Effect of Oxidation of Some Aluminum Alloys on X-ray Attenuation Coefficients

Farid M. Mohammed[1], Raed N. Razooqi[2], and Sokayna E. Yusuf[3]

[1]Dept. of Physics/College of science ,University of Tikrit P.O.Box 42. Iraq, (dr_fr_2006@yahoo.com); [2]Dept. of Mechanical Engineering College of Engineering, University of Tikrit P. O. Box 42 . Iraq (Raidmousis@yahoo.com); [3]Dept. of Physics/College of Education , University of Tikrit P.O.Box 42. Iraq

Abstract

Characteristic X-ray of 35KV (Mo-Tube) was used to determine the attenuation coefficients of x-ray for some of aluminum alloys with different thicknesses after oxidized them at different times and temperatures. By graphic figures and the phases formation on each sample's surfaces, we studied the effect of oxidation circumstance on absorption. The phases (θ-Al_2O_3) and (GeO_2) were formatted on alloy A, (θ- Al_2O_3), (GeO_2) and ($AlGe_{0.0435}$) on alloy B, (MgO) and (Al_2SiO_5) on alloy C hence we found direct proportion between absorption logarithm with thickness and equivalent thickness for alloy C , while we got inverse proportions for alloys A and B which was due to the phases formation on their surfaces, we found absorption logarithm for alloy C increased with ratio 0.178% after 4 hours later comparing with the same sample at same circumstances after the first half hour. The relation between the half value thickness and mean free path with attenuation coefficients were determined also.

Keywords : x-ray absorption , attenuation coefficients , oxidation , mean free half thickness .

تأثير أكسدة بعض سبائك الألمنيوم على معاملات التوهين للأشعة السينية المستخلص

تم استخدام الأشعة السينية المميزة (35) kV مع (Mo –Tube) لحساب معاملات التوهين للأشعة السينية لبعض سبائك الألمنيوم بسماك مختلفة بعد أكسدتها بفترات ودرجات حرارة مختلفة. درسنا تأثير ظروف الأكسدة على الامتصاصية من خلال الأشكال البيانية والأطوار المتكونة على السطح . ان الأطوار المتكونة على السبيكة A هي (θ- Al_2O_3) و (GeO_2)، والسبيكة B (θ- Al_2O_3) و(GeO_2)، اما السبيكة C فكانت الاطوار هي ($AlGe_{0.0435}$) و(MgO) و(Al_2SiO_5). تم ايجاد علاقة خطية بين لوغاريتم الامتصاصية والسمك والسمك المكافئ للسبيكة C. وتكون العلاقة عكسية للسبيكتين A و B بسبب الأطوار المتكونة على سطوحها. يزداد لوغاريتم الامتصاصية بنسبة 0.178% بعد 4 ساعات من أكسدتها مقارنة مع نفس العينة تحت نفس الظروف بعد النصف ساعة الأولى من التأكسد. تم حساب العلاقة بين سمك النصف ومعدل المسار الحر لمعاملات التوهين.

1. Introduction

Uncovered tissue can be severely damaged if it was exposed to the X-ray for a long time. Long-term continual exposures at sensible levels can directly cause a variety of skin disorders , while a continual relatively low-level exposures may be considered as a factor in increased cancer risk exposed workers . Many early workers with X-rays developed serious ailments (from skin lesions to various forms of cancer) as a consequence of their work . Although there are safeguards associated with modern X-ray tools designed to minimize or attenuate radiation in the work surroundings , an awareness of the dangers of radiation exposure and associated safety issues is required for any worker using X-ray laboratories [1] .

2. Theory

X-ray:

The intensity of emitted X-ray by the anti-cathode is directly proportional to the current inside the tube and to the square of the applied voltage .However , the efficiency of the emission process is very low , and even in the best conditions , with a voltage of 100 kV, only 2% of the energy provided is transmitted to the X-rays. Roughly 98% of the electron beams energy is consumed by the Joule effect and heats up the anticathode, which is why it is important to set up a system to

evacuate heat. A cooling system by water circulation is used as shown in Fig. (1) [2 - 6] .

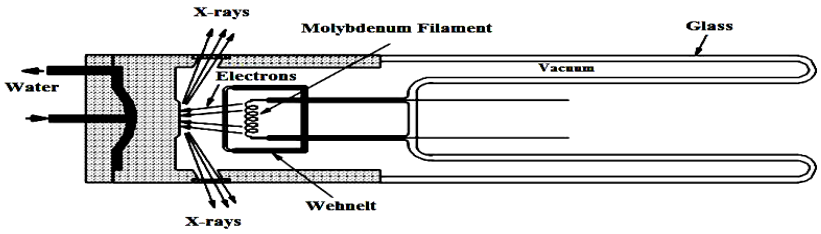

Fig.1 X-ray tube

The Oxidation:

The bulk structures of oxides of magnesium, aluminum, iron, titanium and silicon have been described in detail in several textbooks [7 - 11].

- The metals of the alloys have different affinities for oxygen because of difference free energy to form oxides.
- Form trio oxides or more in the alloys.
- Disparity in acceptability dissolution between the oxides.

Alloys oxidation is so complication cooperation with pure metals because of [12 & 13]:

- Because metal ions are diverse then they possess different mobility in oxides phases.
- Metals in the alloys have different diffusion.
- Oxygen dissolution in alloy form secondary flat precipitation like interior oxides. Fig (2) show oxidation of pure metals and alloys.

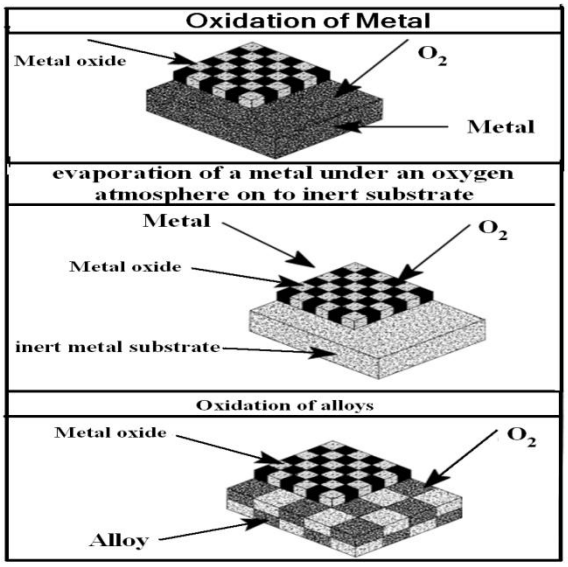

Fig. 2 Oxidation in pure metals & alloys [12]

Experimental , Germanium addition to Aluminum alloys in general has high affection to betterment alloy ductile and oxide plate even betterment oxidation resist at high temperature about (550 °C) , the oxide formation on alloys surface that container Germanium will stay right in all temperature (100 to 550) °C [13 & 14] .

3. Experimental:

a. Sample Preparation

Melting and Casting: after checking alloys constituents by a sensitive electric weighing scale a suitable quantity put in melting pot of silicon carbide in a furnace which corroboration at 700 °C, the melting alloys poured in cast mold , Figure (3)

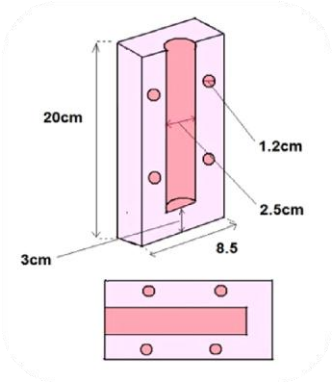

Fig.3 Sketch of cast mold.

then set aside to cool to laboratory temperature , the casting material then it was cut by cutting machine to a pieces of (2.75mm) thicknesses by using a cooling liquid , the alloys constitution were analyzed by Alloys Analyzer using X-Ray device , the results of analyses were given the Table (1) .

Table 1. Constituents the alloys which used in this experiment.

Sample	Al%	Ge%	Si%	Mg%
Alloy A	99.95	0.05	-	-
Alloy B	99.65	0.35	-	-
Alloy C	92.70	-	7	**0.3**

Rolling:

Through this operation different thicknesses were obtained (0.02 , 0.04 , 0.06 , 0.08 , 1) cm the alloys samples .

Cleaning, Grinding, and Polishing the samples :

The samples were cleaned by alcohol and by ultrasonic waves , and grinded by electric system for grinding and polishing to get a soft

Oxidation :

All samples oxidant by the electric furnace in to (0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4) hours at the temperature (200, 300, 400) $^{\circ}$C.

Analysis the Oxidation on the Samples Surfaces:

To know the phases formation on each sample's surfaces after oxidized them at temperature under study , The X-Ray diffraction system were used with (Cu–Tube) and wavelength (λ=1.5406 A$^{\circ}$), by Bragg Law we determined interference distance (d) as follow in eq. (2):

$$2dsin\varphi = n\lambda \qquad \ldots\ldots\ldots (2)$$

After comparison the values with standard tables . The phases formation were selected on the surfaces of alloys .

b. Examination of Samples by x – rays

The (20 , 25 , 30 , 35) kV Mo - X-Ray Tube were used to measure surface , grinding papers were used also of (800 , 1000 , 1200 , 2000) micron , the samples then washed by purified water then by alcohol and dried by drying system , after that polishing by a special kind of polishing cloth and diamond paste with four stages (1 , 3/4 , 1/2 , 1/4) micron incrementally ,from soft to coarse then wash by purified water , alcohol and dried after each stage.

the attenuation coefficients , after measuring the average counts for each samples , theoretical values of attenuation coefficients determined by :

$$I = I_{\circ}\, e^{-\mu x} \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

Such that $I_{\circ}/I$: absorption ratio .

μ : Attenuation coefficient

The experimental values of (μ_L) and (μ_m) determined by the slope of the curves to the logarithmic of absorption per thickness and equivalent thickness on succession for each sample .

4. The Calculations

A. we determined by weighting their masses and found their densities by using the eq.(4) :

$$\rho_{sample.} = \frac{m_{s.}}{V_{s.}} = \frac{m_{s.}}{\pi x r^2} \qquad \ldots\ldots\ldots (4)$$

Such that:

ρ_{sample} : represents the density by gm/cm^3 .

x : thickness of the sample in cm .

r : radius of the sample in cm .

m_s : mass of the sample in gm .
V_s : volume of the sample in cm^3 .

B. In the tables (2-4) experimental values were given for Linear and mass attenuation coefficients as well as mean free path and half thickness for alloys A, B & C, the slopes of the graphic Figures (7 to 14) represent the linear and mass attenuation coefficients.

Table 2 .The experimental results of linear and mass attenuation coefficients, mean free path and half thickness for alloy A oxidized at 400 ℃ which rolled to 0.06 cm.

U (kV)	$\mu_l = \frac{ln\frac{I_0}{I}}{X}$	$\mu_m = \frac{\mu_l}{\rho}$	$\lambda = \frac{1}{\mu}$		$X_{\frac{1}{2}} = \frac{0.693}{\mu}$	
			λ_l	λ_m	$X_{1/2_l}$	$X_{1/2_m}$
20	38.1375	14.16	0.0262	0.0706	0.0182	0.0489
25	37.6000	13.95	0.0266	0.0717	0.0184	0.0497
30	37.2625	13.84	0.0268	0.0723	0.0186	0.0501
35	36.8375	13.68	0.0271	0.0731	0.0188	0.0507

Table 3. The experimental results of linear and mass attenuation coefficients , mean free path and half thickness for alloy B oxidized at 400 ℃ which rolled to 0.06 cm.

U (kV)	$\mu_l = \frac{ln\frac{I_0}{I}}{X}$	$\mu_m = \frac{\mu_l}{\rho}$	$\lambda = \frac{1}{\mu}$		$X_{\frac{1}{2}} = \frac{0.693}{\mu}$	
			λ_l	λ_m	$X_{1/2_l}$	$X_{1/2_m}$
20	38.288	14.22	0.0261	0.0703	0.0185	0.0500
25	37.913	14.08	0.0264	0.0710	0.0188	0.0507
30	37.550	13.95	0.0266	0.0717	0.0191	0.0516
35	37.100	13.78	0.0270	0.0726	0.0194	0.0524

Table 4. The experimental results of linear and mass attenuation coefficients , mean free path and half thickness for alloy C oxidized at 400 ℃ which rolled to 0.06 cm.

U (kV)	$\mu_l = \frac{ln\frac{I_0}{I}}{X}$	$\mu_m = \frac{\mu_l}{\rho}$	$\lambda = \frac{1}{\mu}$		$X_{\frac{1}{2}} = \frac{0.693}{\mu}$	
			λ_l	λ_m	$X_{1/2_l}$	$X_{1/2_m}$
20	52.15	19.30	0.0192	0.0518	0.0133	0.0359
25	49.88	18.45	0.0200	0.0542	0.0139	0.0376
30	48.03	17.71	0.0208	0.0565	0.0144	0.0391
35	45.53	16.83	0.0220	0.0594	0.0152	0.0412

C. Effect of the oxidation:

To know the important of oxidation effects on attenuation coefficients of X-ray for alloys, it is necessary knowing oxidation circumstances from different oxidation times and temperatures . The Phases formation on the samples after tested them by X-ray diffraction shown in Figures (4 , 5 , 6) for example:

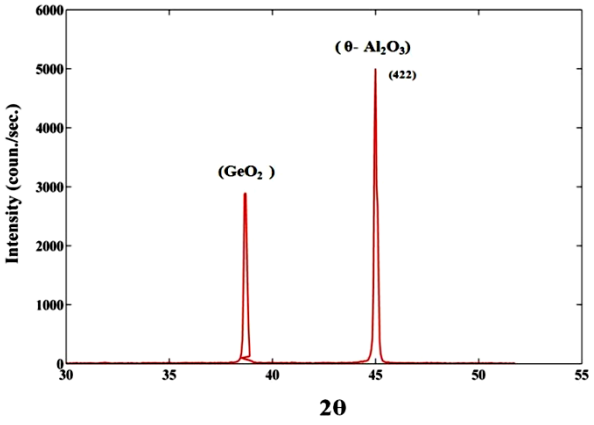

Fig.4 X-Ray diffraction pattern for oxidized Alloy A at temperature 400 °C which rolled to 0.06 cm

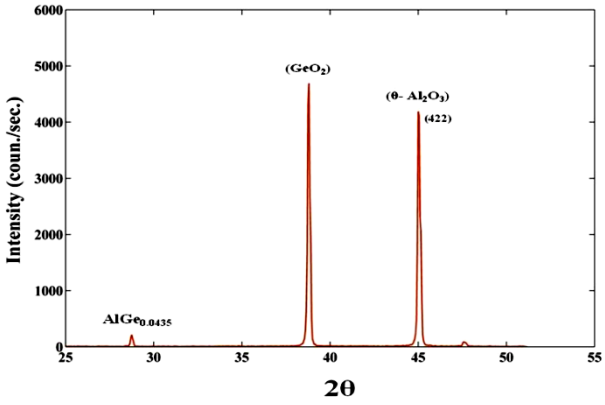

Fig.5 X-Ray diffraction pattern for oxidized Alloy B at temperature 400 °C which rolled to 0.06 cm.

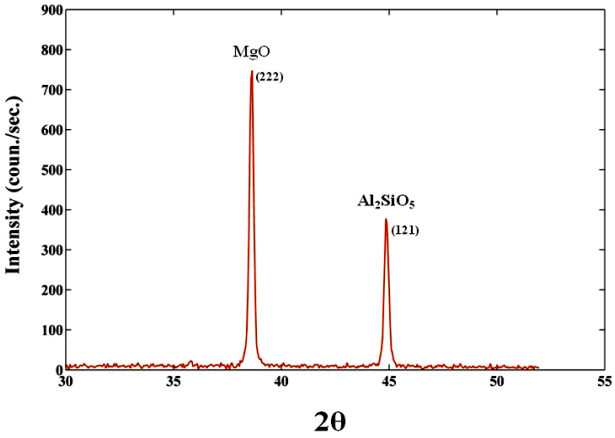

Fig.6 X-Ray diffraction pattern for oxidized Alloy C at temperature 400 °C which rolled to 0.06 cm.

D. Results and Discussion:

1. Figs. (7 , 8 , 9 , 10) shows the relation between logarithm of absorption with thickness for alloys A , B & C at temperature (400 ˚C) it is found an inverse relation for alloys A & B , this means that their absorption of X-ray decreased with increasing time , while the relation between logarithm of absorption with thickness for alloys C is linear this agrees with [15 - 17] , which due to the phases formation as shown in Figs. (4, 5, 6).
2. Figs. (11 , 12 , 13 , 14) shows the same result as in 1 .
3. Absorption Logarithm for alloy C oxidized at temperature (400 ˚C) after 4hr increased with ratio

(0.178%) compared with the same sample in the first half hour of oxidation at same temperature at 20kV , even the same sample oxidized at (400 ˚C) increased with ratio (0.097%) comparing with second alloy in [15] at room temperature at voltage 20kV .

4. The absorption decreases with increasing of voltage for alloys A , B & C .
5. Relation of absorption logarithm with thickness and equivalent thickness for alloys A , B & C that oxidized at temperature (200 , 300) ˚C were the same as in results (1) & (4) .
6. Attenuation coefficients of X-ray for these alloys oxidized at (200,300,400) ˚C have the same trend as in results (1) , (4) & (5) .
7. In Tables 2 to 4 we determined attenuation coefficients from the slope of the curves to the logarithm of absorption per thickness and equivalent thickness on succession for each sample .
8. In Tables 2 to 4 half thickness and mean free path had inverse relation with attenuation coefficients of x-ray .

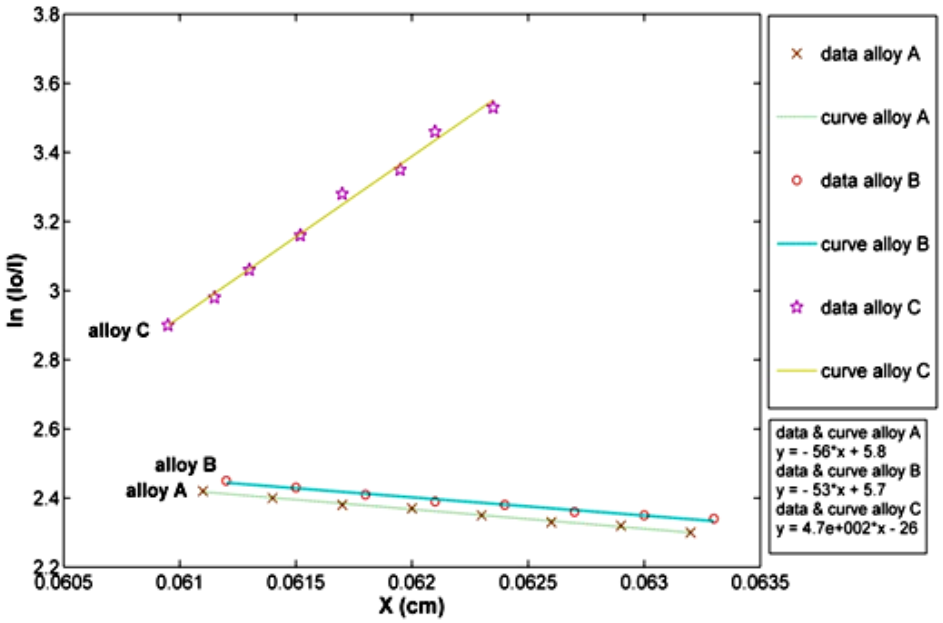

Fig.7 The relation between Logarithm of absorption with thickness for Oxidized alloys at 20kV.

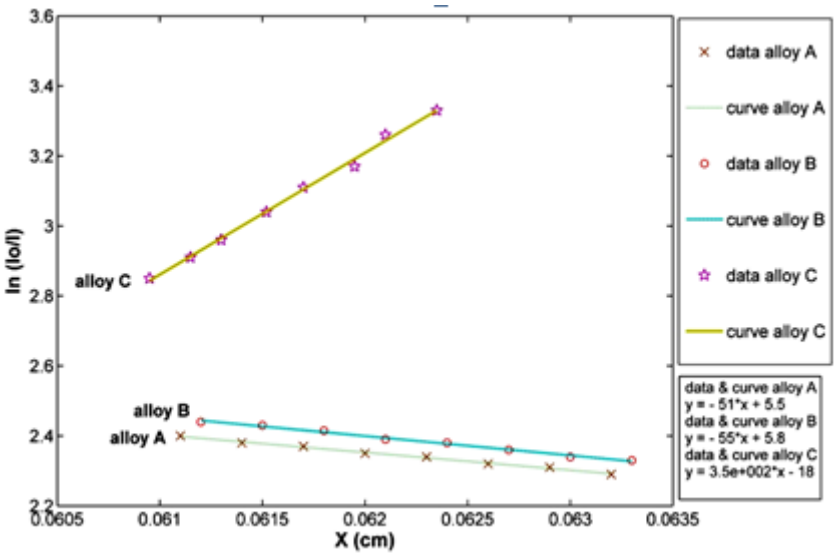

Fig.8 The relation between Logarithm of absorption with thickness for Oxidized alloys at 25kV.

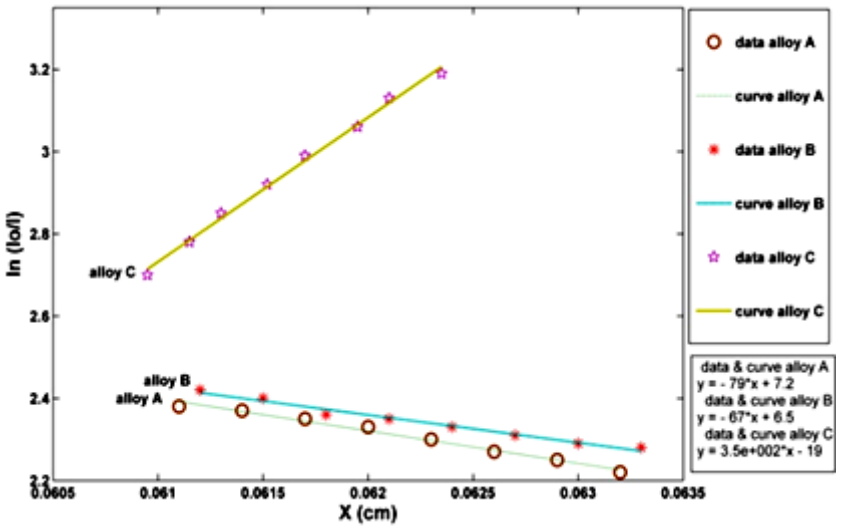

Fig.9 The relation between Logarithm of absorption with thickness for Oxidized alloys at 30kV .

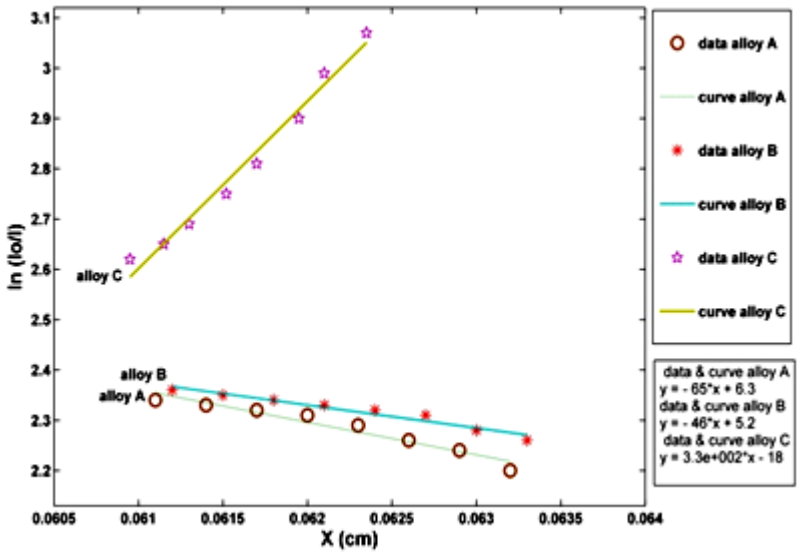

Fig.10 The relation between Logarithm of absorption with thickness for Oxidized alloys at 35kV

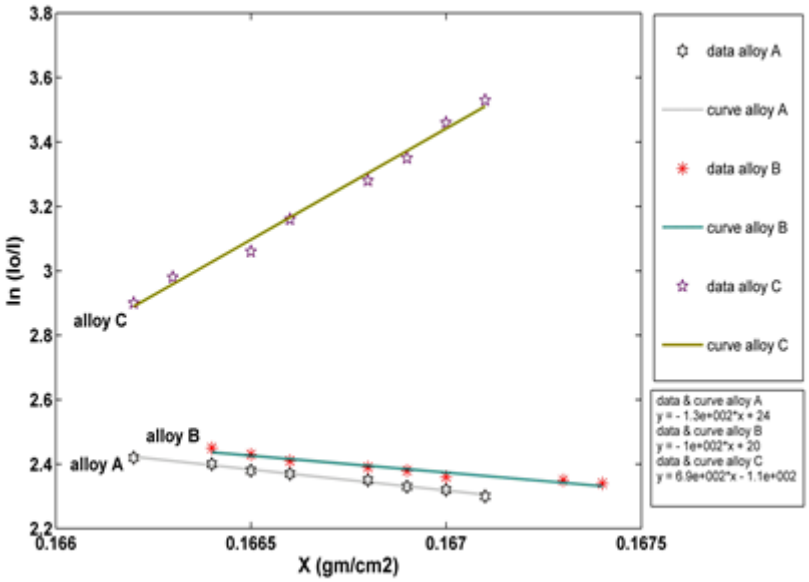

Fig.11The relation between Logarithm of absorption with Equivalent thickness for Oxidized alloys at 20kV .

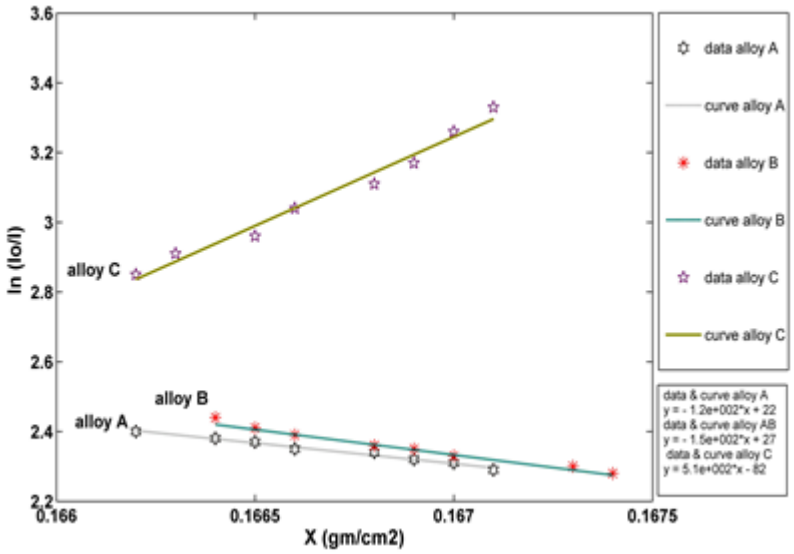

Fig.12 The relation between Logarithm of absorption with Equivalent thickness for Oxidized alloys at 25kV .

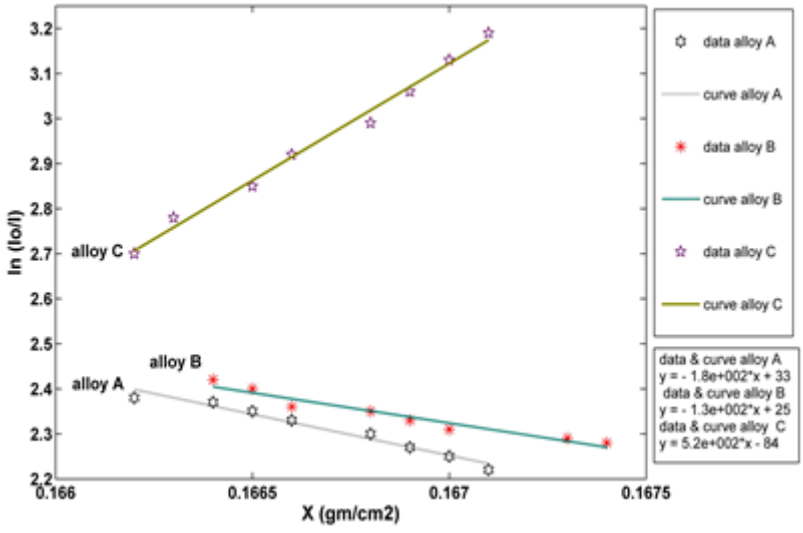

Fig.13 The relation between Logarithmic of absorption with Equivalent thickness for Oxidized alloys at 30kV.

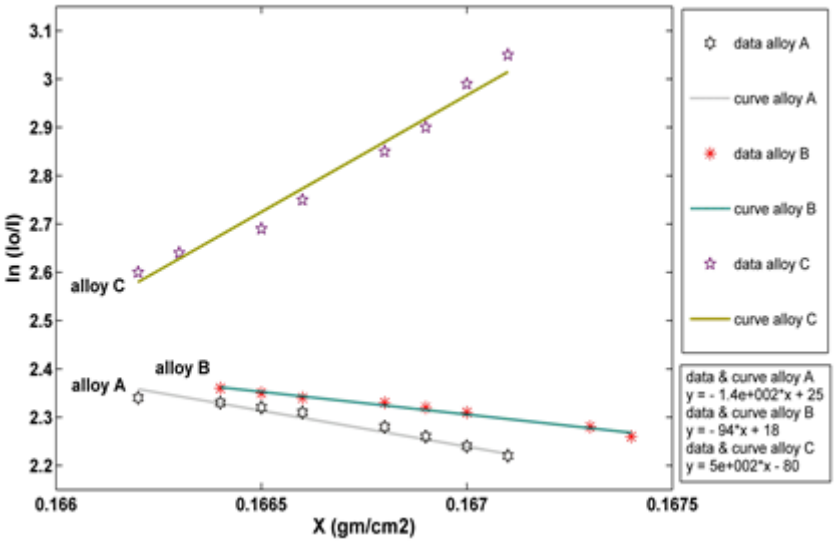

Fig.14. The relation between Logarithm of absorption with Equivalent thickness for Oxidized alloys at 35kV .

E. Conclusion:

1. Increasing of sample thickness hadn't any affection for alloys A & B as shown in the Figs. 7-10.
2. Trio alloy give best result comparing with double alloy even change alloys constituents.
3. Linear relations for (μ_L, μ_m) of X-Ray for alloy C , while it was inverse for alloys A and B .

$X_{1/2}$ and mean free path decrease for alloy C, while both of them increase for alloys A & B at different temperatures.

References:

1. James R. Connolly, "The Interaction of X-rays with Matter and Radiation Safety" , , for EPS400-001 , 2010 .
2. René Guinebretière , "X-ray Diffraction By Polycrystalline Material" , First published by ISTE Ltd in Great Britain and the United States , ISBN-13: 978-1-905209-21-7 , 2007
3. Gibilisco , Stan ''Physics Demystified'' 1st Ed. , U.S.A.2002 .
4. Podgorsak, E.B.'' Radiation Oncology Physics : A handbook for Teacher & Students'' International Atomic Energy Agency , Vienna , 2005 .
5. Hubbell, J.H., S.M. Seltzer '' Table of X-Ray Mass Attenuation Coefficients And Mass Energy – Absorption Coefficients'' National Institute of Standards And Technology , 2004
6. Wafa Altuieb Mohammad Mustafa ''Thickness Measurement Via X – Ray Radiation''Submitted in partial fulfillment of a postgraduate diploma at African Institute for Mathematical Sciences , Stellenbsch university , South Africa , 2010 .
7. Nielslen, J. A. ''Elements Of Modern X-ray Physics'', John Wiley & Sons , ltd , 2004
8. M. Blesa, P. Morando, A. Regazzoni , "Chemical Dissolution of Metal Oxides", CRC Press , Boca Raton, FL , 1993.
9. A.R. West , "Basic Solid State Chemistry", 2nd ed., Wiley, New York, 2000.
10. CRC Handbook of Chemistry and Physics , 72nd ed., CRC Press , Boca Raton, FL, 1991.
11. Hind A. Al-Abadleh, Vicki H. Grassian , "Oxide surfaces as environmental interfaces" , Elsevier Surface Science Reports , pp. 63–161 , Vol. 52 , 2003
12. Franchy, R. ''Growth of Thin , Crystalline Oxide , Nitride and Oxynitride Films on Metal and Metal Alloy Surfaces'' Surface Science Reports 38 pp.195-294 , Germany , 2000 .
13. Raed N. Razooqi , " affection of employment middle (Corrosion-Oxidation-Wear) on alloy properties with base (Aluminum – Lithium) , master a thesis , Application sciences department , Technology University, Baghdad , 1990 .
14. Jaafer T. Al Haidery , Muna K. Abbass " Affection some of alloyed elements on dead plate from Lithium in alloys with base Aluminum –

Lithium at its oxidation at different temperatures " Engineering and Technology Press , Vol.18 , No.1 , 1996 .

15. Farid M. Mohammed ,Raed N. Razooqi ,Safana M. Ismael ''The Effect Of Grain Size For Aluminum and Some Of Its Alloys On Attenuation Coefficients Of X-Ray'' Australian Journal of Applied Science, **(**under publication).
16. Farid M. Mohammed ,Raed N. Razooqi , Omar F. Abdullah''Determinations of the Relation Between The AttenuationCoefficients of X-Ray for Copper and Some of its Alloys With Grain Size'' European Journal of Scientific Research , ISSN 1450-216X Vol.45 No.2 , pp.176-189 , 2010.
17. Farid M. Mohammed ,Raed N. Razooqi , Mohsen H. Ali '' Modeling The Relationship Between Thickness and Hardness With Energy Attenuation of X-ray For Pure Aluminum ''Australian Journal of Basic and Applied Science , Vol.5 , No.10 , pp. 1268 -1272 , 2011 .