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A Study Effect of Irradiation on the Optical Properties of Bi Thin Films

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Abstract: In this work, the effect of irradiation on the optical properties of Bi thin films was studied. The Bi films were deposited on glass substrates at room temperature by thermal evaporation technique with the thickness (0.6 μm) and rate of deposition equal to 6.66 Å/sec. The work had included studying some of the optical properties of Bi thin films before and after irradiation from Co-60 by ray doses (20) Mrad. Analyses performed on irradiated and unirradiated samples showed significant changes in transmittance, transmission spectra. After irradiation, the transmission spectra values increased whereas anisotropy detected in the transmission spectra of unirradiated samples disappeared. The change of color caused by irradiation was noticeable to the naked eye.The optical constants, which are represented by the extinction coefficient (k), and refractive index (n), were determined from the transmittance spectrum in the Near Infrared (2500-3900) nm regions. The value of the optical energy gap increased after irradiation for samples.

Keywords: optical properties, index (n), thermal evaporation.

1 Introduction

Since the interaction of ionizing radiation with materials depends on its photon one energy besides properties of the dense elements in the materials [1]. It should be noted that after irradiation there is a certain fall in the line intensities of the polycrystalline aggregates; this may be associated with the formation of defect complexes and the pinning of these at grain boundaries [1,2]. The effect is stronger for proton irradiation owing to the greater defect density (Fig. lb). The considerable increase in background furthermore supports this fact [2,3]. The unit in Fig. 1 is taken as the line intensity of the samples before irradiation 10. In the case of the single crystals the change in intensity diminishes as the impurity content increases[4]. The principal change in the intensity occurs for the lines of the family of planes which have predominantly covalent bonds. Similar effects were observed when studyingthe effect of plastic deformation on the structure of bismuth alloys[5]. Further investigations are required in order to explain these phenomena.

Bismuth is a semimetal that belongs to the fifth main group of the periodic chemical element system and is rarely present in its elemental form [1,6]. Of all metals, it has the lowest thermal conductivity, while its electrical conductivity is greater in the solid than in the liquid state[8,9].

Bismuth is primarily used in pharmaceuticals, because it has low melting point alloys, fuses, sprinklers, glass, ceramics and as a catalyst in manufacturing rubber. [10,11].

The study of Bi is interesting because it has semi-metallic behaviour and low Fermi energy [12].

The thermal evaporation technique was used to deposit thin films of polycrystalline bismuth because this method is fast and inexpensive for bismuth study [13].

The present work reported the study of the optical properties measurements in thin films of bismuth prepared by vacuum evaporation before and after irradiation from Co-60 with doses (20) Mrad.

The present work's main goal is to investigate collective optical measurements of some selected transition metal oxides.

2 Experimental part

In this study, the preparation conditions of Bi thin films and the technique employed to produce films deposited on glass substrate at constant substrate temperature are described. The evaporation technique involves the use of a molybdenum boat as a source of sample evaporation. An effective boat must have a high melting point and should not react with the material that has been evaporated. A molybdenum boat of 2895K melting point was used to evaporate Bi. It has a solid rectangular shape with an adequate depth to avoid sputtering of material during the evaporation process. The optical constants were determined

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from the transmittance and absorption spectrum, including the refractive index and extinction coefficient.

The substrates are the great influence parameters and the most important effects on the properties of the deposited films. Measurements for Bi films on glass substrate the Structural and optical properties

The vacuum evaporation process with a pressure of 10^{-5} mbar was used to deposit Bi films on the glass substrates. The thickness of everythin film deposited is (0.6) μm.

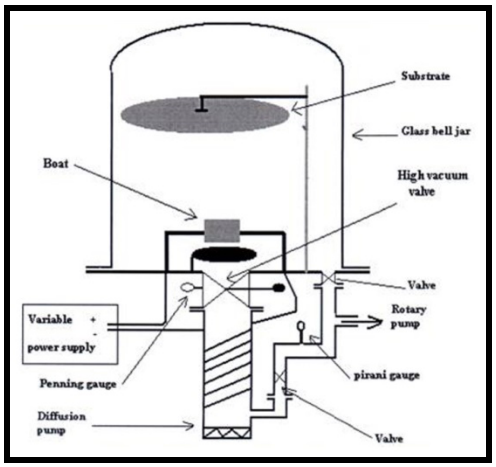

Fig. 1: Typical experimental setup of thermal evaporation system

The optical absorbance spectra of the Bi films are measured using FTIR Shimadzu spectrophotometer model 8300, Japan, with range of wave number (2500-3900) nm overIn order to clean it and push away the surface contamination before the deposition process, the current was passed through the boat. The thickness methods are weighing method.

3 Theoretical part

3-1 Thickness of films

A given film thickness may be obtained by the simple formula [5]:

$t=m/2\rho\pi h^2$ ……………………………………..(a)

where t=is the film thickness in cm

m =is the mass of the materials to be evaporated in gm

h = is the source (boat) to substrate distance.

ρ = is the density of materials to be evaporated.

This method is only approximate, so 20% of the evaporated material should be added to the measured weight to replace the loss of material that falls from the ship or spreads from the substrate surface during the evaporation process..

3-2 The Absorption Coefficient

Absorbance (A) which depends on the material thickness, i.e. [4]:

$$A=\log(1/T)$$ …………………….…………………………… (b)

Then α (absorption coefficient) is given by[4] :

$$\alpha = 2.303\, A/t$$ ……………………………………………… (c)

3-3 The Optical Energy Gap

The Tuac equation is given by [6,7] :

$$\alpha h\nu=B(h\nu\ \ E_{opt})^r$$ …………………………………………(d)

The optical energy gap was calculated by plotting $(\alpha h\nu)^{1/r}$ versus the photon energy (hν) and taking the extrapolation of the linear portion of $(\alpha h\nu)^{1/r}$at $(\alpha h\nu)^{1/r}$ =0 and the value gives the optical energy gap (E_{opt}).

The index (r) takes the value between 0< r < 3[8].

3-4 The Optical Constant

Optical constants, represented by the refractive index (n) and the coefficient of extinction (k). The refractive index from the equation was determined. [9]:

$$n=\left[\frac{4R}{(R-1)^2}-k^2\right]^{1/2}-\frac{(R+1)}{(R-1)}$$

…………….…......…….. (e)

Where R is the reflectance given by the equation[10] :

$$R=\frac{(n-1)^2+k^2}{(n+1)^2+k^2}$$

………………………….….….….……… (f)

And, using the equation, the extinction coefficient (imaginary part of the refractive index) can be calculated. [4] :

$$k=\frac{\alpha\lambda}{4\pi}$$

…………………..…………….….….….…… (i)

4 Results and Discussion

4-1 Atomic Force Microscopy (AFM)

The morphological characteristics of Bi thin films were investigated using (AFM) for nanostructure observation. The surface topographical images recorded for Bi thin films are shown in Fig.(2) prepared before and after irradiation from Co-60 by ray doses (20) Mrad, grown by thermal evaporation technique on glass substrate. The films' AFM images show a dense grain structure, crystalline

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structure and clear grain boundaries which became apparent at irradiation (20) Mrad. The difference in crystal structure and increase in grain size after irradiation can be seen from this figure.

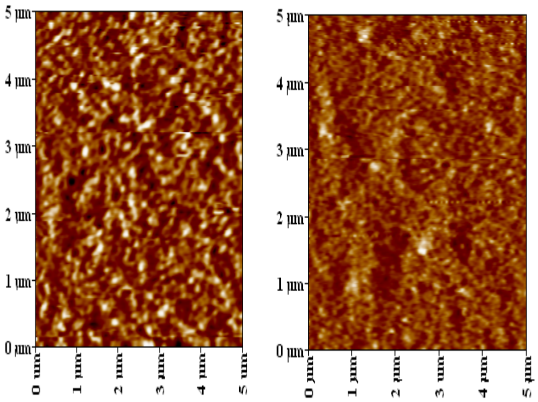
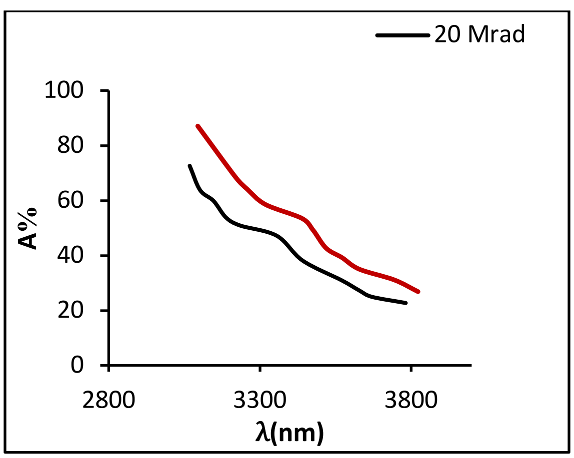


Fig. 2: AFM image for Bi films before and after irradiation from Co-60, 0.6µm

The absorbance spectrum for Bi films with thickness (0.6) before and after irradiation are shown in Fig.(3). The absorbance spectrum shifts to longer wave lengths after irradiation from Co-60 by with ray doses (20) Mrad. It is obvious that the absorbance decreases after irradiation and this may be due to improving the crystallite size and increasing the transmittance.

The transmittance increases after irradiation the films. For all films, as shown in Fig.(4), the changes of the transmittance spectrum to shorter wavelengths after irradiation can be due to the crystallization of the film structure by increasing the grain size.



(a)

Fig. 3: Absorption as a function of wavelength for Bi films before and after irradiation from Co-60 ,0.6µm

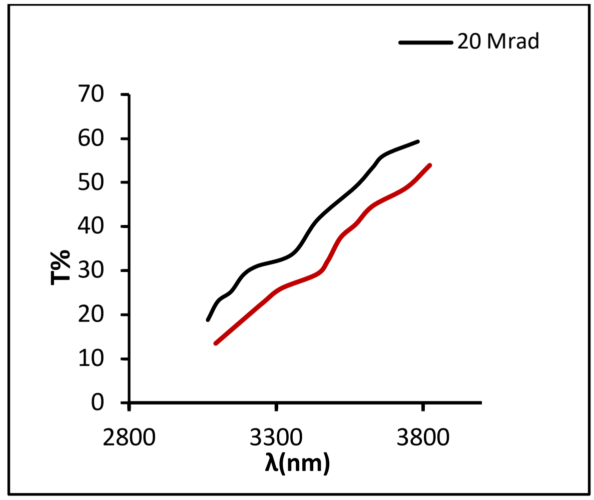
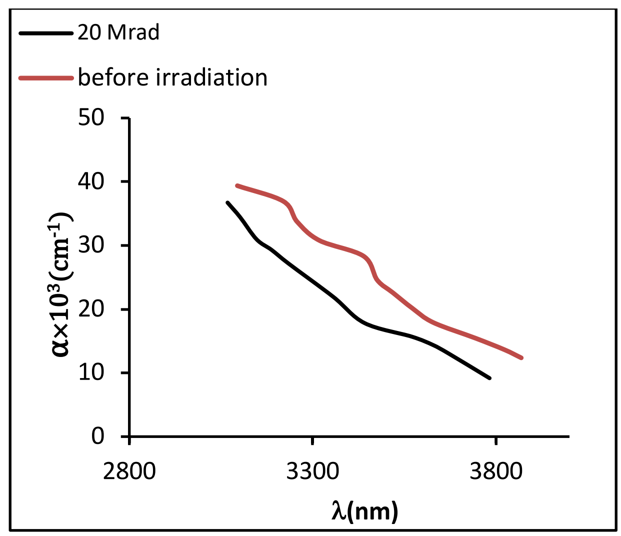


Fig. 4: Transmittance as a function of wavelength for Bi films before and after irradiation from Co-60 , 0.6µm

4-2 The Absorption Coefficient

We can notice that α (absorption coefficient) in general decreased after irradiation for all films as shown in **Fig. (5).** α has the same behavior of the absorbance.



(a)

Fig. 5: Absorption coefficient as a function of wavelength for Bi films before and after irradiation from Co-60 , 0.6µm

4-3 The Optical Energy Gap

The optical energy gap values (E_g) for Bi films have been determined. A plot of $(\alpha h\nu)^{1/2}$ versus hν for Bi films before and after irradiation is shown in Fig. (6). The plot is linear, reflecting the existence of the films' indirect band distance. The value of the optical energy gap for all samples increased after irradiation due to the growth of the crystallites.

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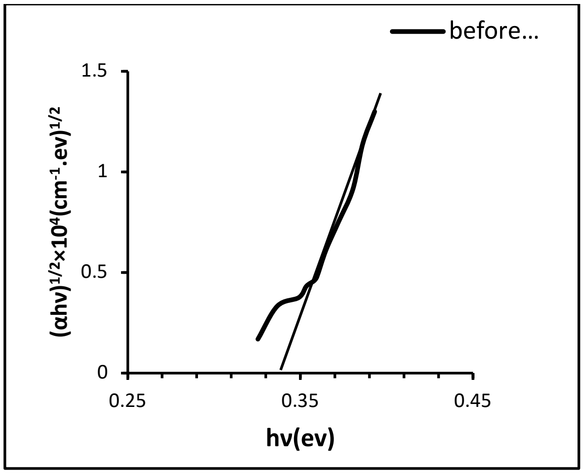


Fig. (6): **$(\alpha h\nu)^{1/2}$ as a function of hν for Bi films before irradiation from Co-60, 0.6µm**

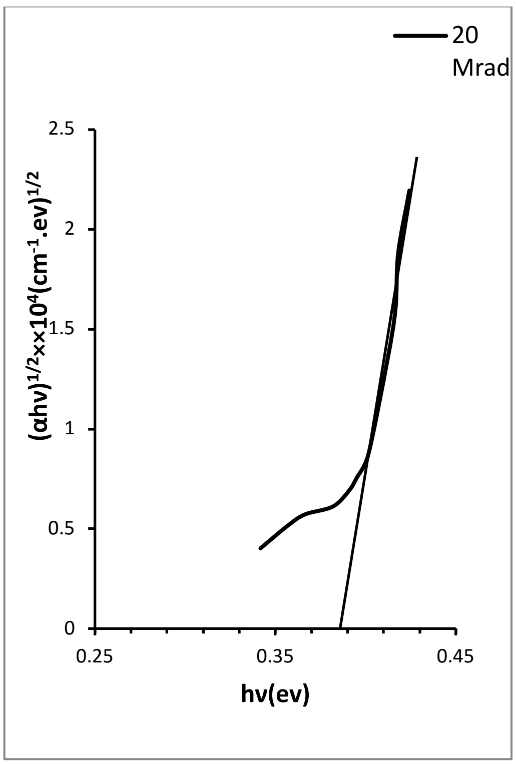
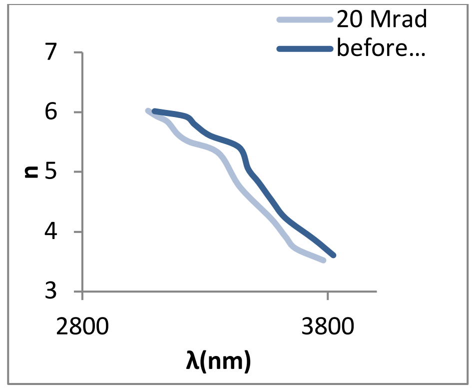


Fig. (7): **$(\alpha h\nu)^{1/2}$ as a function of hν for Bi films after irradiation from Co-60 (20 Mrad) , 0.6µm**

4-4 Refractive Index

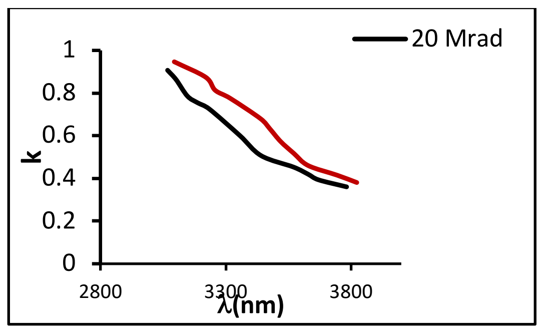
The refractive index decreased with the increasing of irradiation due to the increase of the compactness of the films after the irradiation with the increase of the crystallite size as shown in **Fig. (8).**



(a)

Fig. (8): **Refractive index as a function of wavelength for Bi films before and after irradiation from Co-60 (a): 0.6µm 4-5 Extinction Coefficient**

The extinction coefficient (k) decreased after irradiation for all films, as shown in Fig. (9).This is due to the same explanation previously stated in the absorption coefficient as k's behavior is close to the coefficient of absorption(α)



(a)

Fig. (9): Extinction coefficient*as a function of wavelength for Bi films before and after irradiation from Co-60 (a): 0.6µm*

5 Conclusions

From AFM images of the films we can see the variation in crystal structure and increase in grain size after irradiation. Transmittance spectrum in the near Infrared, The transmittance increased after irradiation. Absorption coefficient (α) decreased after irradiation for films, absorbance spectra it was observed that the optical transition in the Bi thin films is an allowed direct transition and the value of the optical energy gap increases after irradiation for samples. Most of optical characteristics can be improved by irradiation of Bi film.

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