1st International & 28th National Conference on Nuclear Science & Technology 2022 (ICNST22)
Nuclear Science & Technology Research Institute

Fricke Agarose Gel Layers for dose measurements

Pourranjbar F.[1], Edalatkhah E.[2*], Abtahi S.M.M.[1]

[1] Physics Department, Imam Khomeini International University, Zip Code (B.O. Box), Qazvin, Iran
[2]Radiation Applications Research School, Nuclear Science and Technology Research Institute, 14155-1339, Tehran, Iran

[*] *Email: eedalatkhah@aeoi.org.ir*

Abstract

Fricke gel layer dosimeters have revealed promising features for attaining absolute absorbed dose measurements. Investigations regarding the feasibility of Fricke agarose layer dosimeters are presented. Gamma irradiation of the fabricated samples at 10 to 30 Gy represented the color change of the dosimeters. Optical analyses of the fabricated samples showed linear dose dependency. The obtained results support the viability of Fricke agarose gel layer dosimeters for three dimensional dose measurement.

Keywords: Fricke Agarose Gel Layer, Gamma Exposure, Dose Measurement

Introduction

Development of new advanced approaches in modern radiotherapy has made heavy requirements on dosimetry methodology development. The three dimensional treatment planning computerized systems, adopted in the clinical praxis for conformal radiotherapy, intensity modulated radiation therapy or high dose rate brachytherapy, require dosimetry methods capable of reliable 3D dose measurements in order to ensure that the calculated values agree with the delivered dose distributions. The laboratory made Fricke gel layer dosimeters have shown to provide a reliable technique to achieve 2D or 3D dose distributions [1].

Fricke gel dosimeters in form of layers have various shapes and dimensions, depending on the particular requirements [2-3]. In this work, rectangular Fricke agarose gel layers were fabricated and analyzed.

Experimental

In this research, samples of Fricke agarose gel layer dosimeters were fabricated. With this aim, Frick agarose gel dosimeter was prepared at first, using agarose at 1% (Sigma Aldrich), 25 mM H_2SO_4 (Merck), 0.5 mM of ferrous ammonium sulphate hexahydrate (Sigma Aldrich) and 0.165 mM of xylenol orange sodium salt (Sigma Aldrich), which is ferric ion indicator. The gel was prepared following the procedure described in reference 4. Half of the total water was heated at 90°C for 2 min. During this step, the agarose is added to water. Then, the system was set at the boiling point for 20 min to completely dissolve the agarose. A glass rod was used to mix thoroughly the chemicals. When the agarose solution had reached a temperature of 70 °C, the Fricke solution (made with the remaining half of water, sulfuric acid, ferrous ammonium sulphate and xylenol orange) was added to the agarose and mixing was aided by gentle stirring. When the solution reached a temperature of 50 °C, it can be poured into the desired containers.

In Fricke Agarose Gel Layer dosimeters, Fricke gel is enclosed between two transparent sheets (1 mm thick) of PMMA and hold in a PMMA frame 3 mm wide. The final Fricke gel is introduced into each containing structure, by means of a syringe, through a small hole in the frame. The hole is finally closed. Figure 2 represents this step.

Figure 1. Filling step of Fricke agarose gel Layer dosimeters.

The dosimeters are then kept in the dark at room temperature. Samples of fabricated Fricke agarose gel Layer dosimeters are shown in Figure 2. The uniform irradiations were conducted at room temperature with ^{60}Co source, with a dose rate of 1.1 Gy/sec, at Gamma cell 220 Unit. The optical analyses of the dosimeters

were carried out at room temperature after the achievement of chemical equilibrium, i.e. about 30 minutes after irradiation.

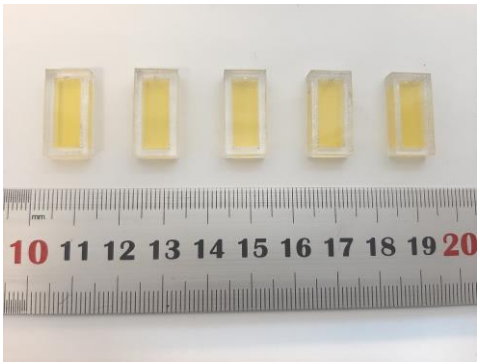

Figure 2. Samples of fabricated Fricke agarose gel Layer dosimeters.

Results and discussion

Irradiation of Fricke agarose gel Layers was done at 10, 20 and 30 Gy. In Figure 3, samples of Fricke agarose gel Layer dosimeters, irradiated at 10, 20 and 30 Gy are shown respectively. Change of the dosimeter color after irradiation is well visible with dose increase.

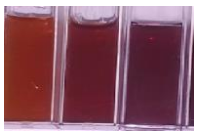

Figure 3. Fabricated Fricke agarose gel Layer dosimetera after irradiation

With the aim of investigating the behavior of the dose response after different exposures, optical analyses were carried out using a spectrophotometer (BECKMAN COULTER-DU-800). Figure 5. shows attained absorption spectra of samples irradiated with 10, 20 and 30 Gy in the range from 350 nm to 650 nm. A linear increase of the dose response can be observed.

Due to radiation exposure of a Fricke agarose gel layer, conversion of ferrous ions to ferric ions was done with oxidation yield proportional to the absorbed dose, up to saturation. Addition of the metal ion indicator, xylenol orange, to the solution allows the optical analysis. The complex that xylenol orange forms with ferric ions causes light absorption around 585 nm with a yield proportional to the absorbed dose. Therefore, such dosimeters are radiochromic. As dose increases, the absorbance seems to increment over the second peak, related to ferric ions whereas the absorbance seems to decrease over the first peak, related to ferrous ions as can be seen in Figure 4. Figure 5 shows dose response curve of the samples. Three samples were surveyed for each point of the curve. Results show good linearity up to 30 Gy.

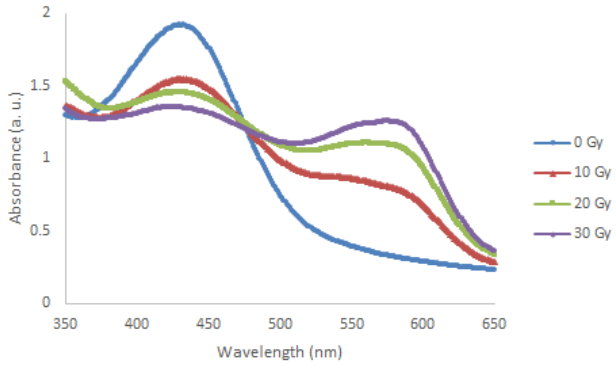

Figure 4. Absorption spectra of fabricated Fricke agarose gel Layer dosimeters.

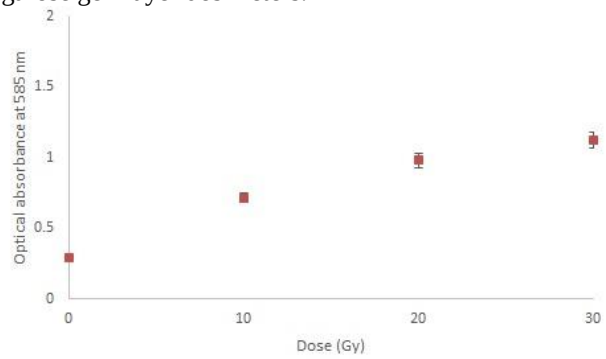

Figure 5. Dose response curve of fabricated Fricke agarose gel Layer dosimeters.

Conclusions

The use of Fricke agarose gel layers shows promise for dose measurement applications, offering 3D dose information with good spatial resolution. Concerning 3D dose distribution reconstructions, a further comparison is, however, necessary between dose volumes obtained from Fricke agarose gel layers and dose matrices calculated with a treatment planning system.

References

[1] M. Carrara, et al. Fricke gel layer dosimetry in high dose-rate brachytherapy, Appl. Rad. and Iso. 68, 722, (2010).

[2] G. Gambarini, et al. Characterization of Fricke-gel layers for absolute dose measurements in radiotherapy, Proceedings of 2nd International Conference on Advancements in Nucl. Instru., Meas. Meth. and their Appl., ANIMMA, Belgium, (2011).

[3] P. Perez, et al. Fricke gel xylenol orange dosimeter layers for stereotactic radiosurgery: A preliminary approach, *Appl. Rad. and Iso.* (2021), doi: https://doi.org/10.1016/j.apradiso.2021.109936.

[4] M. Marrale et al. Correlation between ferrous ammonium sulfate concentration, sensitivity and stability of Fricke gel dosimeters exposed to clinical X-ray beams, Nucl. Instr. and Meth. in Phys Res. B 335, 54 (2014).