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THE ROLE OF DEPOSITION RATE ON THE ELECTRICAL CONDUCTIVITY AND ENERGY GAP OF (a–Ge) THIN FILM

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Abstract

The films of amorphous germanium (a–Ge) were prepared by evaporation under high vacuum conditions (10^{-6}) torr. The influence of various deposition rates within the range(2 – 10)Å/sec on the dc electrical conductivity ($\boldsymbol{\sigma}_{RT}$) and energy gap (E_g).

The temperature dependence of conductivity for various deposition rates recorded in the range (303 – 503)K consist of two conduction regions within the temperature range (303–413)K and (413–503)K.

From the absorbance spectrum E_g (energy gap) were obtained according to Tauce formula. It is found that E_g decreases from 1.08eV to 0.91eV when the rate of deposition increase from (2 – 10) Å/sec while the electrical conductivity ($\boldsymbol{\sigma}_{RT}$) increases from $1.28\times10^{-4}(\Omega.cm)^{-1}$ to $11.53\times10^{-4}(\Omega.cm)^{-1}$ respectively.

Introduction

Amorphous germanium has received relatively much less attention than the crystalline type because of the latter's greater technological importance. It has, however, been the subject of a number of investigation into it's structural, optical and electrical properties, because of the information it can contribute to understanding of other amorphous material more complex in molecular structure. Theoretical studies of amorphous semiconductors indicate that even though long-range order is not preserved, as long as the molecular bonds are not significantly disturbed, an energy band model is still applicable.(1)

The variability with preparation condition of most of the physical properties of amorphous Ge and Si films has for sometime been related to the presence of structural defects of variable nature and density in real amorphous networks. (2,3) These defects are expected to create large potential fluctuations which would essentially be responsible for high density of the localized states in the energy gap between the conduction and valence bands. Defects have generally been associated with the notion of dangling bonds, which may occur during the film formation when the local bonding requirements can not be fulfilled(2). There was submitted for consideration the influence of the technological parameters on the properties of the evaporated and sputtered amorphous germanium layers. The effect of the substrate temperature, residual atmosphere, annealing as well as influence of the material parameter seems to be the deposition rate, it influence on the electrical conductivity and optical energy gap of the evaporated (a–Ge) layers. (4-7). The temperature dependences of the conductivity is approximated by the expression(8):

$$\sigma = \sigma_0 \exp\left(-\frac{E_a}{KT}\right) \quad (1)$$

Where σ_0 is the y-axis intercept for finite temperature, E_a is the activations energy c, and T is the absolute temperature.

The optical absorption $\alpha(h\nu)$ of a-Si or a-Ge falls in three regions (9,10).

1. High absorption region. The interband phonon absorption has the highest absorption value ($\alpha \geq 10^4$ cm^{-1})and can be described as:

$$\alpha(h\nu) = \frac{B(h\nu - E_g)^2}{h\nu} \quad (2)$$

   where α is the absorption coefficient, E_o is the optical band gap, and B is constant. The absorption in this region is considered to be due to transition from the top of the extended states in the valance band to the extended states in the conduction band.
2. Exponential region. This region is supposed to be due to transitions from the

extended states at the top of the valance band to the localized states at the bottom of the conduction band and also to transition from the localized states at the top of the valance band to extended states in the conduction band.

The value of the absorption coefficient in this region ($1\leq \alpha \leq 10^4$) cm^{-1} absorption coefficient (α) obeys the relation:

$$\alpha = \alpha_0 \exp\left(\frac{h\nu}{\Delta E_e}\right) \qquad (3)$$

Where ΔE_e is the width of the tail states.

3. Weak absorption tail. The absorption coefficient here is very low ($\alpha<1$) cm^{-1}. in this region the transition happened in tail states inside the mobility gap.

The optical absorption spectra of defect states provided information on the energy level and the density of defect in amorphous semiconductor. The defect density was found to be depend on the deposition parameter. [10,11]

The effect of deposition rate on the electrical conductivity and energy gap of (a–Ge) studied by several authors like, S. Koc et al[4], P. A. Wally and A. K. Jonscher[1]), P. A. Wally[6]) and J. C. Bruyer et al[12].

The general object of the presence work was to study the effect of deposition rate on the ($\boldsymbol{\sigma}_{RT}$) and (Eg) of (a–Ge).

Experimental Details

Layers of amorphous germanium (a–Ge) were prepared by evaporation of Ge grains from tungsten boat on the glass slides (substrates at room temperature (303K)). Deposition was carried by vacuum system (type Edwards, E 306 A) at vacume condition $(4\text{-}2)\times10^{-6}$ torr. The glass substrates was cleaned carefully with non – organic substance and rinsed with distilled water, then dried . The distance between the vapor source and substrate was 15cm. Thickness of (a–Ge) films (5000±200) Å were measured by using a multiple beam interferometer method. Deposition rates were taken within the range (2 – 10) Å/sec.

Electrical measurements were made on films deposited on a glass substrate at room temperature with aluminum electrodes prepared by evaporation. Electrical connection were attached with silver paste and the sample were mounted in oven.

We used ,power supply PE 1540 DC 40 v-3A ,Keithely 616 Digital electrometer, digital thermometer (273 – 737) K and electrical oven for dc – conductivity measurement .

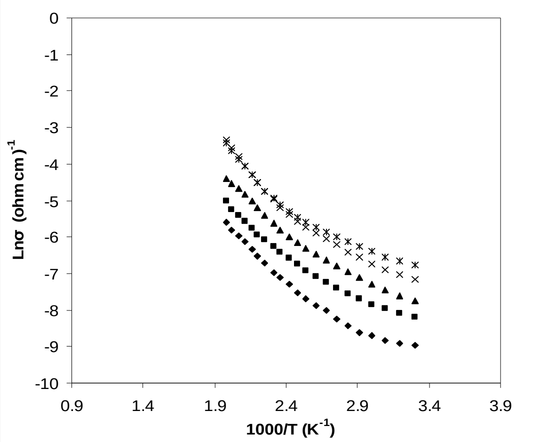
Measurements of temperature dependence were carried out in the temperature range (303–503)K. From the plotting between the conductivity, σ against 1000/T, we calculate the activation energy by using equation (1).

From optical measurement we used the device type Prekin – Elmer Lambda 9 UV/ VIS/NIR spectrophotometer for obtain the change in the absorbance (A) of films as a function of wavelength. The optical energy gap obtained by using Tauc's [11] analysis from linear extrapolation of a plot of $(\alpha h\upsilon)^{1/2}$ against (hυ). Where hυ is the photon energy.

Results and Discussion

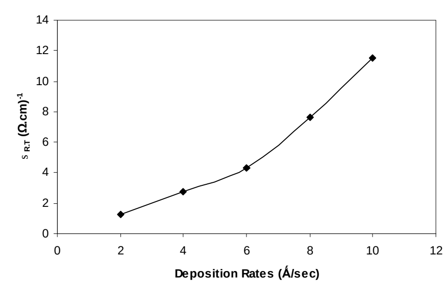
Results of our measurements of the electrical conductivity and optical energy gap (at room temperature) as function of deposition rate are summarized in the figures.

In Fig. (1) the temperature dependence of the electrical conductivity of (a–Ge) layers deposited with different rates (2,4,6,8 &10) Å/sec. As it is usual for (a–Ge) this dependence in lnσ against 1000/T coordinates. The curves are shifted to the lower values of conductivity with decreasing deposition rate and exhibit an increasing the slop in the higher temperature region (303-503)K. Fig. (1) shows two different regions in the temperature range from (303-503)K. In the temperature range from (413-503)K the conduction is due to the transition of carriers in the extended states above the mobility edge for conduction and valance band. While in the range (303-413)K the conduction is due to the excitation of carriers to the extended states near the bands edge a result of carriers hopping between localized tail states near the edge of these states within the range (2-10) Å/sec.

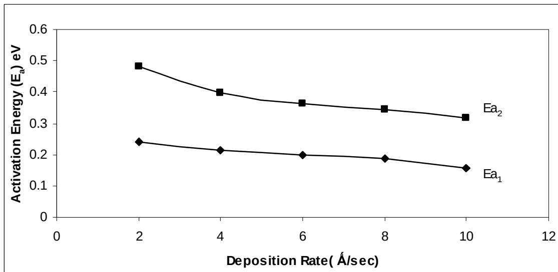


Fig(1) Temperature dependence of Lnσ vs. 1000/T(K-1) for different deposition rate

The effect of deposition rate on (σ_{RT}) and activation energy are summarized in Fig.(2) and Fig.(3) respectively. The electrical conductivity increased from $1.28\times10^{-4}(\Omega.cm)^{-1}$ to $11.53\times10^{-4}(\Omega.cm)^{-1}$ (activation energy decrease from 0.241eV to 0.155eV for Δ T(313-413)K and from 0.483eV to 0.319eV for ΔT(413-503)K) as the deposition rate increase from (2–10)Å/sec. respectively.

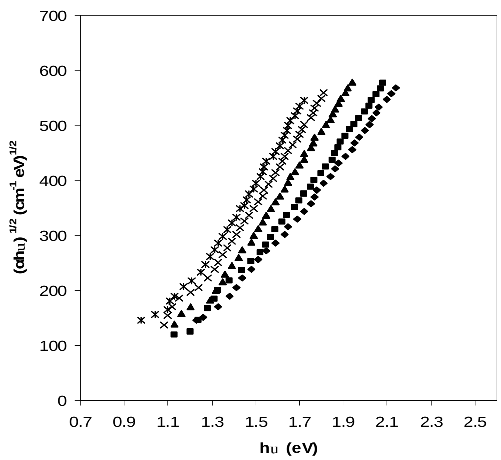


Fig(2) Variation of the electrical conductivity (σRT) vs. deposition rate

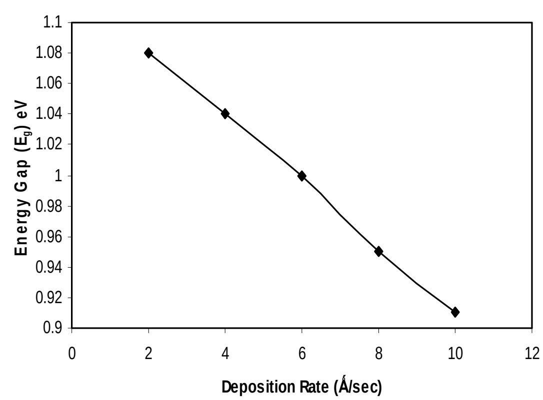


Fig(3) Variation of the activiation energy (Ea) (eV) vs. deposition rate

Absorption edge of (a–Ge) is shifted to the higher energies of incident radiation with decreasing deposition rate as shown in Fig.(4).This shift differs significantly from that caused by high doping. The change of absorption edge that due to the different deposition rate (2-10)) Å/sec are characterized by different values of energy gap as shown in Fig.(5). The energy gap decrease from 1.08eV to 0.91eV as deposition rate increase from (2 – 10) Å/sec.



Fig(4) Plot of (αhυ) 1/2 vs. hυ for variation deposition rate .



Fig(5) Variation of energy gap (Eg) vs. deposition rate

The effect of decreasing deposition rates on the properties of (a–Ge) layers may be due to the inclusion of such amounts of gas in the layers during deposition that the nucleation process is affected, causing more discontinuous structure and hence a higher resistivity[6] Also the increase in the deposition rate leads to increase in the density of evaporated layers of (a–Ge). The increase or decrease in the density was recently associated with the presence of voids in the layer. The presence of voids and the changes of their concentrations must certainly modulate the electrical and optical properties(4). When we take into account the optical absorption or electrical conductivity which would correspond to an equivalent thickness of an ideal amorphous material without the voids. This means that the passive presence of voids alone can not explain the remarkable changes in the electrical and optical properties of layers with the density substantially differing from that found in an ideal amorphous material and, at the same time, substantially different from normal "crystalline" density. However, the voids do influence the properties of surrounding materials. The unoccupied places in an amorphous solid formed by assembly of higher quantity of empty sites produce the interfaces where the dangling bonds can exist and space charge regions with accompanying electrical field can be created(4). This situation displays itself in bending of the bands, but it is simultaneously probable that the atoms in a direct neighborhood of a void are systematically shifted with respect to their equilibrium position, i.e that in the vicinity of a void strong mechanical in homogeneities appear which cause the changes of the conduction-valance band distance (of the gap width)(4).

Conclusions

Substantial changes in the electrical conductivity and the position of optical absorption edge connected with deposition rate were observed on the evaporated (a–Ge).To explain the changes in electrical and optical properties we need in addition to assume active influence of voids on electronic structure of surrounding (a–Ge). This influence may consist in the bending of the bands as well as in the modulation of their energetic distance.

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الخلاصة

درست تاثيرات معدل الترسيب ضمن المدى (2-10)Å/sec لغشاء الجرمانيوم العشوائي المحضر بطريقة التبخير الحراري تحت ضغط فراغ عالي مقداره (10^{-6})torr على التوصيلية الكهربائية المستمرة عند درجة حرارة الغرفة وفجوة الطاقة الضوئية.

من خلال اعتمادية التوصيلية الكهربائية على درجة الحرارة عند معدلات ترسيب مختلفة لمدى (303-503)K حصلنا على منطقتين للتوصيل عند مدى (330-413)K و(413-503)K.

من خلال طيف الامتصاص تم تحديد فجوة الطاقة الضوئية حسب معادلة Tauce، حيث قلت فجوة الطاقة من 1.08eV الى 0.91eV عندما زاد معدل الترسيب ضمن المدى (2-10)Å/sec بينما زادت التوصيلية الكهربائية عند درجة حرارة الغرفة من $1.28\times10^{-4}(\Omega cm)^{-1}$ الى $11.53\times10^{-4}(\Omega cm)^{-1}$ على التوالي.