Measurement and study linear attenuation coefficient of x-ray for epoxy/titanium oxide composites

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قياس ودراسة معامل التوهين الخطي للأشعة السينية لمتراكبات الايبوكسي / أوكسيد التيتانيوم

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المستخلص

في هذه الدراسة، أجريت قياسات توهين الأشعة السينية بفولتيات مختلفة KV (20,25,30,35) باستخدام وحدة الأشعة السينية مع أنبوب توليد الأشعة السينية (النحاس)، للمواد المتراكبة التي تتكون من الايبوكسي كمادة اساس وأوكسيد التيتانيوم كمادة مدعمة بتراكيز وزنية % (4,6) والتي تم تحضيرها بطريقة القولبة اليدوية باستخدام خلاط ميكانيكي. وقد تم الحصول على قيم معامل التوهين الخطي (μ) بواسطة المعادلة الخطية لمخرجات التمثيل للرسم البياني بين لوغاريتم الامتصاص وسمك العينات حيث يمثل ميل الرسم البياني معامل التوهين الخطي. وأظهرت النتائج التي تم الحصول عليها أن معامل التوهين الخطي يزداد بزيادة النسبة الوزنية لأوكسيد التيتانيوم وأن أعلى قيمة تم الحصول عليها عند النسبة الوزنية(6%) . كما استنتجت العلاقة العكسية بين معاملات التوهين الخطية للعينات المحضرة مع فولتية توليد الأشعة السينية. وقد تم حساب قيم متوسط المسار الحر (λ) طبقة سمك النصف (HVL) وطبقة السمك العشري(TVL) في هذه الدراسة، وقد بينت النتائج أن قيم λ، HVL، و TVL للايبوكسي النقي أكبر من قيمتها للمواد المتراكبة المدعمة بأوكسيد التيتانيوم بالنسب الوزنية % (4,6) ولجميع قيم مديات الفولتية المذكورة.

وأظهرت النتائج التي تم الحصول عليها كفاءة المتراكبات المحضرة في امتصاص الأشعة السينية والتوهين، وهذه الكفاءة تتغير نسبيا تبعا لنسبة المادة المدعمة TiO_2 التي أثبتت التأثير الكبير والإيجابي لها على خصائص التدريع الإشعاعي لبوليمر الإيبوكسي.

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Abstract:

In this study, X-ray attenuation measurements for voltages (20, 25, 30, 35) KV using X-ray unit with copper X-ray tube were performed for the composites material that consist of epoxy as a matrix and titanium oxide as a reinforced at concentrations (4 and 6 Wt. %) which was prepared by hand- lay-up method by using mechanical mixer . The linear attenuation coefficient (μ) was obtained by linear equation of the graph representation output between the logarithm of absorption and the thickness of the samples where the slope of the graph represents the linear attenuation coefficient.   The obtained results showed that the

linear attenuation coefficient increased by increasing the weight percentage of titanium oxide and the highest value obtained at 6Wt.% .

The inverse relation between the linear attenuation coefficients of the composite samples with the x-ray voltage was also concluded. The values of mean free path (λ), halve value layer (HVL) and tenth value layer (TVL) was calculated in this study, the results were shown that the values of λ, HVL, and TVL, for pure epoxy is greater than its values of the composite material with 4and 6 Wt. % of TiO_2 at all values of voltages mentioned above.

The results obtained showed the efficiency of the prepared composites in the X-ray absorption and attenuation, this efficiency is relatively variable depending on the ratio of the reinforced material TiO_2 which demonstrating the great and a positive effect of it on the radiation shielding properties of the epoxy polymer.

Key Words: Epoxy, TiO_2, Composites, X-ray, linear attenuation coefficients, Mean free path, Halve value layer, Tenth value layer.

1- Introduction:

Several researchers have consistently measure and calculate the attenuation of X-ray using different energies and materials, although of its uses and applications in various fields, they are constrained because of its weight and high cost[1]. Thus, the objective of this research is to find new alternatives Polymer-matrix with low density has the ability to absorb and attenuation Radiology. Accordingly, the ongoing research is an extension of what happened research from flowing in this regard. Farid and Abdul–Hadi studied the measurement and calculation of the linear and mass attenuation coefficient of X-Ray for the wood materials [2], whereas (Naji at. el) investigated x-ray attenuation in different material which can be used to design anti backscattering control grids or radiation protection shield, the researchers used lead, copper, iron steel and aluminum to measure their ability on attenuation of x-ray [3]. Attenuation of x-ray for (Fe) and at voltage range (120-240) was studied by (Drobantu) [4]. Measurement of linear and mass attenuation coefficients for Al and Mg) by using (80 Kev) done by (David) [5]. In this study we will measurement and calculate the linear attenuation coefficient of x-ray in epoxy and epoxy reinforced by titanium oxide micro particles.

2-Theoretical part:

X-ray is an electromagnetic radiation produced by the ejection of an internal electrons and the transition of atomic orbital electrons from high-energy states to low states [6]. X-rays are attenuated as they pass through matter. That is, the intensity of an X-ray beam decreases the farther it penetrates into matter [7]. There are three main ways that photons can interact with matter: through the photoelectric effect, Compton scattering, or through the production of electron and positron pairs, so the attenuation stemmed only from the photoelectric effect and from Compton scattering [8]. Each interaction of an X-ray photon with an atom of the material removes an X-ray from the beam, decreasing its intensity. The amount of decrease in intensity of the X-ray beam depends upon two factors: x is the thickness of the attenuating material in cm, and μ is the linear attenuation coefficient of the attenuating material.

The exponential decay of photon intensity applies in the optical region of the electromagnetic spectrum as well. In this region, it is known as the Beer–Lambert law[9]:

$$I = I_0 \exp(-\mu x) \dots\dots\dots (1)$$

Where I: is the transmission X-ray beam intensity

$I_\circ$: is the incident X-ray beam intensity.

The mean free path (λ) is the average of distance that a photon travels before any interaction can be occurs. The mean free path is reciprocal of the linear attenuation coefficient [10]:

$$mfp(\lambda) = \frac{1}{\mu} \dots\dots\dots\dots..(2)$$

Half and tenth-value layer is another concept, since we can half or tenth value layer instead of using attenuation coefficient to do shielding calculation [11]. Halve value layer is the thickness of material that produces the photon beam intensity to the one-half, it is inversely proportional to the attenuation coefficient and is expressed in units of distance (cm)

Half-value layer can be calculated by following equation[12]:

$$HVL = \frac{0.693}{\mu} \dots\dots\dots\dots (3)$$

By similar way, tenth value layer TVL defined as that thickness which will reduce the radiation intensity by one- tenth of its original value $I_\circ$, TVL can be calculated using the following equations[10,11]:

$$TVL = \frac{2.303}{\mu} \dots\dots\dots\dots..(4)$$

3-Materials and method:

Material that is used in preparation of research samples consists of the polymer

as a matrix material, low viscosity epoxy, building industries (RAYET AI EAMA AR Company) with density 1.05 g/cm^3. Epoxy resin was mixed with hardener with the ratio (3:2). Epoxy and hardener are weighted using electrical balance with sensitivity 10^{-4} g for suitable mixing ratio, and then mixed continuously and slowly by using mechanical mixer for (15) minute in clean container, the mixture is poured in glass template. To complete hardening process, the samples were left in the template, at room temperature, for the period of 24 hours. Samples are then remove from the template and the heat treated was done by using the oven at 60°c for period of 60 minutes then the samples left for 7 days before any test.

Titanium micro particles by (Cristal Globalpharma) with the mean diameter of (50 μm) and density 3.99 cm^3 were used as reinforcement particles to improve the properties of the epoxy matrix. Samples of composites were prepared by adding micro (TiO$_2$) particles with weight percentage (4and6 %) weighted by electronic balance(SartoriusBL 210s/Germany) .the epoxy resin was added in the clean container and mixing with TiO2 by using the electric mixer, hardener also was added to the mixture. This mixture molded in glass template and left for one day, after that the samples placed in the oven at (

50°C) for period (60) minutes and also left for 7 days before any test.

In order to measured and calculate the linear attenuation coefficient of the prepared composite samples, the copper tube of x-ray is fixed in the space allocated to the system, set the specification time in the experiment (100 S). The detector angle is then fixed to zero by the Goniometer, the voltage values are determined to the extent that the linear attenuation coefficient of the samples is to be measured, and then measure the intensity of the x-ray falling directly in the absence of samples ($I_\circ$) and of X-ray transmission in the presence of samples (I). Steps was repeat by changing voltage values (20, 25, 30, 35) KV.

4- Results and discussions:

By measured the values of the incident x-ray ($I_\circ$) and transmission (I) cross the epoxy and epoxy reinforced with TiO$_2$ (4and6) Wt.% samples and calculate the natural logarithm of the transmission ratio $I_\circ/I$, where the relation between logarithm absorbance and thickness of the samples is linear according to the equation (1) that is become in the form:

$$\mu = \frac{\ln(I_\circ/I)}{X} \ldots\ldots\ldots\ldots\ldots.(5)$$

μ: is the linear attenuation coefficient. When plotted $\ln(I_\circ/I)$ as a function of the thickness for each samples which were studied and taking the slope of each linear curve which represent linear attenuation coefficient (μ) as shown in figures(1,2,3 and 4).

The results illustrated in table (1) and graph in figures (1, 2, 3 and 4) shows that, in general, at all voltages the values of μ increase with increasing sample thickness. Also μ greatest for composite samples that contains 6 Wt. % of TiO_2 and lesser for pure epoxy, and in all samples the values of μ decreased with increasing of the voltage, where found to be greatest values at (20 KV) and lesser values at (35 KV) as shown in figure (5).

mean free path (λ) for pure epoxy and after addition different concentration of TiO_2

and at voltages (20, 25, 30, 35) and calculated by using equation (2) illustrate in table (1), the values of λ plotted as a function of the applied voltage as shown in figure (6), the values of λ are larger of pure epoxy at (35 KV) and decrease with increasing of concentration of additive and with decreasing of the applied voltage. The results in table (2) illustrate the variation of HVL and TVL for the shields samples that taken in the experiment and calculated from equation (3), figure (7) illustrate the variation of HVL as a function of the type of samples for all voltages ranges, the result shows that the value of HVL for pure epoxy is greater than the value of the composite material with 4, 6 Wt. % of TiO_2. These results also are observed with respect to TVL which calculated from equation (4) as

shown   in   figure   (8).

Table (1): variations values of μ and λ for different types of shields sample at different voltages

Sample type	μ(cm^{-1})				λ (cm)			
	U(KV)				U(KV)			
	20	25	30	35	20	25	30	35
EP	0.6143	0.4206	0.359	0.3418	1.6279	2.3776	2.7855	2.9257
EP+4Wt%TiO$_2$	0.708	0.5779	0.4149	0.3961	1.4124	1.7304	2.4102	2.5246
EP+6Wt%TiO$_2$	0.8561	0.7152	0.4939	0.4563	1.1681	1.3982	2.0247	2.1915

Table (2): variations values of HVL and TVL for different types of shields sample at different voltages

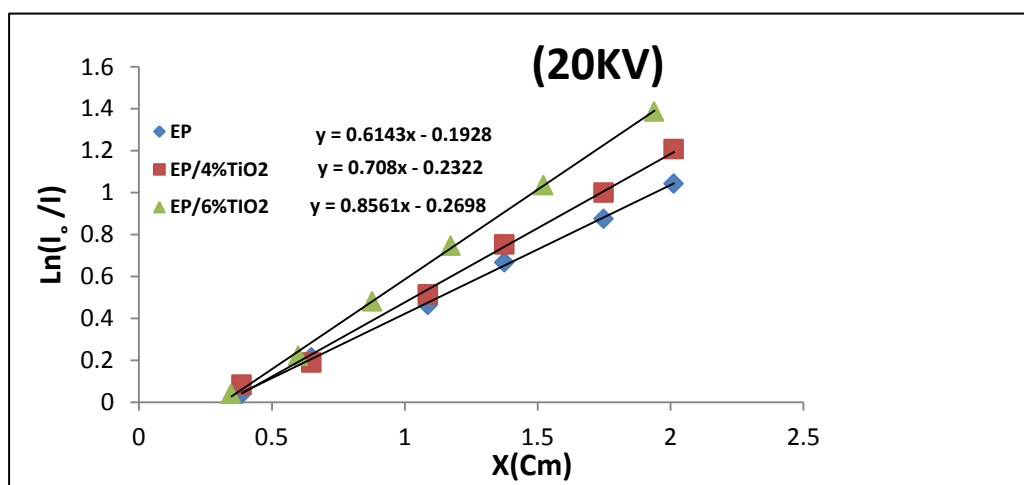| Sample type	HVL (cm)				TVL(cm)			
	U(KV)				U(KV)			
	20	25	30	35	20	25	30	35
EP	1.1281	1.6476	1.9304	2.0275	3.7489	5.4755	6.4150	6.7379
EP+4Wt%TiO$_2$	0.9788	1.1992	1.6703	1.7496	3.2528	3.9851	5.5507	5.8142
EP+6Wt%TiO$_2$	0.8095	0.9689	1.4031	1.5187	2.6901	3.2201	4.6629	5.0471

Figure (1): Shows the relationship between the absorption logarithm of x-ray at (20 KV) and the thickness of epoxy and epoxy /TiO$_2$ with (4, 6) Wt. % samples.
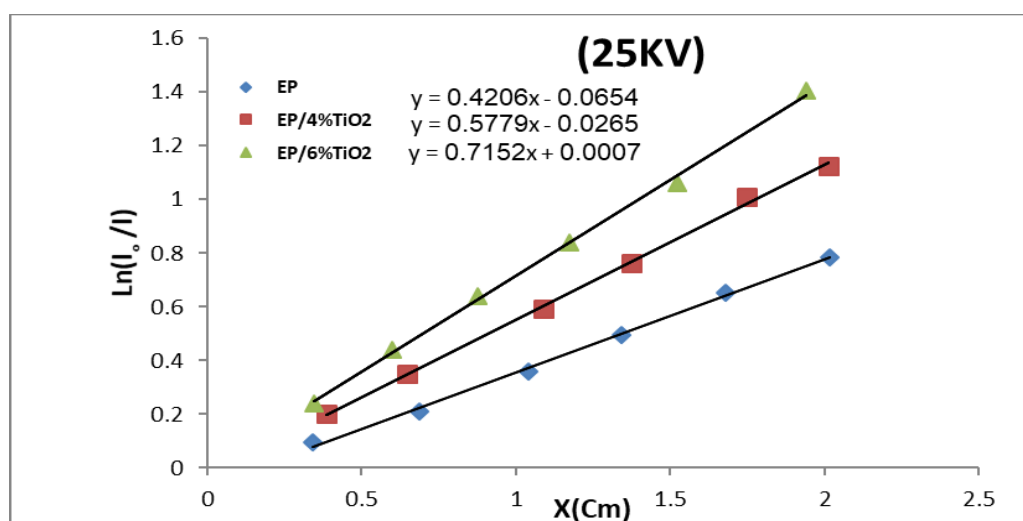

Figure (2) shows the relationship between the absorption logarithm of x-ray at (25 KV) and the thickness of epoxy and epoxy /TiO$_2$ with (4, 6) Wt. % samples.
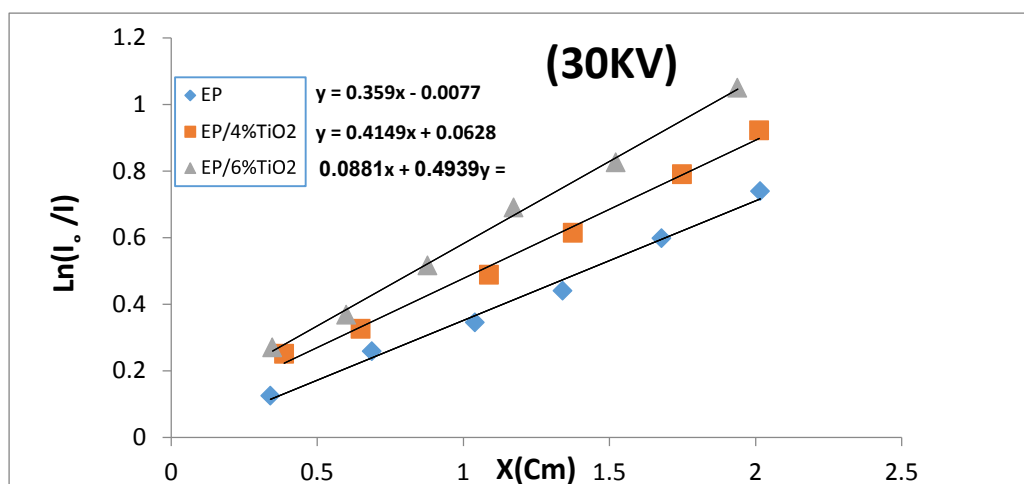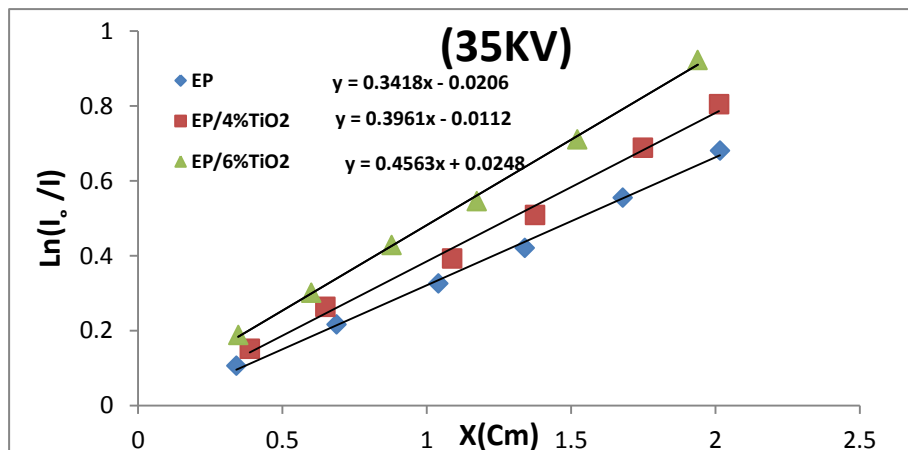
Figure (3) shows the relationship between the absorption logarithm of x-ray at (30 KV) and the thickness of epoxy and epoxy /TiO$_2$ with (4, 6) Wt. % samples.

Figure (4): shows the relationship between the absorption logarithm of x-ray at (35 KV) and the thickness of epoxy and epoxy /TiO$_2$ with (4, 6) Wt. % samples
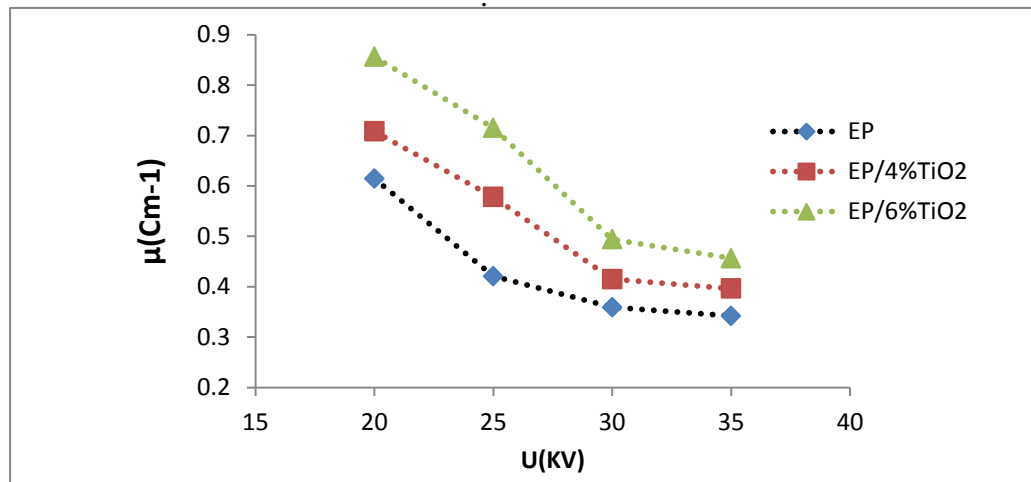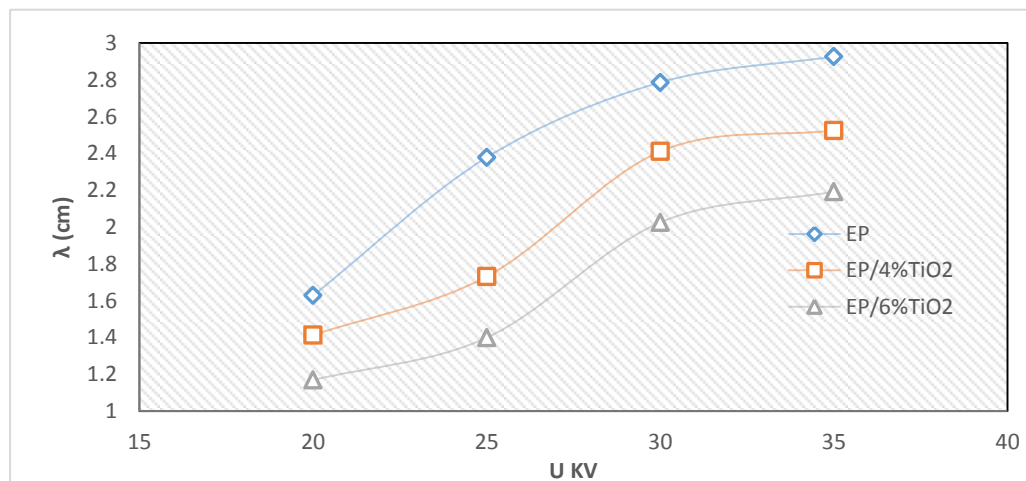
Figure (5): shows the relationship between the linear attenuation coefficient of epoxy and epoxy /TiO$_2$ with (4, 6) Wt. % samples and the x-ray generating voltages.

Figure(6):shows the relationship between the mean free path (λ) of the composite epoxy and epoxy TiO$_2$ composite with (4, 6) Wt. % samples and the x-ray generating voltages.
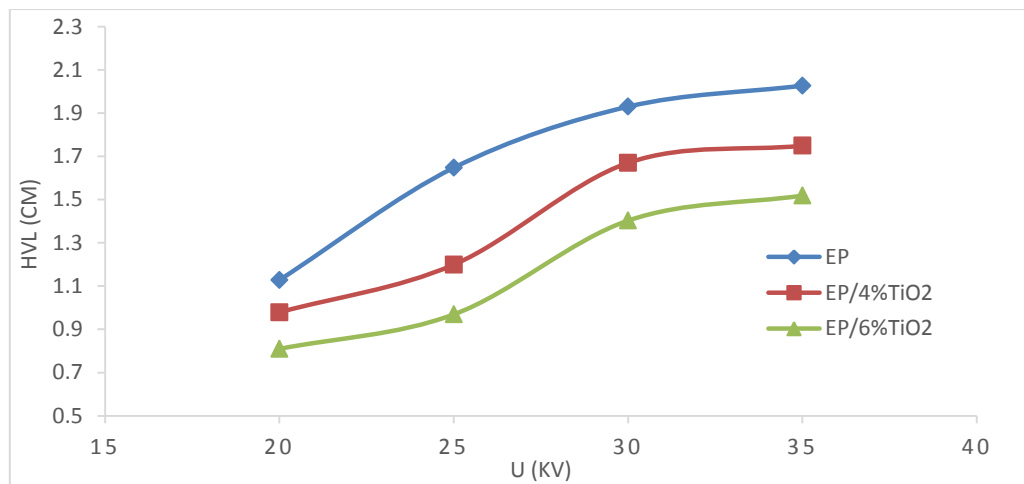
Figure (7): variation of HVL values in cm units versus the selected samples types for all x-ray generating voltages.
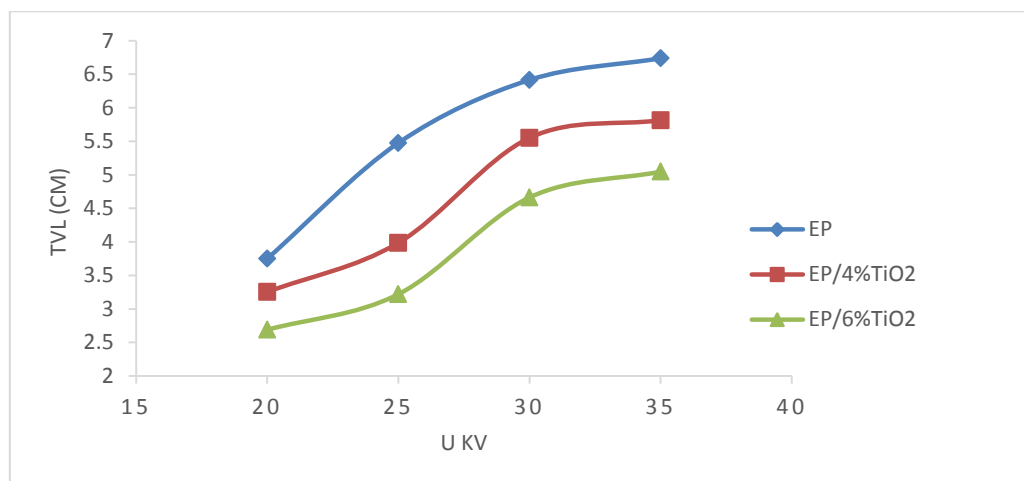

Figure (8): variation of HVL values in cm units versus the selected samples types for all x-ray generating voltages.

5-Conclusion:

From this study, the experimental results had allowed the following conclusions:

The linear attenuation coefficient increases with the increase the weight ratio of the titanium oxide and the highest value obtained was when the epoxy was reinforced with the micro particles titanium oxide material for the weight(6 %) at voltage (20 KV)

It was noticed an inverse relationship between the linear attenuation coefficients and the x-ray voltage. the linear attenuation

coefficient decreases when the voltages increase at all the prepared samples.

The values of λ, HVL and TVL, at all voltages, for pure epoxy is greater than its values of the composite material with 4, 6 Wt. % of TiO_2.

In general, it can be concluded that the epoxy/micro particles TiO_2 composite materials can act as shields against x-ray radiation with maximum values of (μ) and minimum values of λ, HVL and TVL.

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