Optimization of PAV\$AgNO_3$ Films for Measuring Entrance and Exit Radiotherapy Dose Relative to TLDs

Mohammed A. Ali Omer[1, 3], Hamed A. Ismail[2], Mohamed E. M. Garlnabi[3], Ghada A. Edam[3], Nuha S. Mustafa[3]

[1]Qassim University, College of Applied Medical Science, Department of Radiologic Technology, Buraidah – KSA.

[2]Radiation & Isotopes Center of Khartoum (RICK), Khartoum-Sudan.

[3]Sudan University of Science and Technology, College of Medical Radiologic Science, Khartoum–Sudan.

Abstract: ***The aim of this study was to synthesize the PVA\$AgNO_3$ polymer films and to optimize it is radiation measurement based on entrance and exit dose measurement relative to thermoluminiscence detector (TLD) method. The polymer films have been synthesized by casting technique after dissolving of polyvinyl alcohol (PVA) under controlled temperature (80 °C) and stirring and hybridization with silver nitrate ($AgNO_3$). The polymer films have been characterized after irradiation at the entrance and exit sites of Perspex by UV-visible spectroscopy and an optical densitometer (OD). The study revealed that there were absorption peaks at wavelength (λ) 190 and 425 nm related to pure PVA and silver out of UV-visible spectroscope, and the average entrance and exit doses read by TLD was 7.06±4.7 and 3.98±2.8 Gy and they are usually less than the applied dose by an average factor of 0.22 and 3.3 Gy respectively, also there is a linear proportional and significant (R^2 = 0.9) relationship between the applied dose and the measured OD at entrance and exit side of the phantom that could be fitted in the following equation: $y = 0.040x + 0.117$ and $y = 0.031x + 0.099$ respectively, where x refers to the applied dose and y refers to the OD at the entrance and exit sides of the phantom. Also there is a linear proportional and significant (R^2 = 0.9) relationship between the entrance\exit doses measured by TLD and the relative OD at both sides of the phantom which could be fitted in the following equation: $y = 0.035x + 0.159$ and $y = 0.027x + 0.132$ respectively, where x refers to the entrance\exit doses and y refers to the entrance\exit OD and the attenuation coefficient of Perspex (phantom) has been derived correctly from the relationship between the phantom thickness and it's absorption coefficient which was 0.1670 cm^{-1}.***

Keywords: PVA\$AgNO_3$, Film Dosimeter, Radiotherapy, Entrance\Exit dose.

1. Introduction

The main goal of radiotherapy is to give high dose to the malignant tumor and save the surround organs at the same time, to achieve this there are several approaches that contribute to the quality improvements of the dose delivery. One approach is the quality control at each step of the treatment chain [1]. The International Commission on Radiological Units and Measurements ICRU recommends that the dose delivered by a tumor be within ± 5.0% of the prescribed dose [2-3].

To assess and evaluate the dose in radiotherapy there are many tools to do that, such as TLD which is suitable for in vivo dosimeter for more than 20 years [4-7], diodes that having an accuracy of ±3 [3], and semiconductor detectors [8]. One of interesting materials related to such field is the polymer hybridized with metal nanoparticles, in particular silver nanoparticles which exhibit unique optical, electronic and electrochemical properties that answer many potential applications in optical waveguides, optical switches, molecular identifications, oxidative catalysis, etc. [9]. Polyvinyl alcohol (PVA) is a polymer which has been studied intensively because of its good film forming and physical properties, water solubility, biocompatibility, accessibility, and good interact with radiation [10].

Polyvinyl alcohol was first prepared by Hermann and Haehnel in 1924 [11] by hydrolyzing polyvinyl acetate in ethanol with potassium hydroxide. Polyvinyl alcohol is produced commercially from polyvinyl acetate, usually by a continuous process. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of anhydrous sodium methylate or aqueous sodium hydroxide. The physical characteristics and its specific functional uses depend on the degree of polymerization and the degree of hydrolysis. The effect of radiation upon the composites resulted in reducing the silver ions into black metallic silver, so the general film color changed from white to golden according to amount of radiation that received the film [12]. Also in this realm Mohammed et al, [9] confirmed that there is a linear correlation between the applied dose to PVA\Ag films and the optical density as well as the absorption coefficient. There for the aim of this study is to measure the dose at build up region of irradiated phantom and correlate between the dose that measure with TLD and the optical density as well as the absorption coefficient in radiotherapy range, as the induced radiation effects in the film composites could be traced by UV-visible spectroscopy and optical densitometer (depending on the color change) [9] and the ultimate goal of this study is to optimize the radiation measurement by PVA\$AgNO_3$ film.

2. Methodology

Polyvinyl alcohol PVA (Mw = 8200g/mol), Silver nitrate AgNO3 and De- ionizing water DIW.CO-60 machine (Equinox) from MDS Nordion. PVA as 3wt% have been dissolved in DIW and continuous stirring for 3 h. under control temperature of 80 ºC on a beaker. Then when the solution cools down to ambient temperature, we took the PVA solution into dark room and hybridized with 0.2 wt% of $AgNO_3$ and stirred for 1h. Then the PVA /Ag_3 solution poured in a hsidirtep to form films by casting method in dark room. After 3 days the solution dried and the films had been formed. Then films peeled off the hsidirtep, cut into small films 2×2 cm, loaded in sealed black plastic packs. These loaded films fixed together with TLDs chips on the surfaces of a Perspex (40 × 40 × (1-12) cm) i. e. at the anterior and posterior fields of radiation and receiving doses (1, 2, 4-12 and 15 Gy) by ^{60}Co-teletherapy machine, the anterior field given with usage of buildup material of 0.5 cm to obtain the dose at buildup region (for entrance dose) and for the exit dose without build up.

Then the exposed films were characterized with UV-visible spectroscopy to obtain the spectrum of absorption coefficient versus wavelength and densitometer to determine the optical density (OD), and TLDs are evaluated with TLD reading to determine the doses at entrance and exit (Ent.\Exit) of the radiation beam at both sides of Perspex.

3. Results and Discussion

Figure 1 shows the UV-visible spectrum for the PVA\AgNO3 polymer films irradiated at an entrance dose of Perspex phantom; it shows the appearance of two prominent peaks at 190 nm and 425 nm which are relevant to pure PVA and silver absorption coefficients respectively, such peaks increase following the increment of radiation dose from 1-15 Gy. Same spectrum and absorption peaks have shown by Saion et al, [13] which they attributed to the Surface Plasmon Resonance phenomenon of electrons in the conduction band of Ag^0 nanoparticles.

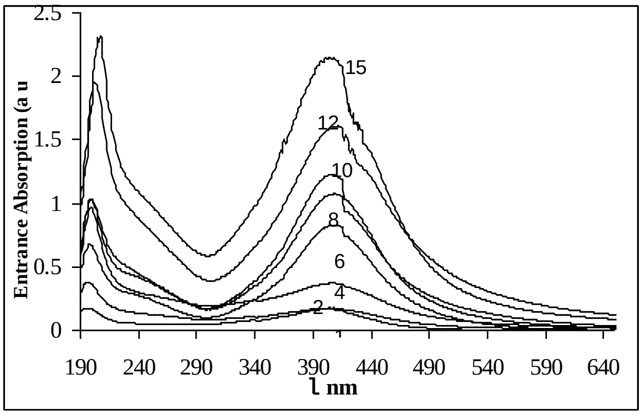

Figure 1: shows the UV-visible spectrum for the PVA\$AgNO_3$ polymer films irradiated at an entrance dose of Perspex phantom

Figure 2 shows the correlation between the applied dose and the entrance and exit dose in Gy. The study reveals that: the average entrance and exit dose in Gy which is measured by TLD was 7.06±4.7 and 3.98±2.8 Gy respectively and they increased as the applied dose increases, however it is usually less than the applied dose by an average factor of 0.22 and 3.3 Gy respectively, which could be ascribed to absorption in air and tissue respectively [14]. The linear correlation between the applied dose and the entrance and exit doses (TLD reading) could be correlated by the following equation: y = 1.910x - 1.543, and y = 1.146x - 1.181, respectively, where x refers to the applied dose in Gy and y refers to entrance\exit doses obtained by TLD in Gy.

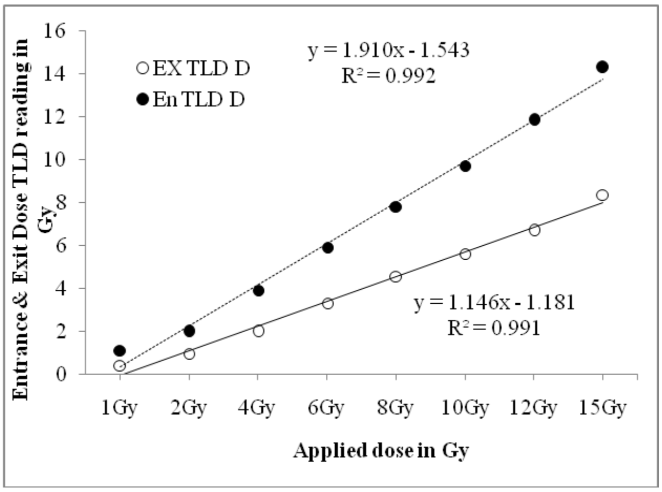

Figure 2: Shows the correlation between the applied dose and the entrance and exit dose in Gy

Figure 3 shows the correlation between the applied dose and the OD for entrance and exit points. In which the data revealed that there is a linear proportional and significant (R^2 = 0.9) relationship between the applied dose and the measured OD at entrance and exit side of the phantom that could be fitted in the following equation: y = 0.040x + 0.117 and y = 0.031x + 0.099 respectively, where x refers to the applied dose and y refers to the OD at the entrance and exit sides of the phantom. Since there is linear relationship between the applied dose and the OD as well so significant, faithfully one can use the OD of the polymer films as a radiation detector as has been contemplated by Mohammed et al, [9].

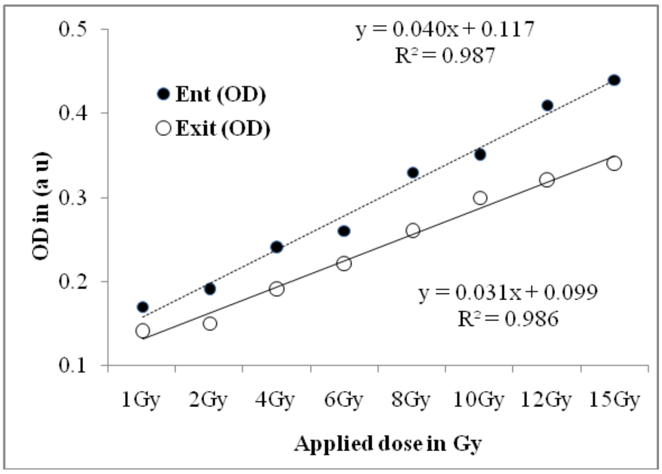

Figure 3: Shows the correlation between the applied dose and the OD for entrance and exit points.

Figure 4 shows the correlation between the Ent\Exit dose in Gy (TLD) and relevant OD in (a u). The data revealed that there is a linear proportional and significant (R^2 = 0.9) relationship between the entrance\exit doses measured by TLD and the relative OD at both sides of the phantom which could be fitted in the following equation: $y = 0.035x + 0.159$ and $y = 0.027x + 0.132$ respectively, where x refers to the entrance\exit doses and y refers to the entrance\exit OD. By comparing and subtracting the OD in Figure (2) and Figure (3), the deduction revealed that: the OD variation was only 0.042 (a. u.) in case of entrance dose and was only 0.033 (a. u) in case of exit dose, therefore the PVA/$AgNO_3$ film could be used optimally to measure the radiation dose with consideration to OD variation and the $AgNO_3$ concentration.

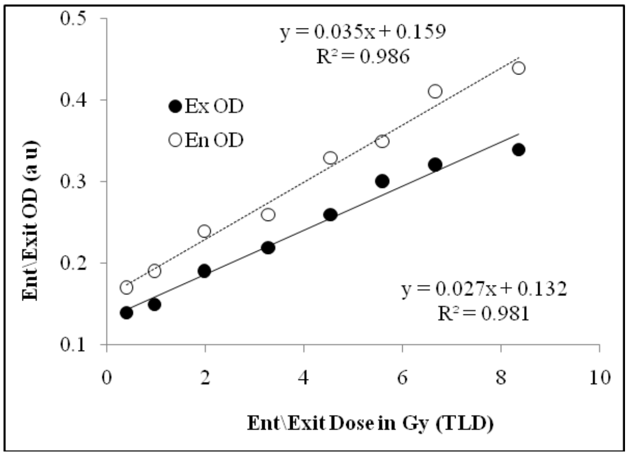

Figure 4: Shows the correlation between the Ent\Exit dose in Gy (TLD) and relevant OD in (a u).

Figure 5 shows the correlation between the phantom thickness in cm and the absorption coefficient. The data revealed that: the absorption coefficient (a) in a.u. has an inverse proportionality versus the material thickness in cm and such relationship could be fitted in exponential equation: $y = 0.230e^{-0.32x}$, where *x* refers to the material thickness in cm and *y* refers to the absorption coefficient in a.u with significant correlation at $R^2 = 0.99$. As the material used was a Perspex ($C_5H_8O_2$), its linear attenuation coefficient (μ) at 140 KeV has been derived from the above equation which was 0.1670; such result is agreed with the study carried out by Saxby et al, [15].

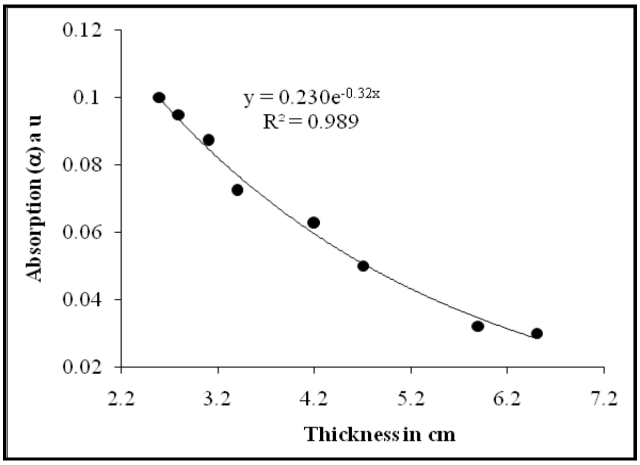

Figure 5: Shows the correlation between the phantom thickness in cm and the absorption coefficient.

4. Conclusion

Depending on the above analyzed data, the PVA\$AgNO_3$ film could be used successfully and optimally in measurement of radiation dose in radiation therapy relative to TLD method as well as the absorbed dose simulation in 3D and dose chart, in addition to specific advantage such as chemical change assessment by Raman spectroscopy.

References

[1] Tung C. J., , H. C. Wang, S. H. Lo, J. M. Wu and C. J. Wang (2004), In Vivo Dosimetry for external photon treatments of head and neck cancers by diodes and TLDS, Radiation Protection Dosimetry, Vol. 111(1), P: 45–50.

[2] Kai Huang, William S. Bice, Jr., and Oscar Hidalgo-Salvatierra. (2003). Characterization of an in vivo diode dosimetry system for clinical use, J. Appl. Clin. Med. Phys. Spring, Vol. 4(2), P: 132-142.

[3] Mutahir Tunio, Mansoor Rafi, Shoukat Ali, Zaeem Ahmed, Asad Zameer, Altaf Hashmi and Syed A. Maqboo, (2011). In Vivo Dosimetry with Diodes in a Radiotherapy Department in Pakistan, Radiation Protection Dosimetry. Vol. 147 (4), P: 608–613.

[4] Korn T., P. M. Ostwald, C. S. Hamilton and J. W. Denham, (1996), TLD extrapolation measurement for entrance and exit dose in radiotherapy. Radiation protection dosimetry, Vol. 66 (1-4), P: 323-326.

[5] Kalef-Ezra J. A, Boziari A, Litsas J, Tsekeris Pkoligliatis T. (2002). Thermoluminescence dosimetry for quality assurance in radiotherapy. Radiat Prot. Dosim. Vol. 101 (1-4), P: 403-405.

[6] Swinnen A, Verstraete J, Huyskens DP, (2004). Feasibility study of entrance in-vivo dose measurements with mailed thermo-luminescence detectors; Radiotherapy and Oncology, Vol. 73 (1): 89-96.

[7] Venables K, Miles E, Aird E, Hoskin P. (2004). The use of in-vivo thermo-luminescent dosimeters in the quality assurance program for the START breast fractionation trial. Radiotherapy and Oncology. Vol. 71, P: 303–310.

[8] Th. Loncol J.L. Greffe, S. Vynckier, P. Scalliet. (1996). Entrance and exit dose measurements with semiconductors and thermoluminescent dosemeters: a comparison of methods and in vivo results. Radiotherapy and oncology, Vol. 41(2), P: 179–187.

[9] Mohammed A. Ali Omer, Mohamed E M, Gar-elnabi, Alyaa, H. Ahmed, Ghada Abaker Eidam and Nasr Aldeen N. Khidir. (2013), Radiochemical Properties of Irradiated PVA\$AgNO_3$ Film by Electron Beam. International Journal of Science and Research (IJSR), India Online. Vol. 2 (9), P: 361-364.

[10] Sen Liang, Jianfeng Yang, Xiao Zhang, Yu Bai (2011), The Thermal-Electrical Properties of Polyvinyl Alcohol/AgNO3 Films, Journal of Applied Polymer Science Vol. 122 (2), P: 813–818.

[11] Kavitha B., D. Dasharatham, D. Srinivasu, CH. Srinivas, and N. Narsimlu. (2011). Synthesis and characterization of TiO2 doped polyvinyl alcohol polymer composites.

Journal of Chemical and Pharmaceutical sciences, Vol. 4 (4), P: 155-157.

[12] Mohammed A. Ali Omer, Mohamed E. M. Gar-elnabi and Elias Sain. (2011). Gamma Radiation Synthesis and Characterization of Polyvinyl Alcohol/ Silver Nano Composites Film Journal of Sc. Tech. Vol. 12 (1), P: 104-110.

[13] Saion E., A. H. Shaari, M. A. Ali, M. Y. Hussain, Ghazanfar Mirjalili and K. Dahlan. (2008). syntheses of conducting polymers and metal nanoparticles by using ionizing radiation, *Solid State Science and Technology, Vol. 16, (1), P:* 114-123.

[14] Khan, Faiz M. (2010). The Physics of Radiation Therapy, 4th. edition, Lippincott Williams & Wilkins, Philadelphia – Baltimore, New York London.

[15] Saxby Browna, Dale L. Bailey, Kathy Willowson, Clive Baldock. (2008). Investigation of the relationship between linear attenuation coefficients and CT Hounsfield units using radionuclides for SPECT. Applied Radiation and Isotopes, Vol. 66, P: 1206–1212.

Author Profile

Mohammed Ahmed A. Omer: received the B. Sc. -1. in Radiotherapy and Nuclear Medicine, B. Sc.-2 in Medical Equipments Technology and M.Sc. degrees in Medical Physics from Sudan University of Science and Technology in 1995, 1998 and 2001, respectively. He has been working as radiation therapy specialist and medical physicist at Radiation and Isotopes Center of Khartoum (1995-2003) as well as a lecturer at College of Medical Radiologic science-Sudan University of Science and Technology. He awarded a Ph. D. degree from University Putra Malaysia - 2007 in Medical physics-Applied Radiation and now working as a lecturer (Associate Prof.) at Al-Qassim University-Buraidah-KSA.

Mr. Hamed Abdallah Ismail Siuliman: received B.Sc. in physics, and M.Sc. degree in Nuclear physics from Sudan University of Science and Technology in 1998 and 2007respectively. He has been working as medical physicist at radiation and Isotopes center of Khartoum – Sudan since 2000 up to date and as a lecturer part-timer at College of Medical Radiologic Science. Now he is working as a Lecturer at Najran University-KSA.

Mohamed Elfadil Mohamed received a B. Sc. in Radiotherapy and Nuclear Medicine, and M.Sc. degrees in Medical Physics from Sudan University of Science and Technology in 1995 and 2001 respectively. He has been working as medical physicist and radiation therapy specialist at Radiation and Isotopes Center of Khartoum as well as a lecturer at College of Medical Radiologic Science, Sudan University of Science and Technology. He received a Ph. D. degree from Natal University South Africa - 2007 in Medical physics and now working as a lecturer (Associate Prof.) at Sudan University of Science and Technology-Khartoum-Sudan.

Ghada Abker Edam Sakin: received a B. Sc. Degree in Nuclear Medicine in 2010 from National Ribat University-Sudan and M. Sc. from College of Medical Radiologic Science-Sudan University of Science and Technology 2013. She has been working as a lecturer (part timer) at Sudan University of Science and Technology department of Radiotherapy and Nuclear Medicine since up to 2013. Now she is a Ph. D. candidate in same field.