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Study of Optical Properties of HgTe Films

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Abstract:

Alloy of (HgTe) has been prepared succesful in evacuated qrtz ampoule at pressure 4×10^{-5}torr, and melting temperature equal to 823K for five days. Thin films of HgTe of thickness 1μm were deposited on NaCl crystal by thermal evaporation technique at room temperature under vacuum about 4×10^{-5}torr as well as investiagtion in the optical porperties included (absorption coefficient , energy gap) of HgTe films and The optical measurements showed that HgTe film has direct energy gap equal to 0.05 eV.

The optical constants (n, k, ε_r, ε_i) have been measured over will range (6-28)μm.

دراسة الخواص البصرية لأغشية **HgTe** الرقيقة

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الخلاصة:

تم تحضير سبيكة HgTe بنجاح في أنبوبة مفرغة من الكوارتز بضغط 4×10^{-5}torr والتي صهرت ألي درجة حرارة تساوي 823K لمدة خمس أيام.

رسبت أغشية بسمك 1μ على بلورة NaCl بتقنية التبخير الحراري عند بدرجة حرارة الغرفة وتحت الضغط الواطئ 4×10^{-5}torr. من خلال دراسة الخواص البصرية والتي تضمنت (فجوة الطاقة، معامل الامتصاص) وجد أن لأغشية HgTe فجوة طاقة مباشرة تساوي 0.05 eV. تم حساب الثوابت البصرية (معامل الانكسار n، معامل الخمود (k)، ثابت العزل الحقيقي (ε_r) وثابت العزل الخيالي (ε_i).

Introduction

Studies of the optical properties, particularly absorption spectra of (HgTe) polycrystalline have not been very popular [1-4].

Mercury tellaride (HgTe) alloys has been the subject of much reseach interest it is an important for infrared detector applications , two main reasons for the interest in this alloys system are (1) It is scientifically interesting because it consists narrow gap a semimetal or negative gap semiconductor (HgTe); (2) It is technologically interesting designable wavelength response [5].

The values of the energy gap (E_g) in HgTe is accurately Known from experimental.

Much research efforts has been focused primarily [6] on the properties of HgTe films very little attention was paid to its thin films optoelectronic properties particularly on the understing of HgTe films.

This paper presents the results of measurements of the absorption coefficient and optical constants of Hate films for the composition x=0.5 optical properties analyzed by Fourier transformer infrared radiation (FT-IRE) spectrophotometer was used for carry out the absorption and transmittance spectrum.

The fundamental absorption edge in the most semiconductors components follows the exponential law.A bove the exponential tails, the absorption of semiconductor has been observed to obey the Tauc equation [7].

$$\alpha h\upsilon = \mathrm{A}(h\upsilon - E_g \ )^{r}. \qquad (1)$$

Where $(\alpha h\upsilon)$ is the absorption coefficient of angular frequency of $\omega = 2\pi\upsilon$, A is aconstant and r is an index which can be assumed to have values of 1/2, 3/2 , 2, and 3, depending on the nature of electronic transition responsible the absorption. r=1/2 for allowed direct transition, r=3/2 forbidden direct absorption, and r=3 for forbidden indirect transition.

The study of the optical constants of materials is interesting for many reasons.

First the use of materials in optical fibers and reflected coating requires accurate knowledge of their optical constants over wide ranges of wavelength.

Second the optical properties of all materials are related to their atomic stucture , electronic band structure and electrical prperties.

Experimental

High purity (99.999) Hg and Te in appropriate proportions were weighted in to a quartiz ampoula (17 length), which mixed from the exact stoichimetric ratio of Hg and Te elements according to the relative atomic weight of the element.The contents of the ampoule (5gm total) which was attached to the evacuated system. when the pressure reashed (4×10^{-5} torr) the ampoule was sealed, then the evacuated ampoule which contained HgTe was placed in an electric furnace of (Heraeni) heated slowly to a temperature of (823 k) which is above the melting point of Hg (189.18 k),Te (710 k) and HgTe alloy (823k) depending on the phase diagram of HgTe system [7]. The ampoule has been kept at this temperature to five days [8], thrugh the heating period; the ampoule is rocked several times to get well homogenous mixture.Aftere that the alloy was cooled slowly from (823k) to room temperature in order to prevemt the explosion which is caused from mercury vapor pressure.

The optical absorption and transmition data were obtained using FT-IR spectrometer. The measurments were carried out in wavelength in the range (6-28)µm. All the optical measurments were carried out at room temperature.

Result and discussion

The Variation of the absorption spectra as a function of wavelength as shown in Fig.(1). It is found from this figure that the absorption decreases with increasing of the wavelength for HgTe film.

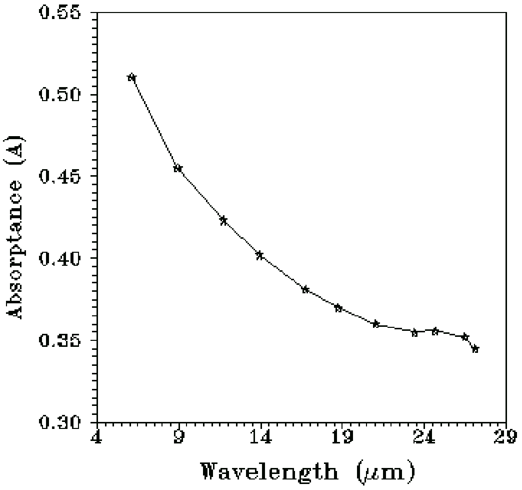

Fig. (1) The variation of the absorption as a function of wavelength for HgTe film.

The energy gap:

From the Tauc equation. (1) and the shape of absorption curve near the band edge, it is possible to determined the optical energy gap of (HgTe) films by plotting $(\alpha h\upsilon)^{1/r}$ where r= (1/2,2,3/2,3) as function of photon energy for points including both high and low absorption. We examined $(\alpha h\upsilon)^{1/r}$ versus photon energy and selected the optimum straight line fitting that was consistent with the dependence of $(\alpha h\upsilon)^{1/r}$. This is considered a direct electronic transition.

Fig.(2) shows the relation between $(\alpha h\upsilon)^2$ and (hυ) for HgTe film at thickness 1.0μm. This figure shows the linear relation obtained for higher values of the absorption satisfied by Tauc formula .The nature of absorption curve is found to be identical to that of the element poly crystalline semiconductor. It is found that the value of the energy gap equal to 0.05 eV at $\lambda_{\text{cut off}}$ = 24μm.

The behavior of the optical gap shown by HgTe film in the range of photon energy (0.203-0.041)eV studied here can explained on the bases of chemical bonding and change in the long range order.

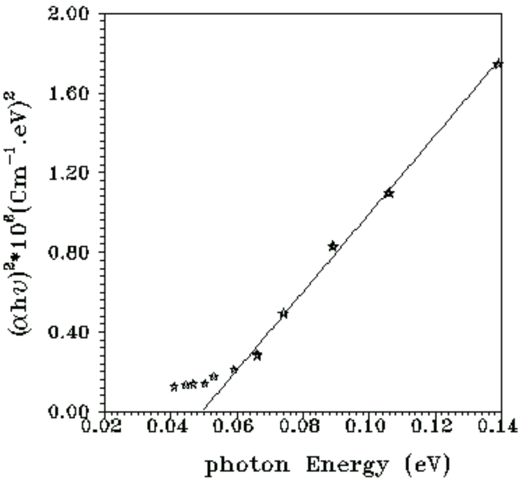

Fig.(2) shows the variation of $(\alpha h\upsilon)^2$ with photon energy for HgTe film.

The absorption coefficient

Our main objective was to determined the absorption coefficient, as accurately as possible.

The absorption coefficient α was calculated from the expression[8]

$$\langle T\rangle = \frac{(1-R)^2 \exp(-\alpha d)}{1-R^2\exp(-2\alpha d)} \qquad (2)$$

Where <T> is the average value of the transmission, d is the ampule thickness, and R is the reflection coefficient , the reflection coefficient R was calculated from the index of refraction , using the expression [9].

$$R=\left(\frac{n-1}{n+1}\right)^2 \qquad (3)$$

Fig.(3) shows the dependence of the absorption coefficient of HgTe films as a function of wavelength in the range of (6-27) μm at room temperatur.

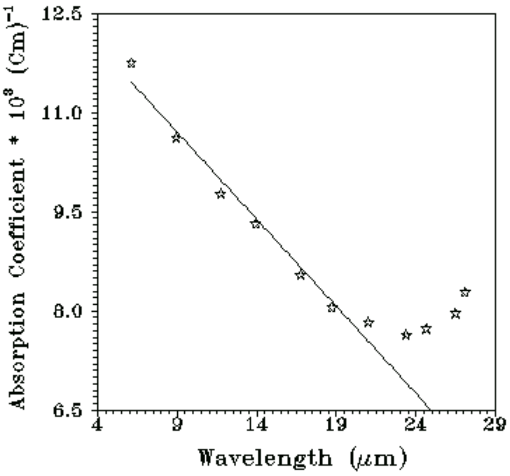

Fig.(3) The variation of the absorption coefficient as a function of wavelength for Hate film.

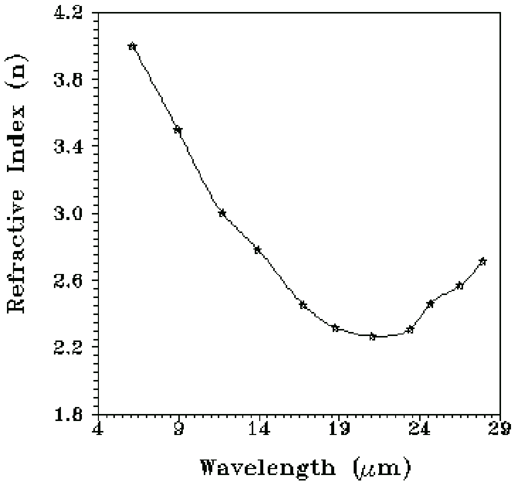

Fig.(4) The variation of the refractive index as a function of wavelength for Hate film.

The refractive index

The usual procedure of obtaning the index of refraction from the interference patterns. The refractive index was approximated using

$$n = \frac{1}{2d\Delta\nu} \qquad (4)$$

Where (Δv) is the average energy spacing in wavenumber between interference frings, and d is the sample thickness .

This value helped determined thre frings order (m) which used to calculate n from:

$$n = \frac{m\lambda}{4d} \qquad (5)$$

where m is even for masimum and odd minimum.

Fig.(4) shows the dependedece of the refraction of index on the wavelength for HgTe films.

We can see from this figure that the refractive index decreased with inecreasing of wavelength .

The extinction coefficient

The radiation absorption occurs in the media then the intensity of the radiation is generally attenuted in exponential form of the type $e^{-\alpha t}$ where α is related to the imaginary part of the refractive index called extiction coefficient which can be calculated by the relation:

$$k = \frac{\alpha\lambda}{4\pi} \qquad (6)$$

The behavior of the extinction coefficient of HgTe film as a function of wavelength is shown in Fig.(5) .It is seen from this figure that *k* decreased with inecrasing of wavelength.

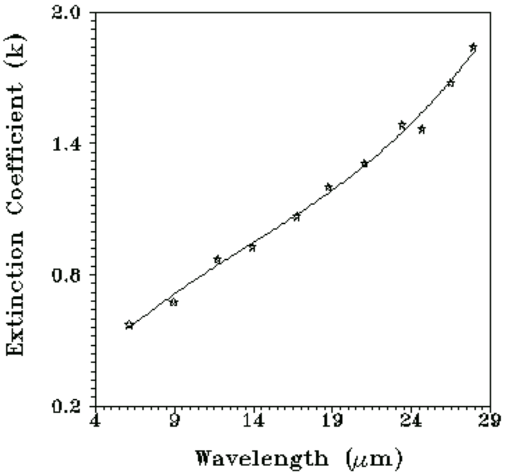

Fig.(5) The variation of the extinction coefficient as a function of wavelength for Hate film.

The Dielectric constant

The dielectric constant consist of real part (ε_r) and imginary part (ε_i) which dependend on the frequency of the electromagnetic waves.

Figs. (6, 7) show the variation of real and imaginary parts of dielectric constant as a functon of wavelength for HgTe film.

We can observed from these figure that the variation of ε_r has similar trend to the variation of (n) because of smaller value of k^2 in comparion with n^2 where ($\varepsilon_r=n^2-k^2$), while the variation of ε_i mainly depends on the variation of *k* values which are related to the variation of α..

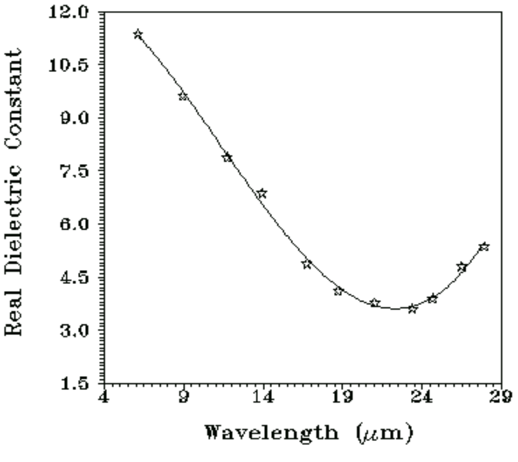

Fig. (6): The variation of real part of dielectric constant as a function of the wavelength for HgTe film

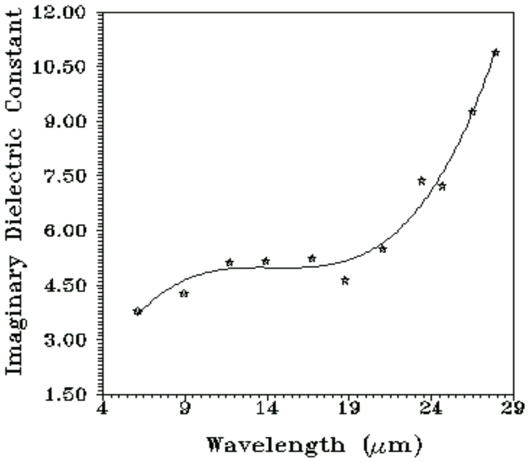

Fig. (7): The variation of imaginary part of dielectric constant as a function of the wavelength for HgTe film

Conclusion

1- The optical properties (energy gap, absorption coefficient) and optical constants (n, k, ε_r, ε_i) have been measured in the range of (6-28) μm
2- From the FIR transition and absorption spectra we found the absorption decreases with increasing the wavelength.
3- The optical transition in the HgTe films is observed to be alowed direct transition.
4- The refractive index decreases with increasing the wavelength,while the extinction coefficient increases with increasigthe wavelength.The variation of the real and imaginary part of the dsielectric constants have similar trend as for the (n) and (k).

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