Chapter Four
Result and discussion

4.1 Results:

The results highlighted the photograph of prepared films with relevant received radiation doses, the UV-visible spectrum for the relevant films, the absorption coefficient relative to absorption peaks at ultraviolet and visible bands versus the doses, he energy band gaps for the prepared films and the correlation between the optical density and the relevant applied doses.

Figure 4.1: shows the irradiated composite films of PVA\Cu_2O receiving γ-radiation doses in the range of 0 – 12 Gy

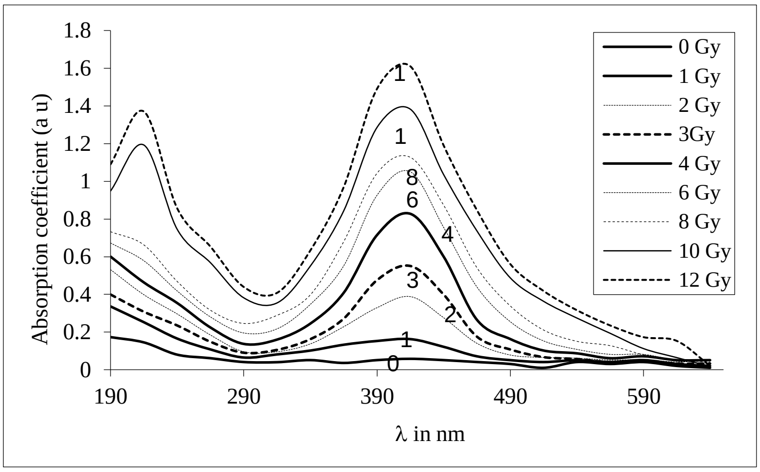

Figure 4.2: shows the spectrum of ultraviolet visible spectroscope for irradiated PVA/Cu_2O films at γ-radiation doses 0–12 Gy.

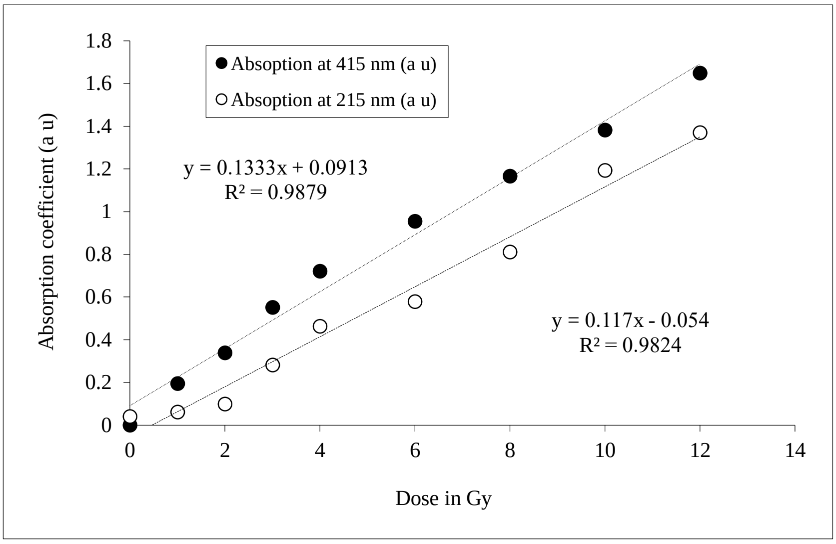

Figure 4.3: shows the correlation between radiation Dose in Gy and the relative absorption coefficient at λ = 415 and 215 nm.

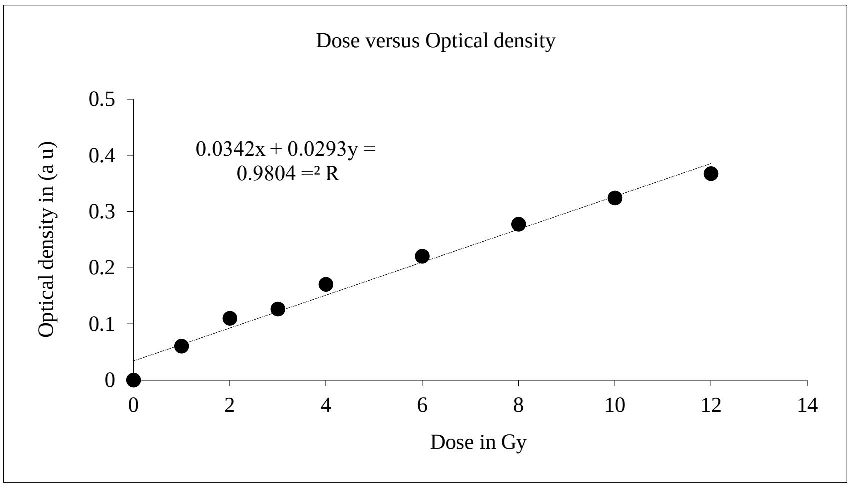

Figure 4.4: shows the correlation between radiation Dose in Gy and the relative optical density in (arb. unit).

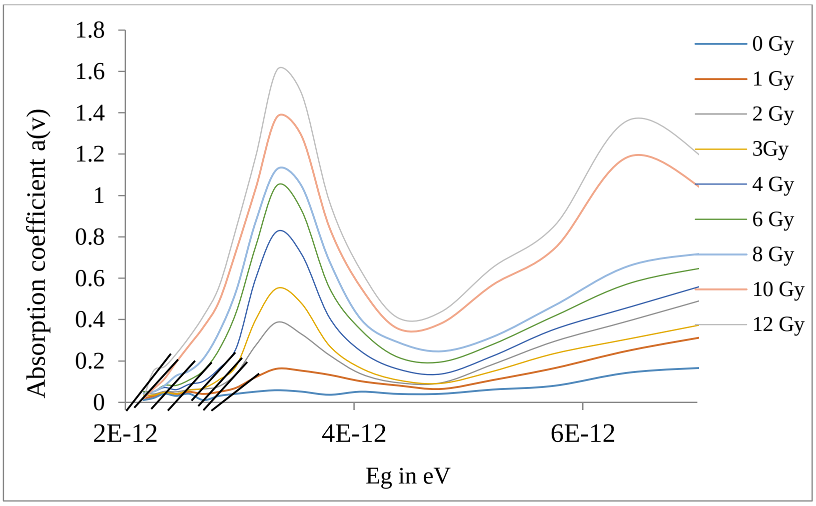

Figure: 4.5 shows the energy band gaps in electron volt (e*V*) of the irradiated PVA\\Cu_2O composite films

4.2 Discussion & analysis:

The composites film of PVA hybridized with cuprous oxide Cu_2O has typical response to γ-irradiation as PVA/$AgNO_3$ or PVA/FeO; which shows a gradient pink color change from light pink to dark one (Fig. 4: shows the irradiated composite films of PVA\\Cu_2O receiving γ-radiation doses in the range of 0 – 12 Gy). Such change in color ascribed to formation of cupric oxide in the binder. This dry chemical interaction occurs due to absorbed radiation energy that leads to formation of reactive species such as hydrated electron (e_{aq}), hydrogen atom radical (H_o) and hydroxyl radical (OH_o). Among these species, (e_{aq}) and (H_o) are very powerful reducing agents; hence both of them reduce cuprous oxide Cu_2O within the PVA binder to cupric oxide CuO as expressed by Ramnani, et al, (2007) as well as in case of irradiated silver nanoparticles supported on silica aerogel as described by Elias et al, (2008). The radiochemical interaction of γ-radiation and the composite of Cu_2O/PVA films in which cuprous oxide reduced to cupric oxide (CuO) could be presented in the following radiochemical interaction equation (1):

$$(R\text{- }CH_2\text{-}CH_2OH)_n + Cu_2O + \gamma\text{-ray} = (R\text{-}CHCu\text{-}CHCuOH)_n + {}_nH_2O \qquad (1)$$

Structure of Cupric/Polyvinyl alcohol films after irradiation could be morphologically obvious as studied by Aliyah et al, (2015) in x-ray diffraction pattern. The color change could encourage the feasibility of utilization such composite in personal dosimetry i.e. plotting of permanent graph for the relation of radiation dose versus optical density that could be utilized to read any dose for radiation worker based on pre-determined optical density. The gradient color changes induced by irradiation in films have been confirmed by ultraviolet visible spectroscope (Fig. 5: shows the spectrum of ultraviolet visible spectroscope for irradiated PVA/Cu_2O films at γ-radiation doses 0–12 Gy) rather than necked eye; in which the irradiated PVA/Cu_2O films at γ-radiation doses 0 – 12 Gy shows two prominent peaks at λ = 415 nm and 213 nm. These peaks were related to absorption coefficient of formed cupric oxide (CuO) and pure PVA for visible light band and ultraviolet band respectively. However, Troudi et al, (2016) have obtained a UV-visible spectrum for hydrothermal synthesis of PVC/CuO with prominent peak at 272 nm and with bulky CuO in binder; the initial absorption encountered a red shift as 670 nm; confirming that cupric oxide film has absorption coefficient in the range of visible spectrum and the change in the absorbed wave length could be due to concentration, binder and the method of preparation. The absorption coefficient increases as the radiation dose increase from 0 Gy up to 12 Gy. Such result is parallel to the study done by Mohammed et al, (2013) and Ramnani et al, (2007), about the color change of $AgNO_3$ hosted in PVA binder and on silica aerogel. In which they stated that the absorption coefficient increased following the radiation dose increment.

From the UV-visible spectrum; a correlation between the radiation dose in Gy and the relative absorption coefficient at λ = 415 and 215 nm has been plotted (Fig. 6: shows the correlation between radiation Dose in Gy and the relative absorption coefficient at λ = 415 and 215 nm); which revealed a proportional, linear and significant (R^2 = 0.9) correlation. Such correlation has been fitted to equations: $y = 0.13x + 0.09$ for irradiated PVA/Cu_2O at visible light band and $y = 0.12x - 0.05$ for pure PVA at ultraviolet light band (*x refers to radiation dose in Gy and y refers to absorption coefficient in au*) i.e. the PVA/Cu_2O film sensitivity to radiation equivalent to absorption of 0.2 (arb. unit) at 1 Gy, however such sensitivity could be increase to less than 1 Gy depending on the saturation of the binder by dopant. Further analysis for the correlation between radiation dose in Gy and the relative optical density in (arb. unit) (Fig. 7: shows the correlation between radiation Dose in Gy and the relative optical density in (arb. unit)); reveal a linear, proportional and significant (R^2 = 0.9) correlation fitted to equation: $y = 0.03x + 0.03$, indicating the feasibility of utilizing PVA/Cu_2O film as radiation dosimeter with a sensitivity of 0.06 (arb. unit) at 1 Gy; depending on easy optical density measurement rather than chemical dosimetry or TLD dosimetry; with utmost encouraging fact that the induced color change in the films is permanent and consistent as a function of duration unless exposed to radiation, heat and humidity.

The effect of radiation on the cuprous films (PVA/Cu_2O) also leads to obvious reduction in the band gap energy from 3×10^{-12} to 2×10^{-12} eV relative to radiation dose from 0 – 12 Gy (Fig. 8: shows the energy band gaps in electron volt (e*V*) of the irradiated PVA/Cu_2O composite films). The reading of energy band gap derived from extrapolating the curves of absorption coefficient α(υ) versus energy (*h*ν) at x-axis as stated by Uma et al, (2002). Such process indicating the possibility to render the composite from insulator state to semiconductor with band gaps 4.6 e*V or*1.8-2.5 e*V* (Kannaki et al, 2012; Ning et al, 2010) or even conductive state; case more radiation dose is applied with adjusted dopant. The reduction in the band gap could be ascribed to quantum size effect of the synthesized sample i.e. reduction in the band gap (Kannaki et al, 2012; Swarnkar et al, 2009); as the irradiation lead to transforming of cuprous (PVA/Cu_2O) to upper oxidation state as Cupric (PVA/CuO)