Particle size analysis of PAGAT gel dosimetry

E J J Samuel, P Sathiyaraj, D Titus and D S Kumar
Photonics, Nuclear and Medical Physics Division, School of Advanced Sciences, VIT University, Vellore, India

E-mail: ejames@vit.ac.in

Abstract. This work represents the response of PAGAT gel dosimeter using UV-Visible Spectrophotometry. The particle size and optimal wavelength of the gel sample were analyzed from the obtained spectrum. In addition, the compressibility was estimated using Ultrasonic Interferometer. The results showed that the particle size of the PAGAT varied appreciably with respect to the dose applied but did not vary significantly with the post irradiation time.

1. Introduction

Understanding the chemistry of polymer gel dosimetry is worthy of attention. Jirasek *et al* [1] discussed the consequence of chemistry on gel dosimetry. Baldock *et al* [2] reviewed the basic radiation chemistry of the polymer gel dosimetry. Poly Acrylamide Gelatin and Tetrakis hydroxyl phosphonium chloride (PAGAT) is one of the members of polymer gel family. Radiation induced polymerization in PAGAT [3] is the witness of absorbed dose and the dose can be extracted from different techniques such as Magnetic Resonance Imaging (MRI) [4-6], Optical Computed Tomography (Optical CT) [7, 8], X-ray CT [9, 10], Ultrasound CT (UCT) [11-13] and vibrational spectroscopy [14-16]. Chemistry of radiation induced polymerization in PAGAT contains the processes such as water decomposition, radical formation, chain growth, cross linking and termination. Each process depends on different factors including concentration of ingredients, concentration of radicals, temperature, pH, dose, dose rate, post irradiation time, energy of interacting radiation and their types (charged particle, uncharged particle and photons). Among these, we considered the effects of dose and post irradiation time for analysing particle size of PAGAT. This study may handout one of the faces of the PAGAT gel dosimeter via particle size variation. Heather *et al* [17] measured the particle size for MAGIC-2 gel dosimetry for different doses and dose rates. In this study, spectrophotometer acts as an analytical tool to measure the particle diameter for PAGAT gel at different doses at various time intervals post irradiation. .

2. Materials and Method

2.1. Gel Preparation

We chose PAGAT gel due to its tissue equivalence property and stability [18]. PAGAT gel consisting of 3.5% (w/w) BIS (C_7 H_{10} N_2 O_2), 3.5% (w/w) acrylamide (C_3 H_5 NO), 5% (w/w) of gelatin (C_{17} H_{32} N_5 O_6) n, 10Mm of THPC (C_4 H_{12} CLO_4 P) and 89% of distilled water (mille pore) were prepared in normal atmospheric condition. The gel preparation is reported elsewhere [19]. After preparation, the solution was filled in plastic cuvettes of 4.5 ml volume and the cuvettes openings were sealed with

transparent adhesive tapes to prevent oxygen entry. All the samples were refrigerated overnight for perfect gellation.

2.2. Gel Irradiation

Gel samples were irradiated with cobalt-60 (Theratron 780c). Source to surface distance (SSD) was maintained at 80 cm with the field size of 10 x 10 cm^2. Samples were irradiated from 3 Gy to 18 Gy in the range of 3 Gy intervals. After irradiation, the samples were maintained at 4 degree Celsius for 24 hours to attain complete polymerization.

2.3. Functional group identification

The functional group of PAGAT has been confirmed by Fourier Transform Infrared (FT-IR) spectrometer. 1654.92cm^{-1} and 1629.85 cm^{-1} represents the carbonyl group(C=O) associated with Acrylamide and Bisacrylamide. 3485.37 cm^{-1} represents the OH functional group associated with THPC and Gelatin.1550.77 cm^{-1} denotes the bending vibration of N-H in amide group. After polymerization the band 3400 cm^{-1} was shifted to 3450 cm^{-1} [20]. The shift of stretching N-H group from Acrylamide to Polyacrylamide indicated the presence of polymerization action. Figure 1 shows the IR-spectrum of the samples.

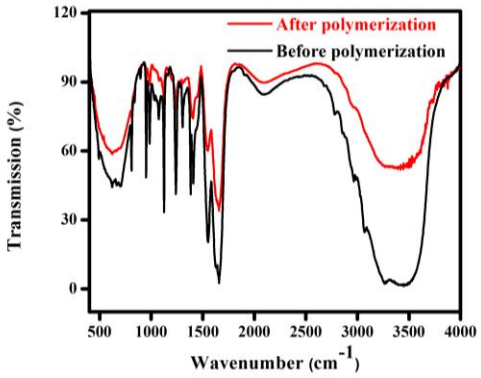

Figure 1. FTIR Spectrum of PAGAT.

2.4. UV Spectrophotometry for PAGAT

U2800-Hitachi was used for UV Spectrophotometry on PAGAT. The un- irradiated gel (0 Gy) acted as a control sample for irradiated gel, and it was used for baseline correction in spectrophotometer analysis. The absorption wavelength was selected from 350 to 800 nm with 1 nm interval.

The samples were read after one day of irradiation. The particle size was determined from the relation between maximum absorption and Mie-Debye efficiency factor. It is given by the following equation,

$$D = \frac{(Ka)\lambda_{\max}}{n\pi} \tag{1}$$

where, D is the diameter of the particle, Ka is the Mie-Debye efficiency factor which is found to be 4.34 [20], n is the refractive index of the sample which is calculated as 1.5.

2.5. Linearity and Particle size measurement

Linearity of the PAGAT was obtained by choosing the different absorption values such as 460nm, 480nm, 500nm and 550 nm. Samples were read at different time intervals of 24, 96 and 240 hours.

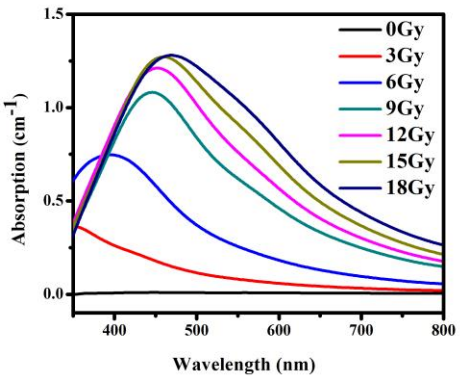

Figure 2. UV-Visible spectrum of PAGAT

Figure 3. Irradiated PAGAT gel

2.6. Refractive index and compressibility of PAGAT

The travelling microscope method was used for measuring the refractive index (RI) of non- irradiated gel. The same method was not used to determine the RI of exposed gel due to its opacity to light. Instead, Abbe's refractometer was used for measuring the RI on irradiated gel. The Ultrasonic interferometer was used for measuring the velocity of ultrasound in PAGAT at 27^0C.The compressibility of irradiated PAGAT gels was calculated by the following relation,

$$\beta = \frac{1}{\rho v^2} \qquad (2)$$

where β is the compressibility, v^2 is the velocity of sound, ρ is density of the gel. The density of PAGAT was 1026 Kg/m^3 [21].

3. Result and Discussion

3.1. UV Spectrophotometry Analysis of PAGAT

Absorption of the PAGAT increased with respect to dose it is clearly shown in the absorption spectrum (figure 2). No other absorption peaks were seen in the spectrum up to 18 Gy. Particle size at different doses and time intervals as shown in figure 5.It shows that the particle size increased with increasing dose. Heather M *et al* [17] Maryanski *et al* [22] and Oldham *et al* [23] demonstrated particle size increased with increasing dose. But our study found that time intervals of post irradiation did not change the particle size significantly.

3.2. Linearity and particle size measurement

Figure 4 shows the linearity of PAGAT for different absorption wavelengths, It shows good correlation (R^2 = 0.9677) than other wavelengths. Figure 5 shows the particle size variation of PAGAT as a function of dose and post irradiation time. Post irradiation time was not influence in particle sizes of PAGAT.

3.3. Refractive index and compressibility of PAGAT

The travelling microscope method measured the refractive index of non- irradiated gel as 1.4899. Abbe's refractometer measured the RI of irradiated gel as 1.4998, 1.5101 and 1.5123 for 1 Gy, 2 Gy and 3 Gy respectively. The average value of 1.5 was considered as the RI at 26^o C. The velocity of ultrasound in irradiated PAGAT was found to be 1520.49 ms^{-1}, 1555.5 ms^{-1} and 1570 ms^{-1} for 1 Gy, 2 Gy and 3 Gy respectively. The corresponding compressibility of the irradiated PAGAT gels was 4.2, 4.02 and 3.95 x 10^{-10} m^2/N for 1 Gy, 2 Gy and 3 Gy respectively. These values show that the compressibility of gel reduced with respect to dose which is due to the stiffness of gel after irradiation.

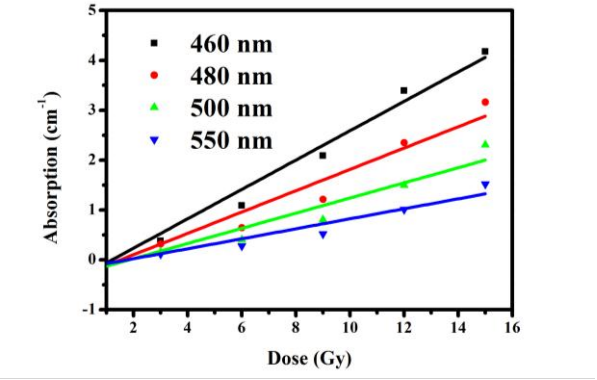

Figure 4. Absorption for different wavelength.

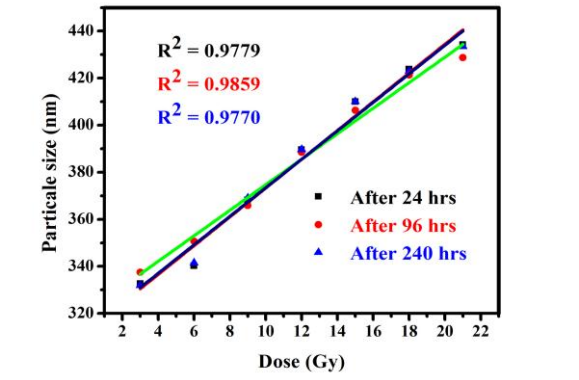

Figure 5. Particle size for diff. post-irradiation time.

4. Conclusion

The average particle size of PAGAT was found to be 385 nm and was not affected by the post irradiation time. The particle size analysis will be extended to several types of gel dosimeters with different composition and irradiation. The linearity of PAGAT was excellent at 460 nm, and this is the suggested optimal wavelength for PAGAT. The extended study will correlate the ultrasound velocity and molecular weight of PAGAT with respect to different dose rates.

5. Acknowledgements

The authors are grateful to the DST-SERB, Government of India for their financial aid and one of the author gratefully acknowledge the Research Associateship provided by the VIT University.

6. References

[1] Jirasek A *et al* 2009 *J. Phys.: Conf. Ser.* **164** 012003
[2] Baldock C *et al* 2010 *Phys. Med. Biol.* **55** R1-63
[3] Venning A J *et al* 2005 *Phys. Med. Biol.* **50** 3875-88
[4] Lepage M *et al* 2002 *Phys. Med. Biol.* **47** 1881-90
[5] Venning A J *et al* 2004 *J. Phys.: Conf. Ser.* **3** 155-8
[6] Murry P *et al* 2000 *Australas. Phys. Eng. Sci.* **23** 44-51
[7] Bosi S *et al* 2007 *Phys. Med. Biol.* **52** 2893-903
[8] Bosi S *et al* 2009 *Phys. Med. Biol.* **54** 275-83
[9] Hill B *et al* 2005 *Brit. J. Radol.* **78** 623-30
[10] Hill B *et al* 2005 *Med. Phys.* **32** 1589-97
[11] Mather M L *et al* 2002 *Phys. Med. Biol.* **47** 4397-409
[12] Mather M L *et al* 2003 *Ultrasonics* **41** 551-9
[13] Mather M L *et al* 2003 *Phys. Med. Biol.* **48** N269-75
[14] Baldock C *et al* 1998 *Phys. Med. Biol.* **43** 3617-27
[15] Lepage M *et al* 2001 *J. Appl. Polym. Sci.* **79** 1572-81
[16] Rintoul L *et al* 2003 *Appl. Spectrosc.* **57** 51-7
[17] Heather M *et al* 2006 *J. Phys.: Conf. Ser.* **56** 160-3
[18] Taylor M L *et al* 2008 *Australas. Phy.Eng. Sci. Med.* **31** 131-8
[19] Subramanian B *et al* 2006 *J. Med. Phys.* **31** 72-77
[20] Ozeroglu *et al* 2007 *eXpress Polymer Letter* **1** 132-41
[21] Brown S *et al* 2008 *Appl. Radiat. Isotope* **66** 1970-1974
[22] Maryanski M J *et al* 1996 *Phys. Med. Biol.* **41** 2705-17
[23] Oldham M *et al* 2003 *Med. Phys.* **30** 623-34