Fabrication of Laser Detectors using Ge wafer Doped with Sb

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Abstract

Germanium antimony (Ge:Sb) thin films have been fabricated by thermal evaporation system deposition at atmospheric pressure between ($5.8x10^{-6}$ to $7.5x10^{-6}$) mbar. The (Ge:Sb) thin films then exposure to Nd:YAG laser with 1064µm wavelength at different energy densities (100,200) mj/cm^2. XRD analysis show that Germanium antimony thin films are polycrystalline and the full width at half maximum (FWHM) increase as laser energy densities increases. Photocurrent and quantum efficiency of the detector increases as the laser energy densities increases.

Keywords: Germanium, Antimony, thin films, Nd:YAG laser.

Introduction

The ability of germanium oxide glasses and germanium metal to transmit near-IR radiation in the 1600 to 1800nm range has long been applied in night vision systems of the passive kind. Germanium is readily machinable into IR windows and lenses, and its high refractive index and low chromatic dispersion allow the use of simple, sometimes uncorrected, lenses in IR imaging systems. In addition, germanium is mechanically strong, hard, and has good thermal conductivity valuable properties for imaging devices, most of which are employed for military or security surveillance purposes and subject to rough use in harsh, wide-ranging environments[1] .

In 2009, K.R. Jackman and S.R. Biegalski used different methods and software for predicting Germanium detectors full energy peak efficiencies [2].

Now day Germanium utilized in solar cell for Satellite application or high resistivity material for the fabrication of nuclear radiation detectors [3,4,5].

Experiment

Several step has been used for detectors fabrication.

A. **Etching process**:

Chemical etching technique is used in this work. The slice of germanium is immersed in the etching solution (H_2O: H_2 O_2, 9:1) for several minutes.

B. Thermal evaporation process:

Thermal evaporation system (Edward speedvac unit) is used to deposited different materials on the germanium and antimony surfaces. antimony as ado pant material with 7.31 g/cm^3 was deposited on an the germanium surface with thickness 200nm.

C. Diffusion by using laser Nd:YAG laser

With 1064µm wave length at different energy densities (100,200) mj/cm^2 is used to diffused the antimony inside the germanium crystal with 10 laser shots.

It is important to remove the excess dopant material from the surface of Ge and Sb thin films the dopnt material (antimony) has a certain reflection transmutation and absorption coefficients which different from chemical solution which is consists of HNO_3 and H_2O and HCL (1:1:1) and deposited by aluminum mask with high pure purity (99%) in order to used as an electrode Cutting germanium and antimony to small pieces with different area, each piece was fixed on a slide of glass and connected with copper wires

Results and Discussion

X-diffraction anlysis(XRD)

Take the X-Ray diffraction (X-RD) (shimadzu) is used to study the crystal structure of pure germanium thin film and germanium (Ge)doped with antimony (Sb)thin films XRD analysis of Ge films is a single crystal since one peak was found 10 coated at ($2\theta=53.28^0$) belong to Ge(232). Fig.(2) shows two different peaks belong to Ge and four different peaks belong to Sb. This figure indicates the Ge:Sb thin films by thermal evaporation process are polycrystalline structure.

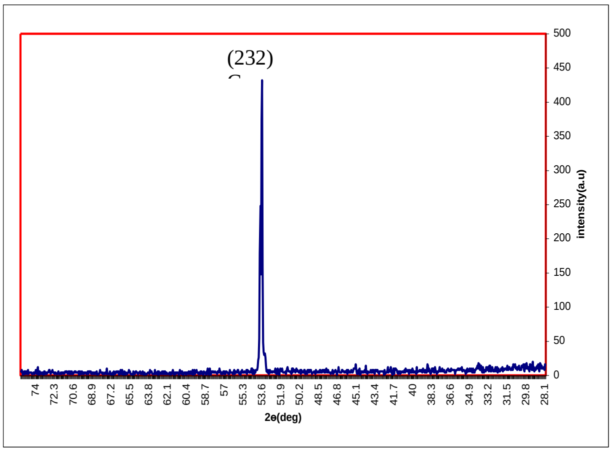

Fig.(1): XRD analysis for pure germanium.

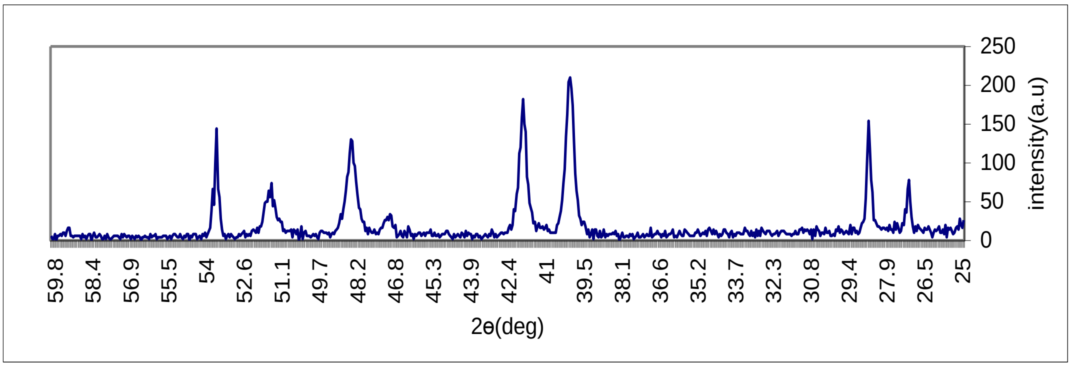

Fig.(2): XRD analysis for germanium wafer doped with antimony.

Also the gains size and the lattice constant were near calculated from Scherer equation are show in Table (1).

Table (1)
The obtained results from XRD for germanium doped with antimony.

sample	2θ	hkl	d (A^0)	Lattice Constanta (A^0)	FWHM Degree
Ge	53.67^0	131	1.7058	4.6414	0.1000
Ge	27.12^0	313	1.4600	6.9601	0.25230
ASTM Ge	**53.285^0**	**131**	**1.7103**	**5.014**	**0.10530**
Sb	28.64	107	1.4757	9.2634	0.25620
Sb	40.10	122	1.3653	10.9841	0.36000
Sb	41.91	012	3.1050	11.7549	0.33410
Sb	48.47	202	1.7675	5.3077	0.15000
Sb	51.59	205	1.8753	7.8265	0.39170
Sb	59.37	208	1.0749	12.0636	0.13340
ASTM Sb	**41.94**	**012**	**3.1090**	**11.7330**	**0.3290**

X-RAY diffraction analysis of Ge:Sb thin film exposure to Nd:YAG laser with 1064 nm energy density (100,200) mJ/cm^2 as shown in Fig. (3).

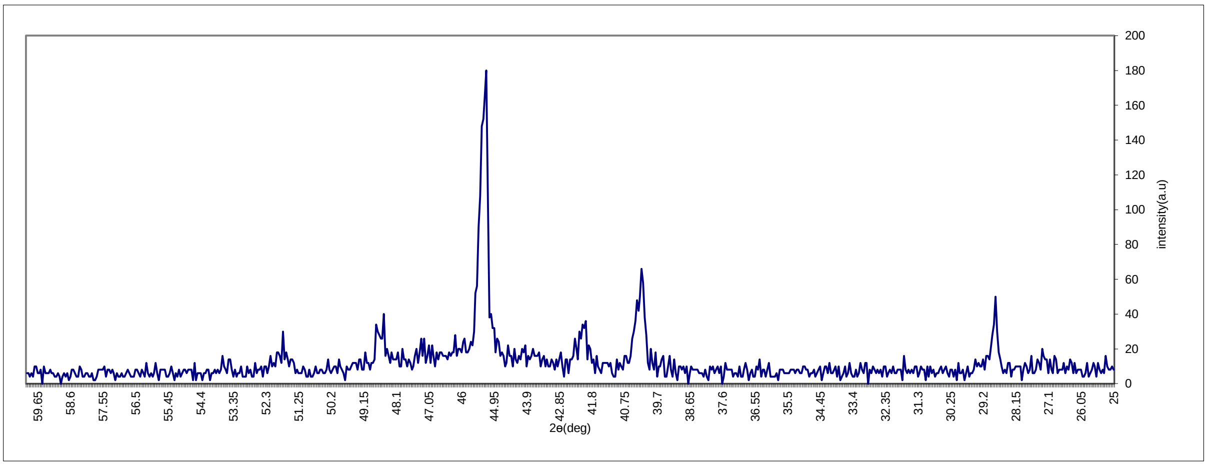

Fig. (3): X-Ray analysis for germanium wafer doped antimony using Nd:YAG laser energy density (100mJ/cm^2).

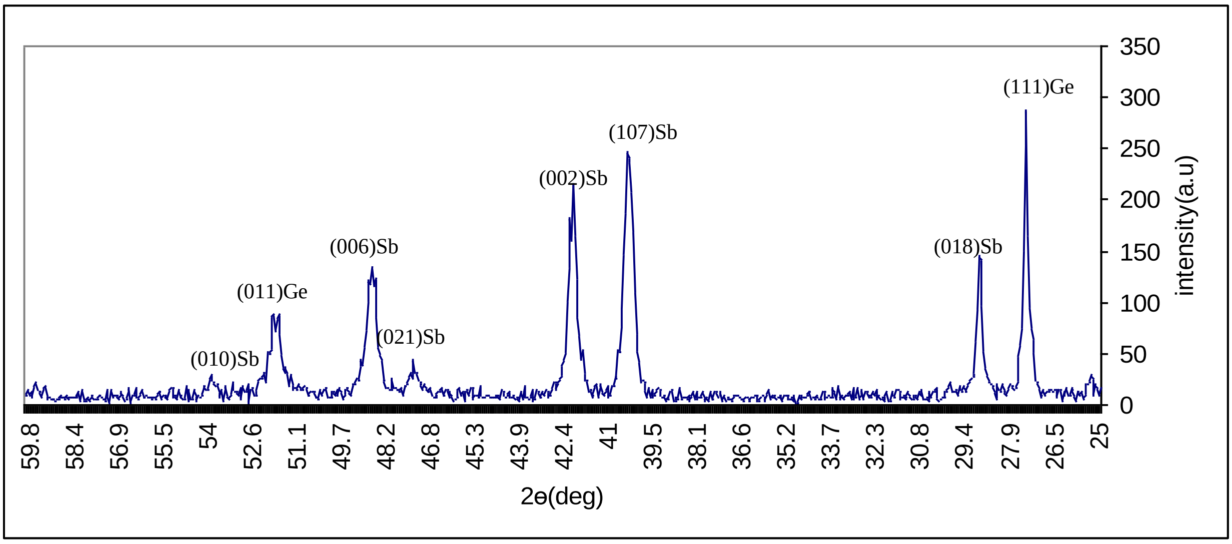

Fig. (4): X-Ray analysis for germanium doped with Sb at energies (200 mJ/cm^2).

The Nd:YAG laser (λ=1064 nm) with different energy density (100m J/cm^2 and 200mJ/cm^2) used to diffused the Antimony inside the germanium samples and the results of XRD analysis for germanium doped with Antimony can be shown in Fig.(3) and Fig.(4). Fig.(3) show the XRD analysis for germanium sample after doped with antimony using Nd:YAG laser (λ=1064 nm, energy density 100m J/cm^2). At The grain size can be calculated by using equation and has a value of (20.58) Å

$$g_s = \frac{\kappa\,\lambda}{B\cos\theta}$$

Where B is the broadening solely due to small crystallite size, κ is a constant whose value depends on particle shape and usually taken as 1; θ the Bragg 's angle, λ is a wavelength of incident X-ray beam [6].

While for energy density 200m J/cm^2 as shown in Fig.(4), The grain size can be calculated by using equation and has a value of (26.38)Å.

Current-Voltage (I-V) curves are the most commonly used characterization tool for photovoltaic devices. In this technique, the current is measured as a function of voltage of the Ge:Sb detectors, in both light and dark. Fig.(5) shows the current and voltage in the reverse bias at dark condition, under reverse bias voltages larger than 6 Volts, tunneling current becomes dominant, in addition to increasing the balk diffusion current which is due to cattier generation- recombination outside the depletion region and surface diffusion current. Therefore, the current increases with increasing the bias voltage and increasing the projected energy we use (I_d = I dark) as shown in Fig.(8).

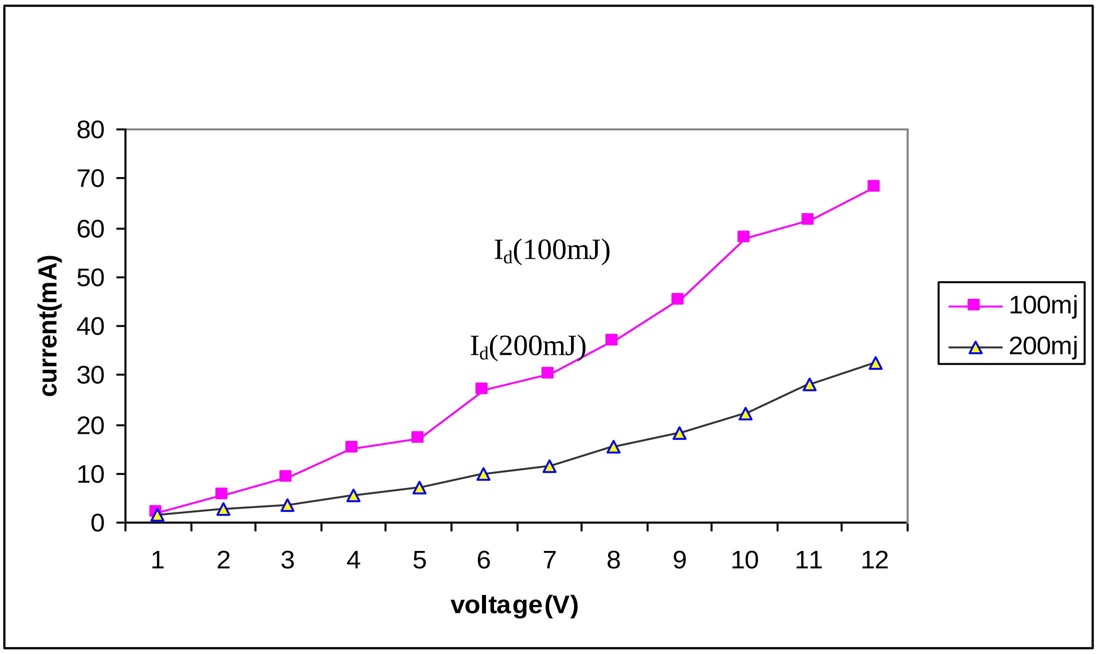

Fig.(5): Current-voltage for Ge:Sb detectors in dark at laser density (100/200mJ).

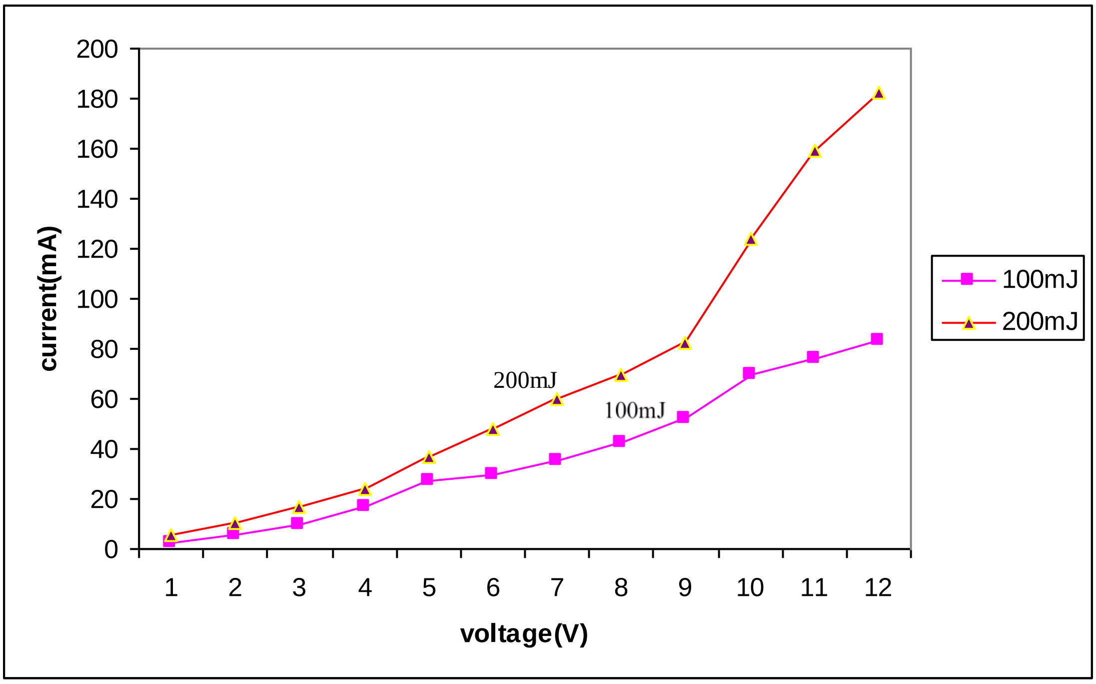

Fig.(6): Current-voltage Ge:Sb detectors illumination(100/200mJ).

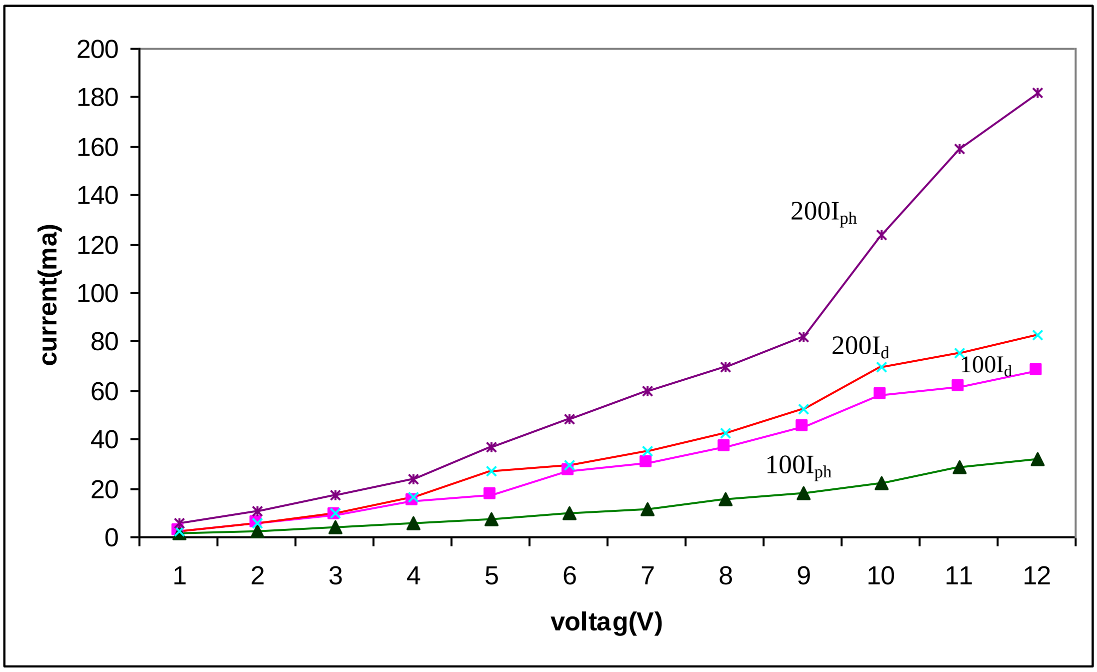

Fig.(7): Current –Voltage for Ge:Sb detectors.

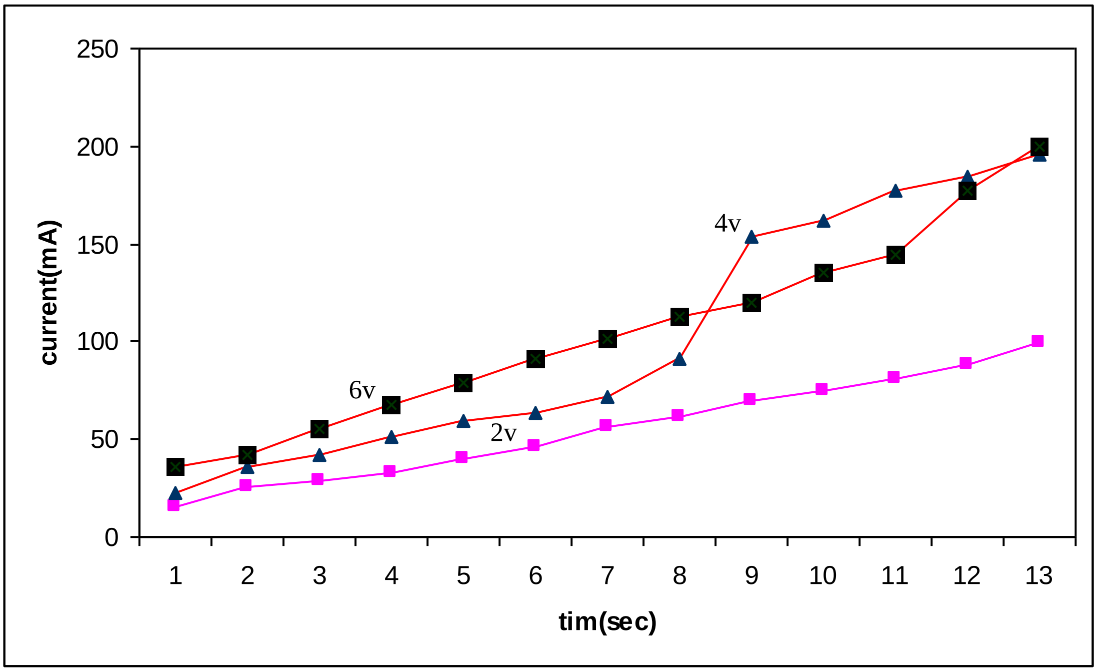

Fig.(8): Current-time character tic for Ge:Sb detectors under illumination using laser energy (100/200mJ/cm^2) at fixed bias voltage (2V,4V,6V).

Fig.(8) shows the relationship between the photocurrent and the time of sample exposure to CO_2 Laser beams in reveres bias voltage. It is noticed that the photocurrent increases with increasing the time of sample exposure to CO_2 Laser beams, due to the increasing in the number of the generated photo carriers in the depletion region. The photocurrent increases with increasing of projecting energy due to the diffusion depth for carriers. Figs. (9) and (10) show the relationship between the voltage and the temperature for germanium and Antimony samples.

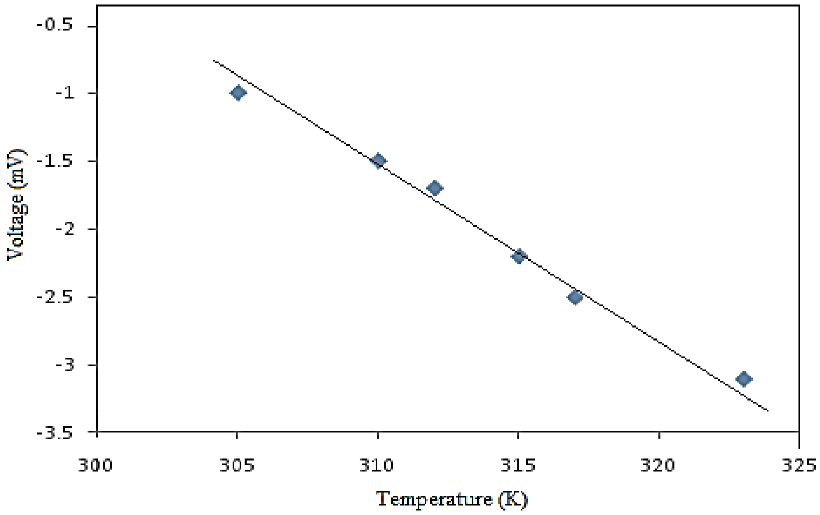

Fig.(9): Voltage as a function of temperature for Ge:Sb detectors laser density (100mj/cm^2).

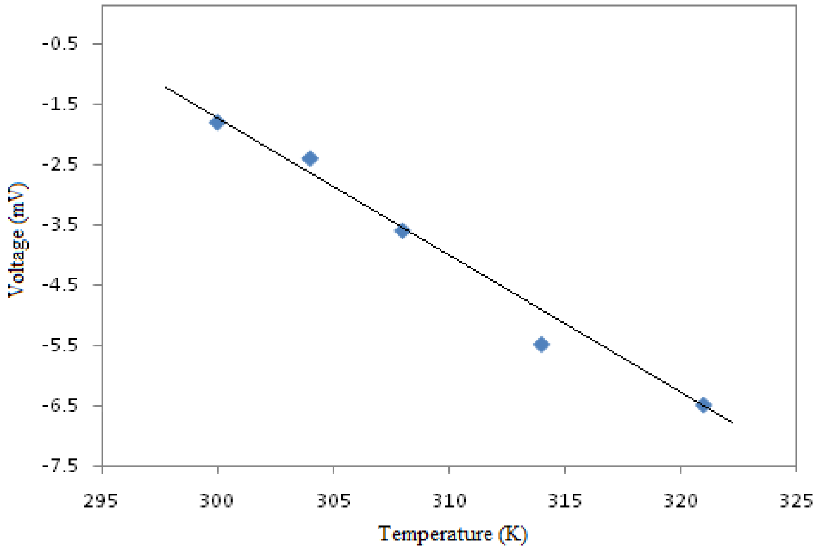

Fig.(10): Voltage as a function of temperature for Ge:Sb detectors laser density (200mj/cm^2).

The values of quantum efficiency, spectral responsively, noise equivalent power, and directivity are calculated. For germanium detectors. These results can be shown in Table (2).

Table (2)

The values of detectors area, noisecurrent, quantumefficiency, spectral responsively, noise equivalent power, detectivity, and normalized detectivity for Ge detectors.

Detectors	**Detector area cm^2**	**Noise current A**	**Quantum efficiency (%)**	**Spectral responsivity A/W**	**NEP W**	**Detectivity W^{-1}**	**Normalized detectivity cmH$^{1/2}$W^{-1}**
Germanium detector doped with antimony usig laser energy 100mJ	0.15	031*10^{-10}	3.81	32.98*10^{-6}	28*10^{-7}	0.35*10^{9}	0.185*10^{9}
Germanium detector doped with antimony usig laser energy200mJ	0.25	1.01*10^{-10}	4.21	35.98*10^{-6}	27.5*10^{-7}	0.36*10^{9}	0.19*10^{9}

The results in Table (2) were taken using CO_2 laser which has a wavelength 10.6µm and power 0.8W, this type of laser is used because all detectors it work in the range (5-25)µm which the best absorption occur in this region. The area of the detectors are affected on the behavior of detectivity and it is clear from Table (2) that the noise current increases with increasing the detector area. The increasing of detector area causes decreasing in its resistance i.e increasing the output current which consists of dark current and photocurrent (at constant reverse bias voltage). In dark conditions the photocurrent equal zeo so the increasing of area causes increasing in dark current and consequently noise current. The increasing of laser energies which are used to diffused the antimony inside the germanium samples produces increasing in crystalline defects which ply a great role in increasing the amount of noise current, so the increasing of laser energy is another factor which causes the decreasing of the detectivity.

Conclusion

From the results of the fabricated detectors and measurements it can be concluded the following:

1- The doping process for Ge wafers in Antimony Sb compound leads to increasing the full width of half maximum of a curve X-ray diffraction, which means a decrease in d-spacing between the surfaces of crystalline.

2- All fabricated detectors works in the range (5-25) µm and it can be detect the wavelength for CO_2 laser.

3- Increasing the projecting energy leads to the increase of the absorbance as well as the absorption coefficient.

Acknowledgements

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الخلاصة

في هذه الدراسة، حضرت أغشيه الجرمانيوم المشوبة بالانتموني في منظومة الترسيب التبخير الحراري عند ضغط جوي $(5.8\times10^{-6}-7.5\times10^{-6})$ ملي بار. عرضت الاغشية لليزر نيدميوم ياك ذي الطول الموجي 1064 نانو متر عند كثافة طاقات ليزرية مختلفة (100 و 200) ملي جول/سم^2.

اظهرت النتائج تحليل حيود الاشعة السينية ان الاغشية جميعها متعددة التبلور. ان زيادة طاقة الليزر تودي الى زيادة FWHM.

ان تيار والكفاءة الكمية للكاشف يزداد بزيادة كثافة طاقة الليزر.