoluminescence (TL) detection technique. The experiment results showed that tellurite investigation of thermoluminescence, tellurite's potential use as the materials of gamma-ray thermoluminescence [8]. Beside that, The behavior of the different types of tellurite glasses is analyzed regarding to their kinetic parameters and luminescence emission which enhances the claim of tellurite glasses for use as TLD material at therapeutic radiation doses. It is suggested that the present tellurite glass can be used at therapeutic radiation doses [9]. The purpose of this study is to provide a better understanding of the response of sulfonated grafted polymers to gamma radiation to determine the sources of uncertainty to obtain accurate gamma dose measurement.

2. Materials and methods

2.1. Materials

The samples used are (LDPE-g-p (AAm/AAc)) Sulfonated grafted Low density polyethylene (LDPE) grafted by acrylic acid acrylamide, acrylic acid actinamide polymer of thickness 35 mm.

A standard ^{60}Co-source dose was used at rate 9.512 rad/min at medical Radiation Dept., King Feisal Hospital, Riyadh, Kingdom of Saudi Arabia. The farmer dosimeter of the type 2570 manufactured by Nuclear Enterprises Ltd, UK with its special ionization chamber 2571 sufficiently sensitive to γ-rays under the optimum condition of pressure and temperature was used to determine the dose rate of the ^{60}Co source.

A 4500 TLD reader (Harshow, Bicorn Company), the consortium "Saint-Gobain, Paris, France" was used. The heating rate was 5 °C/s. The maximum reading temperature was 600 °C. A set of six ($5 \times 5 \times 0.3$ mm^3) high-quality grafted polymers detectors cut from different wafer have been prepared. They are transparent and polished on both sides. The readings must be taken after 30 min to reach the stability. The symbols used are taken mainly from the Technical Report Series No. 374 [10]. The meanings have been given in the text, including the appendices, where they occur, but are repeated here for convenience of reference:

C_i sensitivity coefficient used to multiply an input quantity x_1 to express it in terms of the output quantity y.

$$Us \text{ (standard uncertainty)} = \text{positive square root of the sum of the square quantities } Us^2$$

$$U \text{ (expanded uncertainty)} = Us\text{(standard uncertainty)} \times \text{coverage factor } K = 2 \text{ (in confidence level 95\%)}$$

$$Uc(y) \text{ (combined uncertainty)} = \text{the positive square root of the combined variance } U^2c(y) = \sum (\partial f/\partial x_1)^2 U^2(x)$$

Combined uncertainty for different errors of our experiment means the standard uncertainty for errors: due to the detector, thermal treatment, reader, evaluation procedure and overall response.

3. Methods

3.1. A-TL response

The TL response has then been measured with a Harshaw 4500 Reader using the planchet heating method. The sample is heated in contact with a stainless steel crucible; the temperature is controlled by a thermocouple placed in close contact with the sample holder. After irradiation, the sample is heated with a linear ramp of about 1.5 °C s^{-1} from 50 °C to 500 °C. This procedure ensures the complete reset of the films, so that no additional annealing stage is needed [11]. The TL response is the integral of the glow curve between 50 °C and 500 °C divided by the temperature rate. The dosimetric characterization has been performed with ^{60}Co photons from Cobalt therapy Unit, at the National Research Center. Atomic Energy Authority, Egypt. The dose has been evaluated according to the IAEA code of practice [10,12], with accuracy of 2.5%. For the irradiation with photon beams, the finger is placed in the same phantom at a 5 cm water-equivalent depth for ^{60}Co with SSD, respectively, of 80 and 95 cm, the field was 10×10 cm^2. The dose has again been evaluated according to the IAEA code of practice, with an accuracy of about 2%.

3.2. B-Determination of the uncertainty of (LDPE-g-p (AAm/AAc)) dosimeters

According to Ref. [13] Technical recommendations for the use of thermoluminescence for dosimetry in individual monitoring for photons and electrons from external sources, a list of commonly encountered sources of errors that affect the precision and accuracy in determining the dose under geometrical conditions could be driven. The errors including the errors due to detectors, reader, thermal history and the sensitivity of the detector to photon [14].

4. Results and discussion

Available evidence for effectively treating certain types of cancers points to the need for an accuracy of about 5% in dose delivery [15,16]. Calculation of overall uncertainty in a radiotherapy procedure is a complex problem, because some errors are random while others can be systematic [16]

Table 1 shows the different uncertainty components of the detector for (LDPE-g-p (AAm/AAc)) film. The largest value of uncertainty was due to the contamination of TLD-materials. The expanded uncertainty at 95% confidence level was 0.14 nC which should be added to