The Effect of Photo irradiation by Low Energy Laser on the Optical Properties of Amorphous GaAs Films

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Abstract: Amorphous thin gallium arsenide films have been evaporated by flash evaporation technique with thickness of about 3500 Å, under vacuum of about 10^{-6} mbar, on ultrasonically cleaning corning glass substrate, at substrate temperature 423 K. GaAs films have been irradiated by continuous Ar^+ ion laser with power nearly 120 mW for different duration times. X-ray diffraction of the as prepared and irradiated GaAs films is amorphous structure. The optical properties of GaAs films were investigated by studying the infrared and ultraviolet spectra and some optical constants were founded and compared before and after irradiation, the absorption edge shift toward the longer wavelengths (red shift) after irradiation process with respect to the as deposited film, the value of the absorption coefficient for GaAs films at the absorption edge has decreased slightly after irradiation process by factor of about 4. The direct optical energy gaps of GaAs films were estimated to be 1.78 eV for the as prepared decrease to 1.52 eV after irradiation process.

Keywords: Ar+ ion irradiation; Amorphous GaAs film, UV-Visible Spectrum.

I.   Introduction

The study of the interaction of laser radiation (LR) with semiconductors is a very important task in physics and semiconductor technology. Due to the great scientific developments in semiconductor physics during the last two decades, new applications to opto-electronic devices are quite frequent and successful. It is well known that optical and transport properties in semiconductor systems have a strong relation with the degree of localization of electronic states in the material. Nevertheless, a much simpler situation occurs when the laser is tuned far from any resonances, since the main physics of the laser±semiconductor interaction may be theoretically described by using a non-perturbative one-body approximation. From the experimental point of view, the shifts on impurity levels induced by laser light may be used as a possible application to ultrafast opto-electronic devices where no photon absorption occurs in the device. A detector capable to respond to virtual transitions where the number of photons is preserved may be very useful because it is suitable to non-destructive measurements [1]. III–V semiconductors have demonstrated high-performance detection in a wide spectrum range with cutoff wavelengths ranging from UV to far-IR [2]. GaAs and other III-VI compounds semiconductors have been identified as "materials of the future", in view of some of their unique and interesting properties, such as its direct band gap energy (Eg) of 1.42 eV, Relative high dielectric constant (εr) of about 7 [1, 3], Refractive index near (n) 3.4, Absorption coefficient near (α) 104cm–1. Gallium arsenide is a compound semiconductor with a combination of physical properties that has made it an attractive candidate for many electronic optoelectronics devices [1, 4] applications. III/V semiconductor, and is used in the manufacture of devices such as microwave frequency integrated circuits, monolithic microwave integrated circuits and millimeter wave integrated circuits, infrared light-emitting diodes, laser diodes, solar cells and optical windows, in mobile phones, satellite communications, microwave point-to-point links and higher frequency radar system, used in the manufacture of Gunn diodes. Complex layered structures of gallium arsenide in combination with aluminum arsenide (AlAs) or the alloy AlxGa1-xAs can be grown using molecular beam epitaxy (MBE), metal organic vapor phase epitaxy (MOVPE) and pulsed-laser deposition (PLD) [1, 5]. In this search, flash

evaporation technique was used to solve the problem of Ga and As separation. Then we study the effect of ion laser irradiation on the prepared films. Argon ion laser was used, which is one of class of noble-gas ion lasers that operate in the visible and ultraviolet spectral region operating in ionized species of the noble – gas of argon. The argon ion lasers are primary continues laser, although a few of these lasers are also commercially available as pulsed lasers [1]. Ar- and Kr-ion lasers are the most powerful continuous gas lasers in the visible and UV. Ar-ion lasers can emit tens of watts on their most powerful green lines. Especially in the context of strategic applications in the areas of advanced electronics and Laser-induced etching, an improved etching process, is very much needed in the fabrication of III-VI integrated optic and microelectronic devices. Several studies of laser induced etching have shown the importance of its higher processing rate than the conventional etching techniques. With this technique the etching is initiating non-thermally by light-generated electron-hole pairs, which diffuse to the surface and greatly enhances the oxidation-reduction reaction between the semiconductor and a dilute acid solution [6, 7].

II.   Experimental Work

GaAs films have been prepared by flash evaporation technique using Edward 306A vacuum coating system under a pressure of about 2×10-5mbar. This films deposited on 7059 corning glass slides cleaned ultrasonically with acetone, demonized water and finally air dried. The deposition process was done at substrate temperature about 473K achieved by resistive heater measured by thermometer with K-type thermocouple. The thicknesses (d) of the prepared films were measured using weighting method which is about 3500 ± 50 Å. GaAs alloy and films have been done by Phillips PW3710 X-Ray diffractometer of 1.5405Å wavelength with CuKα source radiation, current 20 mA, Voltage 40 KV and scanning speed 2 cm/minute. GaAs films were irradiated by continuous Ar+ ion laser placed at a distance about three meters from the films which exposed to laser radiation and maintained for 30 and 60 minutes. The beam of laser was focused by a lens placed in the middle of laser radiation path. Figure 1 illustrates diagram of irradiation mechanism of GaAs films. The wavelength of the used laser was 514.5 nm and the power intensity was 150 mW. The optical properties have been investigated by UV/Visible Centra 5 Spectrometer to compute some optical parameters.
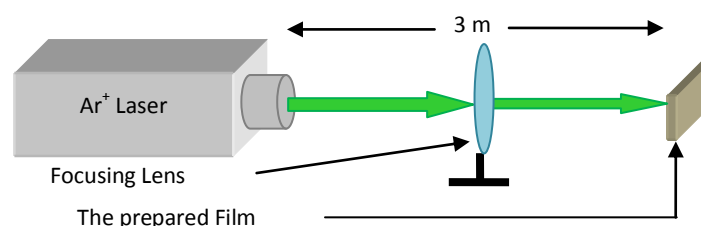

Figure 1: Schematic diagram of irradiation mechanism of GaAs films**.**

III.   Result and Discussion.

The structure of the GaAs alloy has been investigated as shown in figure 2. The XRD spectrum of the GaAs alloy indicates main planes of GaAs alloy at (111), (220) and (311) direction which reflected at Braggs' angles (27.24o), (45o☐ and (53.3o) respectively, and coincide exactly with that of the ASTM, similar results have been found by Razooqi [8]. The X-ray diffraction of all prepared GaAs films without and with irradiation process is amorphous structures similar structure has been found by [9].
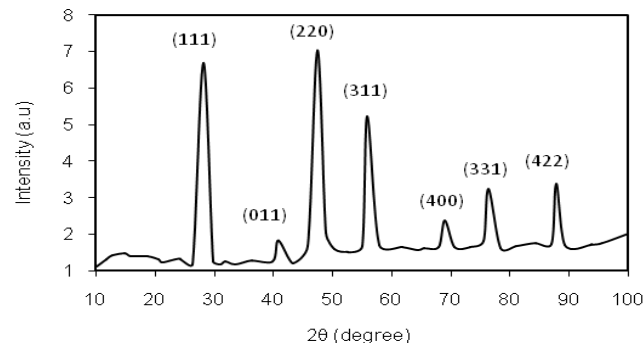
Figure 2: X-ray diffraction spectrum GaAs alloy.

The absorbance spectra of GaAs thin films for as deposited and irradiated films are shown in figure 3. It can be observed that the absorption edge shift toward the longer wavelengths (red shift) after irradiation process with respect to the as deposited film.
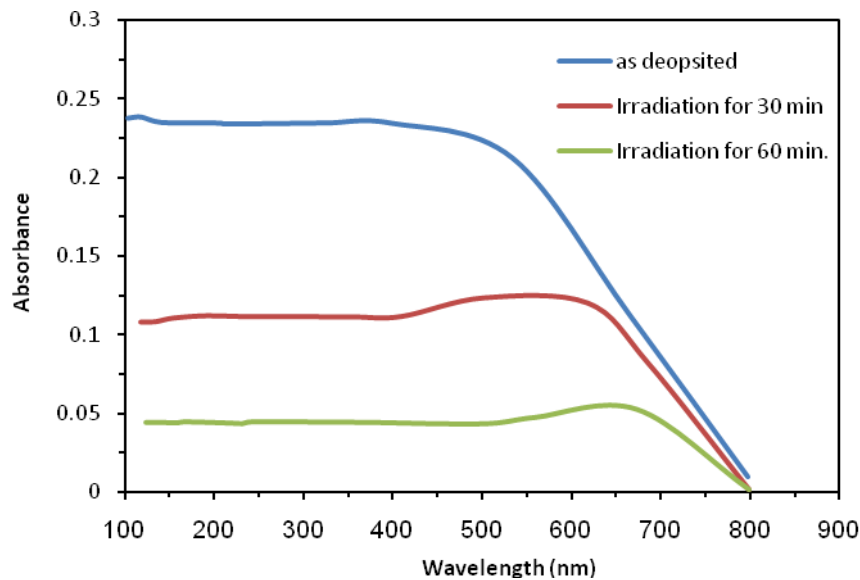

Figure 3: The absorbance spectra as a function to wavelength for as deposited thin GaAs films and irradiated films at different duration times

The absorption coefficient (α) can calculated from the relation [11]:

$$\alpha = 1/t \ln (1/T) \tag{5}$$

Where t is the sample thickness and T is the transmittance. One can observe from figure 4 that GaAs films exhibits a strong absorption of photons at the short wavelength region within the range 100-600 nm. In the strong absorption region, the absorption coefficient takes higher values up to cut off wavelength (λ_{cutoff}) at the absorption edge. The values of the absorption coefficient are tabulated in Table 1.Then after this region, the absorption coefficient is slightly decreased with increasing of the wavelength. On the other hand, the value of the absorption coefficient for GaAs films at the absorption edge has decreased slightly after irradiation process by factor of about 4 from $0.49\times10^4 cm^{-1}$ to $0.12\times10^4 cm^{-1}$, this slightly decreasing

may be due to structural improvement . The optical energy gap (E_g) has calculating using the following relation [12]:

$$\alpha = A(h\nu - E_g)^n / h\nu \qquad (6)$$

Where A is constant, hν is the photon energy and n is constant equal to 1/2 for allowed direct transition. The values of energy gap estimated from the extrapolation to zero absorption in this equation. Figure 4 showed the variation of $(\alpha h\nu)^2$ with photon energy for GaAs thin film. The variation of E_g is tabulated in Table 1. The direct optical energy gaps of GaAs films were estimated to be 1.78 eV for the as prepared decrease to 1.52 eV after irradiation process. Our results are nearly in agreement with Razooqi [8], Baker et al [13]. The decreasing of E_g after irradiation process is probably due to irradiating effect which may have lower density of crystalline defect [14].

The values of refractive Index (n), extinction coefficient (k) and dielectric constant (real (ε_r) and imaginary (ε_i) parts) can be calculated from the following equations [15]:

$$n = [(4R/(R-1)^2) - k^2]^{1/2} - [(R+1)/(R-1)] \qquad (8)$$

$$k = \alpha\lambda/4\pi \qquad (9)$$

$$n^2 - k^2 = \varepsilon_r \qquad (10)$$

$$2nk = \varepsilon_i \qquad (11)$$

Where R is the reflectance and λ is the wavelength of the light. The values of refractive Index (n), extinction coefficient (k) and dielectric constant (ε) for GaAs films at cut off wavelength are tabulated in Table 1.
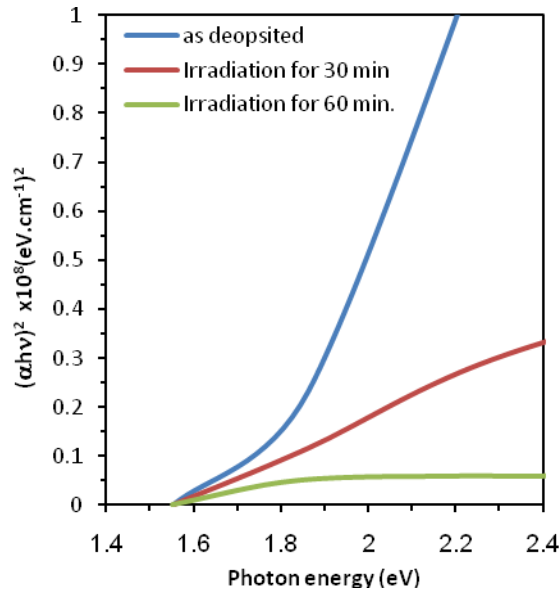

Figure 4: The plot of $(\alpha h\nu)^2$ versus photon energy for thin GaAs films and irradiated films at different duration times.

It can see that they decrease after irradiation process, similar data has been observed by M. Razooqi [8]. The variation of real and imaginary part of dielectric constant respectively for GaAs films respectively.

The behavior of εr is similar to refractive index because of the smaller value of k2 comparison to n2, while εi depends mainly on the k values, which is related to the variation of absorption coefficient. For GaAs films, it is found that both εr and εi decreased after irradiation process.

Table 1: Cut off wavelength, Absorption coefficient, optical energy gap, refractive index, extinction coefficient and the dielectric constants of GaAs thin films.

Treatment	λ_{cutoff} (nm)	$\alpha \times 10^4$ (cm^{-1})	E_g (eV)	n	K	ε_r	ε_i
As deposited	534.145	0.489	1.78	2.434	0.021	5.926	0.101
30min. Irrad.	617.808	0.276	1.54	2.069	0.013	4.283	0.056
60min. Irrad.	673.293	0.121	1.52	1.659	0.006	2.754	0.021

IV.   Conclusions

The X-ray diffraction of the as prepared and irradiated GaAs films by continuous Ar+ ion laser with power nearly 120 mW for different duration times are amorphous structure. After irradiation for 60 minutes a peak of transmittance spectrum of FTIR spectrum appeared at 38 μm wavelength, also a slightly difference between the spectrum of as deposited and irradiation GaAs films for 30 minutes. The absorption edge shift toward the longer wavelengths (red shift) after irradiation process with respect to the as deposited film, the value of the absorption coefficient for GaAs films at the absorption edge has decreased slightly after irradiation process by factor of about 4. The direct optical energy gaps of GaAs films were estimated to be 1.78 eV for the as prepared decrease to 1.52 eV after irradiation process.

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