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Water equivalence study of metal impregnated PAGAT gel dosimeter in terms of variation of effective atomic number

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Abstract. The aim of this study is to evaluate the water equivalency of metal doped PAGAT gel dosimeter in terms of its effective atomic number. Auto-Zeff software and NIST XCOM data base were used to perform this study. Initially Gold (Au) and Silver (Ag) were taken and divided into different concentration (from 0.01 to 100Mm) with standard PAGAT formalism and the elemental composition was determined. Using these elemental compositions Z_{eff} was generated for photon interaction using Auto-Z_{eff} software. Au doped gel was found as a water equivalent in the concentration range of 0.01 to 0.1Mm. Ag doped gel have matched well with water from 0.01 to 1Mm concentration in terms of water equivalence. In these concentrations, it has been concluded that metal doped gel is more water equivalent than plain PAGAT gel based on the Z_{eff} data obtained.

1. Introduction

Effective atomic number (Z_{eff}) is an important parameter to consider a material to be substituted for water for radiation dosimetry [1, 2]. Many researchers reported the method of finding Z_{eff} for a compound or mixture [3, 4]. Z_{eff} of any medium depends on the energy of the incident photon beam so, a single number cannot be a representative of Z_{eff} of a compound material [4]. Hence Z_{eff} depends on the photon energy, it is mandatory to compute the Z_{eff} with respect to different range of energy. There are well reported publications available regarding Z_{eff} of different gel dosimeter [5-7]. As per the best knowledge of the author there is no publication of computing Z_{eff} for metal doped PAGAT gel dosimeter [8-11]. Recently metal nano particles (MNP) are an interesting candidate for dose enhancement effect (DEE) study in gel dosimeter [12, 13]. MNPs increase the probabilities of photon interaction cross sections due to their high atomic number (high Z) and yield greater secondary radiations within the gel causing DEE. Different types of MNPs were reported for gel dosimeter such as Gold (Au, Z=79), Silver (Ag, Z=47), Platinum (Pt, Z=78) and Bismuth (Bi, Z=83) [14-17] for DEE. Though DEE is a great advantage by MNPs, its high Z presence in the gel should be evaluated to consider the MNP doped gel for water equivalency. In this study, Z_{eff} parameter was studied for evaluating the water equivalency of metal doped PAGAT gel dosimeter.

2. Materials and Method

2.1. Computation method

To evaluate the water equivalency of metal doped PAGAT (MPAGAT) Au and Ag dopants with different concentration (0.01, 0.05, 0.1, 1, 5, 10, 50 and 100m M) were considered. In this study, we used Auto-Z_{eff} software for generating the Z_{eff} [18]. In the first step elemental composition analysis was performed by NIST XCOM data base. Elemental compositions were normalized to unity and feed the compositions in the Auto-$Z_{eff.}$ Z_{eff} was generated from 0.01 to 1000 MeV for all the concentrations.

3. Results and Discussion

3.1. Water equivalency of Au doped MPAGAT

The variation of Z_{eff} with respect to energy is shown in figure 1. Initially, Z_{eff}s are increasing from 0.01 to 0.02 MeV. Since photoelectric absorption cross section (PACS) is directly proportional to Z^4 at this low energy region PACS was higher, especially for 10, 50 and 100m M due to the large abundance of Au. The rapid fall was starting at 0.02 to 0.2 MeV by typical Compton scattering interaction. All MPAGAT have almost constant from 0.4 to 2 MeV. The lowest Z_{eff} was found in this energy range for all MPAGAT. Z_{eff} increases with energy starting from 2.044 to 200 MeV due to pair production and above 200 Z_{eff} was constant. Z_{eff} of gel dosimeters was compared with water (figure 2). The maximum percentage of

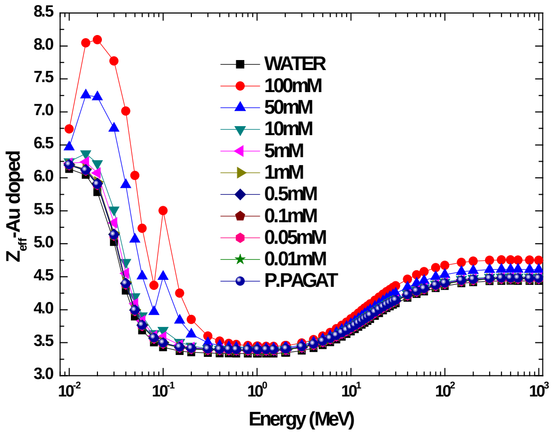

Figure 1. Z_{eff} of MPAGAT for various concentrations of Au.

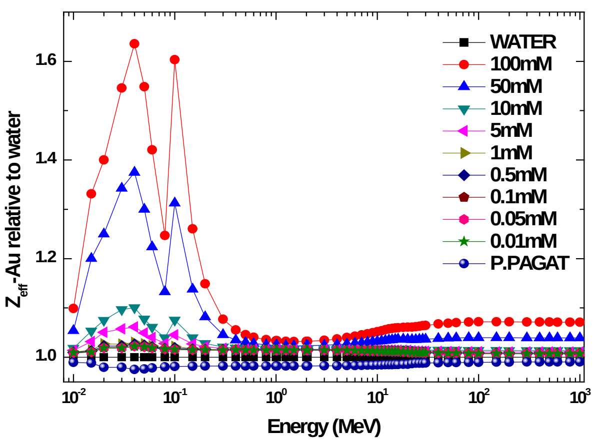

Figure 2. Z_{eff} variation of MPAGAT from water.

Variation obtained at 0.04MeV for all MPAGAT. Highest percentage variation was 63.5% for 100Mm. From 0.01Mm to 0.5Mm the percentage variation was less than 2% over all the energy region. For 1Mm the Z_{eff} variation is less than 2% from 0.15 to 1000MeV. For 5, 10, 50 and 100 Mm the Z_{eff} has greater than 3% from water. In addition to these results we noticed an interesting behavior of MPAGAT that is 0.01 and 0.05Mm concentration of Au make the gel more water equivalent than plain PAGAT (PPAGAT) (figure 3). The arrow mark indicated that the curves are approaching water closer than PPAGAT.

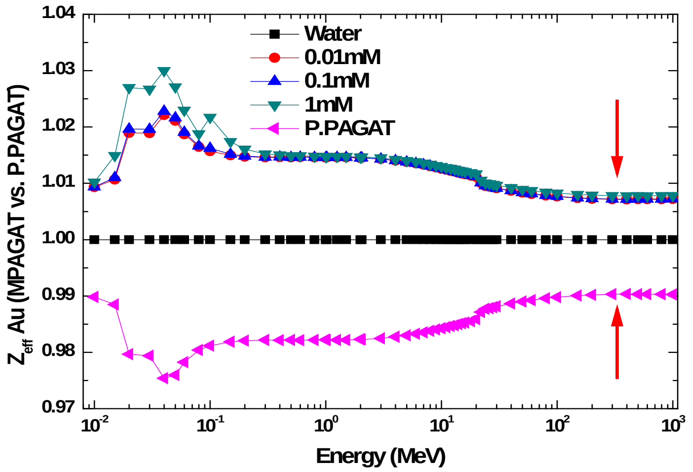

Figure 3. Comparison of PPAGAT and MPAGAT with respect to water.

3.2. Water equivalency of Ag doped MPAGAT

The variation of Z_{eff} with respect to energy is shown in figure 4. In this case all Z_{eff}s started to fall from 0.01MeV. However, 50 and 100Mm MPAGAT rapidly increased from 0.02to0.03MeV. Though the same rapid increment was presented in other concentration, it is very less compared with 50 and 100Mm concentration. The sudden jump in Z_{eff} from 0.02 to 0.03 represents the K-edge of Ag. After K edge all the curves rapidly fell up to 0.2MeV due to Compton scattering. Z_{eff} values are higher in low energy range due to PACS of Ag was higher at this energy, but comparing with Au it was less due to its less atomic number. From 0.3 to 2MeV all the curves were constant (Minimum Z_{eff} was found from these energy region for all concentration values) and slowly start to increase from 2MeV to 300MeV due to the dominance of Pair production. Beyond 300Mev Zeff was constant. Ag doped MPAGAT was compared with water to evaluate the discrepancy in Z_{eff} (figure 5).

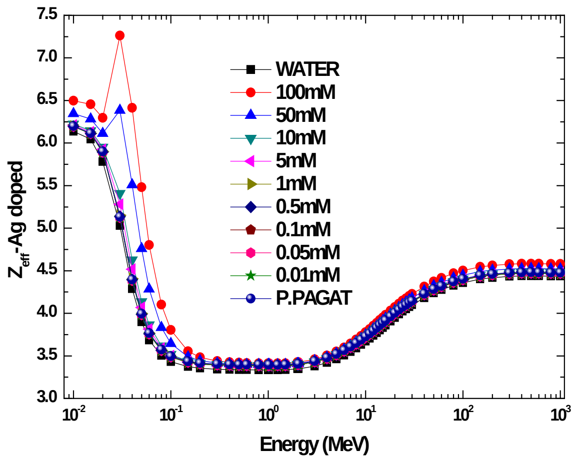

Figure 4. Z_{eff} of MPAGAT for various concentrations of Au.

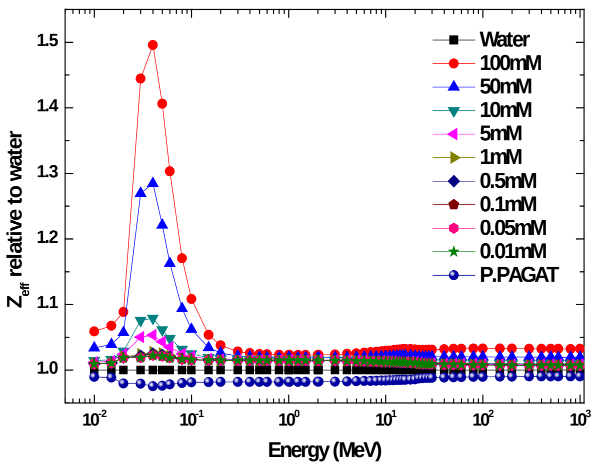

Figure 5. Z_{eff} variation of MPAGAT relative to water.

The highest percentage of variation obtained (49.5%) at 0.04MeV in 100Mm concentration. Up to 1Mm the percentage variation is less than 2%. By doping Ag from 0.01 to 1Mm we can achieve more water equivalency of PAGAT gel (figure 6).

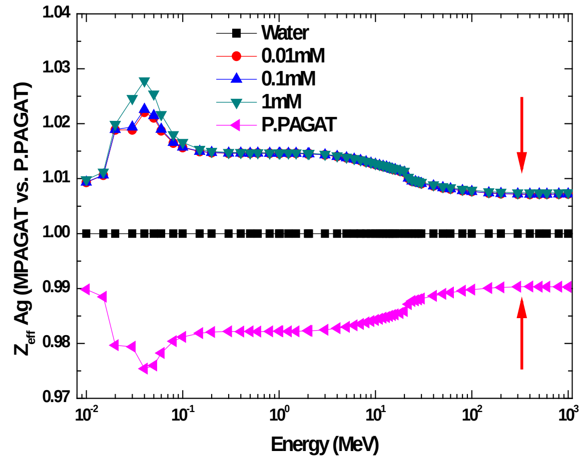

Figure 6. Comparison of PPAGAT and MPAGAT with respect to water.

Both Au and Ag doped gel were more water equivalent than PPAGAT gel because of the increasing effective electron density by addition of high Z material up to certain range of concentration. Over concentrations (1,5,10,50 and 100mM for Au, 5, 10, 50 and 100mM for Ag) make the gel in equivalent to water.

4. Conclusion

Water equivalence of PAGAT gel was evaluated in terms of its Z_{eff} from 0.01 to 1000MeV. By adding Au (0.01 to 0.1mM and Ag (0.01 to 1Mm) they have shown better water equivalence based on Z_{eff} data. At above mentioned concentration MPAGAT was more water equivalent than PPAGAT. One should consider this Z_{eff} variation for any gel while introducing metal nano particle for DEE. More research required in the energy range below 0.01MeV, in addition, different methods should apply and compare the results of Z_{eff} for more reliable results.

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