THE EFFECT OF THICKNESS ON DC CONDUCTIVITY AND OPTICAL ENERGY GAP OF (A–GE) THIN FILM

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Abstract

The films of amorphous germanium (a–Ge) were prepared by thermal evaporation under high vacuum conditions (10^{-6}) torr. The influence of various thickness (1000–5000) Å on the d.c electrical conductivity (σ_{RT}) at 303K and optical energy gaps (Eg) of (a – Ge) was studied.

The temperature dependence of conductivity for various thickness recorded in the range (303–503) K consisted of two regions, medium and high temperature regions. It's found that the results of the energy gap decrease from 1.05 eV to 0.86 eV.as the thickness increase from 1000 Å to 5000 Å respectively while d.c conductivity (σ_{RT}) increase from $3.05\times10^{-4}(\Omega.cm)^{-1}$ to 2.209×10^{-3} $(\Omega.cm)^{-1}$ respectively with the same variation of thickness.

Introduction

The physical properties of amorphous germanium (a–Ge) and amorphous silicon (a–Si) may be divided in two categories: those that do not depend significantly on either thermal history or preparation conditions and those that do. A review of some properties in the former category has been given by Connell(1).The latter category which includes most properties attributed to states in the pseudo gap (1).

The recent widespread interest in amorphous semiconductors has included considerable work on amorphous germanium because it is, in principle, a simpler material than most amorphous semiconductors and has a crystalline analog (2).

Thin films of (a–Ge) and (a–Si) produced by evaporation or sputtering on substrates at room temperature contain structural defects consist of regions of missing atoms called Voids[1]. sometimes the Voids in (a–Ge) are such that the density of the resulting films is about 30% less than of crystalline germanium(C–Ge). Other technological method are less frequently(3) thin films amorphous solid such as (a–Si) and (a–Ge) are often viewed as having relatively constant short range order (4).

The presence of these voids and other defect during growth gives rise to the states in the pseudo gap and these have a great affects on the properties such as low temperature d.c transport and low level optical absorption(5). Electrical and optical properties of (a–Ge) deposited by evaporation techniques have been reported by several authors(6). In comparison with crystalline material, sensitivities are higher, densities are lower and there is no definite absorption edge. The amorphous states however are not well defined, and the degree of disorder is very dependent on the method of deposition the thin film(6).

The tails of localized states for valance and conduction bands, and the edge of localized states near the middle of mobility gap lead to three conduction mechanisms for three range of temperature(7,8)

1- High temperature region. in this region the conductivity obey the relation

$$\sigma_{ext} = \sigma_0 \exp\left(-\frac{E_c - E_f}{KT}\right) \qquad (1)$$

σ_0 is the conductivity when temperature approach to zero.

2- When the temperature decrease, then the conductivity obey the relation:

$$\sigma_{ho} = \sigma_1 \exp\left(-\frac{E_A - E_f + W_1}{KT}\right) \qquad (2)$$

W_1 is the activation energy for hopping.

3- At low temperature (less than 303 k). The conductivity obey the relation:

$$\sigma_h = \sigma_2 \exp\left(-\frac{W_2}{KT}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

W_2 is the activation energy for hopping of localized states near Fermi level (E_f). the electrical conductivity of (a–Ge) obey to Stuke equation (9):

$$\sigma = \sigma_0 \exp\left(-\frac{E_a}{KT}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where σ is the electrical conductivity at T, σ_0 constant.

Many authors show remarkable different in their physical properties for (a–Ge), for example

In 1967 Jonshr and Walley[10] prepared (a–Ge) by thermal evaporation, they conclude that the resistivity of (a–Ge) remain constant on 1.4×10^2 (Ω.cm) as the thickness increase from 350 Å to 4500 Å.

In 1968 Wally[11] prepared (a–Ge) and (a–Si) by electron been method, they found that the resistivity is not change as the thickness increase from 1000 Å to 5000 Å. Alhadad [12] prepared (a–Si) in 1986 by evaporation, he found that the resistivity of (a–Si) decrease as the thickness increase.

Experimental Details

Amorphous germanium films were obtained by evaporation of (Ge) grains from tungsten boat on the glass slides or substrates at room temperature.

Deposition was carried by vacuum system (type Edwards, E 306 A) at vacuum $(4 - 2)\times10^{-6}$ torr. the glass substrates was cleaned carefully with non–organic substance and rinsed with distilled water, then dried.

A multiple beam interferometer was used to measure the film thickness. (a–Ge) films prepared under deposition rate 5 Å / sec.

Electrical measurement were made on a film grown on a glass substrates with aluminum electrodes formed by evaporation.

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

For 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 analysis[13].

Result and Discussion:

The temperature depends of the dc conductivity of (a–Ge) as a function of temperature exhibited two activation energies as shown in Fig.(1).

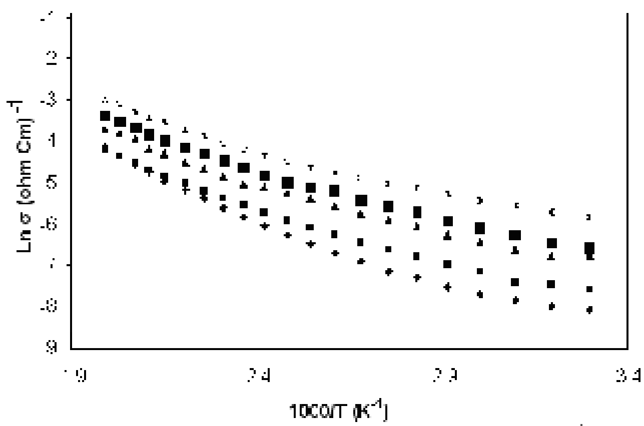

Fig. (1) : Temperature depend of ln*σ *vs. 1000/T(K^1) for different thickness.

In this Fig. the (a–Ge) thin films are characterized by tow stages of conductivity through heating in the range (303-503) K. The first stage is within temperature range (413-503)K with activation energy equal to (0.379) eV,(0.344) eV, (0.327) eV, (0.318) eV and (0.293) eV. for the films prepared at thickness (1000) Å, (2000) Å, (3000) Å,(4000) Å and (5000) Å respectively. The conduction is due to the excitation of electrons in to extended states beyond the mobility edge of the conduction band. These results are listed in Table (1) and shown in Fig. (2).

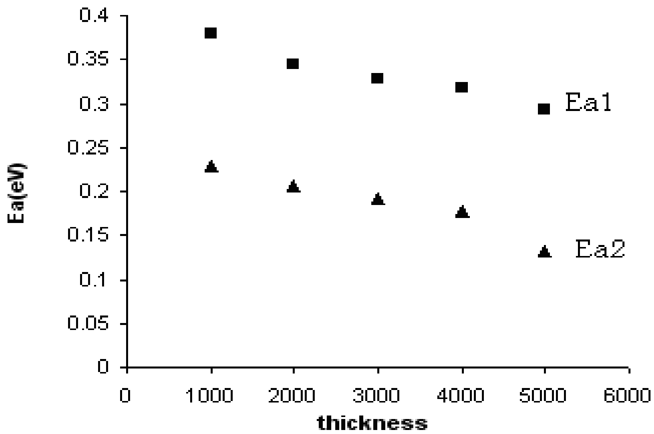

Fig. (2): Variation of the activation energy (Ea) vs. Thickness.

The second stage was found in temperature range (303-413) K with activation energy equal to (0.229) eV, (0.207) eV,(0.191) eV,(0.177) eV and (0.131) eV for thickness (1000), (2000), (3000), (4000) and (5000) Å respectively. The conduction in this stage is due to the transport of carriers to localized states near the band edge (see Table ((1)) as shown in Fig.(2). Two or three conduction mechanism are expected result for amorphous materials, Mott and Devis[7] mentioned that a change in the conduction mechanisms depend on the temperature.

Fig. (3) show the influence of thickness on the room temperature conductivity for (a-Ge). We see that (σ_{RT}) increase from 3.05×10^{-4} $(\Omega.cm)^{-1}$ to 2.909×10^{-3} $(\Omega.cm)^{-1}$ as the thickness increase from 1000 Å to 5000 Å, All these results are listed in Table (1).

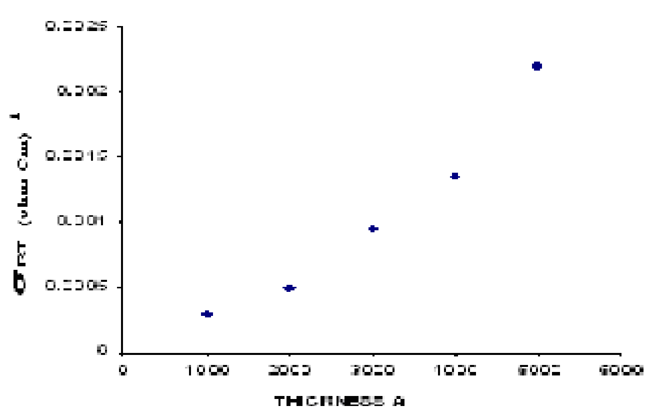

Fig. (3) : Variation of the conductivity (s_{RT}) vs. Thickness.

For optical measurement, Fig.(4) show that the absorption edge of (a-Ge) is shifted to the higher energies of incident radiation with decreasing the thickness.

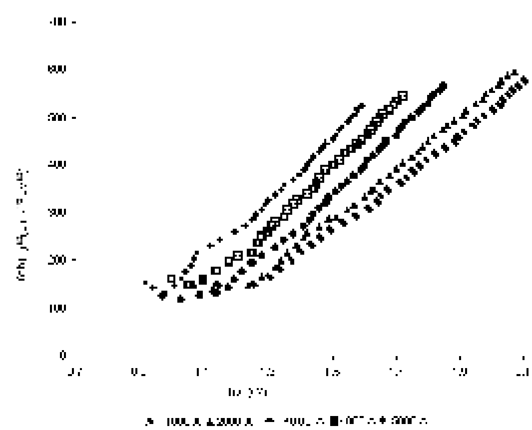

Fig.(4) : Plot of $(\alpha\, hy)^{1/2}$vs. hy of a-Ge for various thickness.

The optical energy gap (Eg) decrease from 1.05 ev to 0.86 ev for the same range of increasing thickness as shown in Fig.(5).

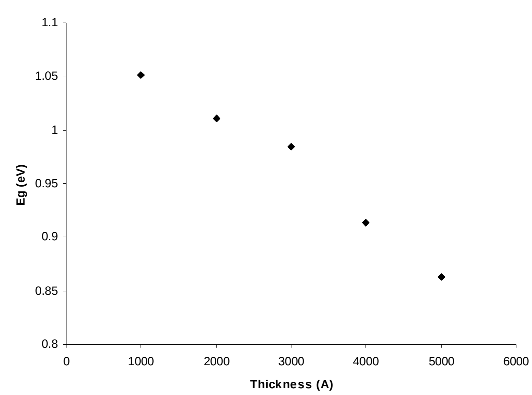

Fig. (5) : Variation of energy gap (Eg) vs. thickness.

According to Mott and Devis [7] the width of mobility edge depends on the degree of disorder and defects present in the amorphous structure. Increase the thickness of the films leading to increase the localized states in the band gap or decrease the optical band gap. The values are given in Table (1).

These results are in agreement with results obtained by P. Sharam et al 2006 [14] and Izzat et al 2004[15].

Table (1).

Thickness Å	σRT at 303K $(\Omega.cm)^{-1}$	Ea1 ev	ΔT K	Ea2 ev	ΔT K	Eg ev
1000	3.05×10^{-4}	0.379	303-383	0.229	383-503	1.05
2000	5×10^{-4}	0.344	303-393	0.207	393-503	1.01
3000	9.49×10^{-4}	0.327	303-403	0.191	403-503	.98
4000	13.5×10^{-4}	0.318	303-413	0.177	413-503	.91
5000	2.2×10^{-3}	0.293	303-413	0.131	413-503	.86

Conclusion

Optical transmission is used to calculate the energy gap of (a-Ge) as a function of thickness. It is found that the conductivity, activation energy and optical band gap of the (a-Ge) films on thickness dependent. The decrease in band gap and activation energy explained are the basis of defect states.

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الخلاصة

تم تحضير غشاء الجرمانيوم العشوائي بطريقة التبخير الحراري تحت ضغط عالي مقداره (10^{-6} torr) ودراسة تاثير السمك ذو المجال من Å (1000-5000) على التوصيلية الكهربائية المستمرة بدرجة حرارية (303 K) وفجوة الطاقة الضوئية لغشاء الجرمانيوم العشوائي.

تم الحصول على منطقتي توصيل عند الدرجة الحرارية الوسطى والعالية من خلال دراسة اعتمادية التوصيلية الكهربائية على درجة الحراراة ضمن المدى (303-503)K وقد وجد ان فجوة الطاقة تقل من 1.05 eV الى 86eV.

عندما يزداد السمك من Å 1000 الى Å 5000 على التوالي بينما ازدادت التوصيلية الكهربائية المستمرة عند درجة حرارة الغرفة من $^{-1}$(ohm.Cm) 3.05×10^{-4} الى 2.209×10^{-3} $(ohm.Cm)^{-1}$ على التوالي تحت نفس تغير السمك.