Pakistan J. Sci. Ind. Res., Vol. 31, No. 9, September 1988

SOME PROPERTIES OF FLASH EVAPORATED GALLIUM ARSENIDE THIN FILMS

M.N. Islam and S.K. Mitra

Department of Physics, Edward College, Pabna 6600, Bangladesh

(Received August 19, 1985; revised September 22, 1987)

Thin films of gallium arsenide were deposited upon glass substrates by the flash evaporation technique at temperatures ranging from room temperature to 350°. The electrical and optical properties of the films depended strongly on substrate temperature. It was observed that the films deposited at about 250° had minimum resistivity. The thermoelectric power was measured as a function of temperature and all the films so far tested were found to be p-type. The optical band gap for the samples deposited at room temperature was 0.92 eV but that of the samples deposited at 250° was 1.33 eV.

Key words: Gallium arsenide, Thin films.

INTRODUCTION

The study of the physical properties of thin films of gallium arsenide (GaAs) are of great importance in the sphere of industrial, scientific and technical applications. Flash evaporation [1] is an attractive method for the deposition of films whose constituents have different vapour pressures like GaAs. Since in this method the compound GaAs or the mixture of Ga and As in a proper proportion is ground to fine powder and is allowed to fall grain by grain in an evaporator which is maintained at a suitable high temperature in vacuum. Since the material is evaporated quickly, the decomposition of compound is minimized. Secondly, the time of contact of the material with the high temperature evaporator source being almost negligible the source contamination is also minimized in this technique. Thirdly, flash evaporation in high vacuum minimizes the effect of environmental impurities on the material of the film. Choosing suitable conditions for flash evaporation, thin films of GaAs have been obtained, having stoichiometric composition and good electrical and optical properties [2-5]. Gheorghiu *et al.* [2] and Barthwal *et al.* [3] studied the structural and electrical properties of amorphous GaAs films. Takahashi [4] also studied the transport properties of GaAs films deposited on quartz plates. Only Pankey and Davey [5] have reported the optical properties of thin GaAs films on glass substrates deposited by this technique. In the previous studies [6,7] we have investigated the electrical and optical properties of annealed GaAs thin films on glass substrates. The purpose of this paper is to present experimental results on electrical and optical properties of GaAs films deposited upon glass substrates at temperatures ranging from room temperature to 350°.

EXPERIMENTAL

Thin films of compound GaAs were prepared using a Edwards high vacuum coating unit model E306 with an arrangement for flash evaporation. The compound GaAs of high purity grade was obtained from Ultra-pure Chemical Corporation, New York. The substrates were glass, which cleaned with chromic acid, alcohol and in ultrasonic cleaner. Prior to film deposition, the substrates were degassed in high vacuum. The substrate was placed at a distance of 10 cms. from the evaporator. Flash evaporations were carried out when powder GaAs was allowed to fall slowly onto the previously heated tantalum cup of about 1400°. The rate of powder flow was adjusted by using a vibrator. The pressure during evaporations was maintained at about 5×10^{-6} Torr. The mean film deposition rate was about 20 Å/sec. The evaporator temperature was determined by an optical pyrometer.

Electrical resistivity measurements were carried out by van der Pauw method [8]. Ohmic contacts were made using indium under high vacuum. A keithly 610C solid state electrometer and Hewlett Packard model 412A DC multimeter with high input impedance were used for resistivity measurements. Chromel-alumel thermocouple was used to measure the substrate temperature. The thermoelectric power of GaAs samples with respect to gold was measured as a function of temperature within the range between 303°K and 400°K. The thicknesses of the films were measured using Tolansky's interferometric method [9].

Optical absorption measurements of GaAs samples were made in the wavelength range of 0.50 μm to 0.90 μm of photon energy, using a Shimadzu UV-180 double-beam spectrophotometer. The absorption spectra thus obtained were not corrected for reflection losses. High absorption levels being used, the reflection correction is not very important. From the absorption data absorption coefficient α was calculated and the optical energy gaps were determined graphically.

RESULTS AND DISCUSSIONS

The room temperature resistivities of the GaAs films were found to vary between 6 x 10^7 Ohm.cm to 1 x 10^7 Oh.cm for thicknesses between 1.10 μm to 0.40 μm. These results are close to those of Sequi *et al.* [10] of GaAs films obtained by plasma deposition method. The films deposited at room temperature were slightly transparent and dark-grey and they appear to be stable under ordinary atmospheric conditions. Figure 1 shows the changes in resistivity as a function of substrate temperature. The measurements were carried out on fresh samples of about 0.30 μm thickness without any heat treatment. The dependence of the resistivity on the substrate temperature may be interpreted in terms of structural properties of the films. From Fig. 1 it is observed that the resistivity of the films increased slowly with increasing substrate temperature upto about 200°. This result is thought to be due to the reduction of imperfections in the deposited films. There is a decrease of resistivity after 200°. This may be due to the onset of crystallization in the films. The lowest resistivity measured was 2.5 x 10^4 Ohm.cm for a substrate temperature of 250°. This large decrease is probably a result of the amorphous phase completely transforming into a crystalline phase. With a further increase of the substrate temperature the resistivity increased remarkably. This sharp increase in resistivity may be due to the increase in grain size because the samples became more transparent when the substrate temperature is higher than 250°. Similar variations in resistivity with substrate temperature have been observed by Davey and Pankey [11] for GaAs films deposited by the three-temperature zone method. However, the lowest resistivity they reported is rather lower than that of the present work. Because of high resistivity, it was not possible to measure Hall effect of the GaAs films deposited at a temperature 250° or above. The conduction type of the GaAs samples studied here are found to be p-type, as indicated by the thermoelectric power measurements. These results are not in agreement with Yamashita *et al.* [12] who found that the films thinner than 1 μm exhibited *n*-type conductivity which were obtained by the simultaneous evaporation method but in agreement with Davey *et al.* [11] who obtained GaAs films by the three temperature zone method.

The behaviours of the absorption coefficient α of GaAs samples deposited at room temperature and the samples deposited at a substrate temperature of 250° as a function of photon energy (h ν) are shown in Fig. 2. The optical

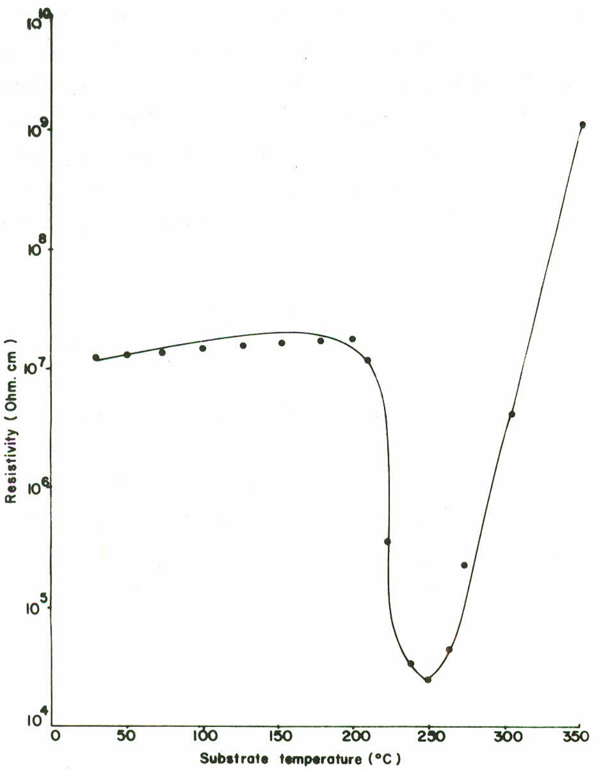

Fig. 1. The variation of resistivity of GaAs films as a function of substrate temperature.

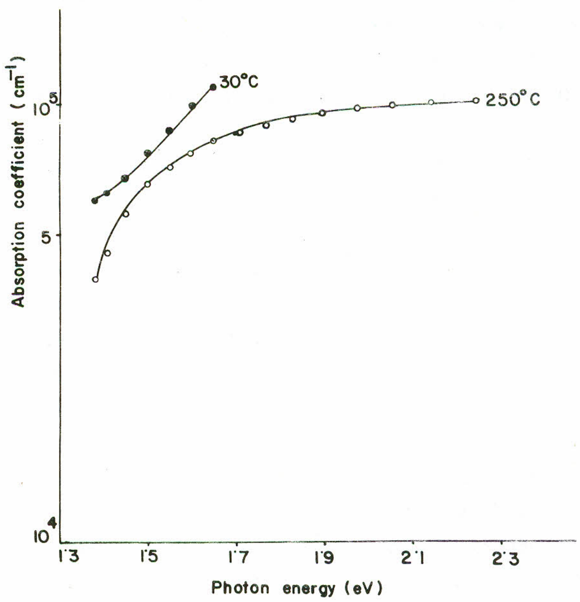

Fig. 2. The variation of the optical absorption as a function of photon energy for GaAs films deposited at room temperature and that of the films deposited at 250°

energy gap of samples deposited at room temperature for the indirect allowed transition has been determined graphically by plotting $(\alpha h\nu)^{1/2}$ versus $(h\nu)$ and extrapolating the linear portion to $\alpha=0$. But the variation of samples deposited at 250° are indicative of direct transition and it appears that the variation of $(\alpha h\nu)^2$ versus $(h\nu)$ offers the best fit to the optical absorption data. The values of optical band gap of the samples deposited at room temperature and the samples deposited at a temperature of about 250° are 0.92 and 1.33 eV respectively. Our results of optical gap for the samples deposited at room temperature and the samples deposited at 250° are comparable with the value of amorphous GaAs films [13] and the bulk value of about 1.37 eV [14] respectively. Thus we are in agreement with the report published by Yamashita *et al.* [12] that the optical gap considerably approached the bulk value when the samples were crystallized.

CONCLUSIONS

From the experimental results it may be concluded that the GaAs films deposited on glass substrates at room temperature are amorphous and that of the samples deposited upon glass substrates at about 250° are polycrystalline. All the films studied here are characteristic of *p*-type conduction.

Acknowledgement. One of us (SKM) gratefully acknowledges the award of a Research Fellowship from the University Grants Commission and the grant of deputation by the Ministry of Education, Government of the People's Republic of Bangladesh, to carry out the research.

REFERENCES

1. L. Harris and B.M. Siegel, J. Appl. Phys., **19**, 739 (1948).
2. A. Gheorghiu, T. Rappeneau, S. Fission and M.L. Theye, Thin Solid Films, **120**, 191 (1984).
3. S.K. Barthwal and K.L. Chopra, Phys. Stat. Sol. (a) **36**, 345 (1976).
4. Kiyoshi Takahashi, J. Vac. Sci. Technol., **9**, 502 (1971).
5. Titus Pankey and John E. Davey, J. Appl. Phys., **37**, 1507 (1966).
6. M.N. Islam and S.K. Mitra, J. Mat. Sci., **21**, 2863 (1986).
7. M.N. Islam and S.K. Mitra, J. Mat. Sci. Letters, **6**, 151 (1987).
8. L.J. van der Pauw, Philips Res. Rep., **13**, 1 (1958).
9. S. Tolansky, *Multiple beam interferometry of surfaces and films* (Oxford University Press, London, 1948).
10. Y. Segui, F. Carrere and A. Bui, Thin Solid Films, **92**, 303 (1982).
11. John E. Davey and Titus Pankey, J. Appl. Phys., **35**, 2203 (1964).
12. A Yamashita, T. Tuzuki, T. Yamada and I. Yamauchi, J. Appl. Phys., **38**, 2359 (1967).
13. Nubuo Matsumoto and Kenji Kumabe, Japan. J. Appl. Phys., **19**, 1583 (1980).
14. M.D. Sturge, Phys. Rev., **127**, 768 (1962).