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ELECTRICAL CONDUCTIVITY OF AMORPHOUS GaP FILMS

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GaP thin films have been prepared by electron beam evaporation method by keeping the glass substrates at room temperature. Films of different thicknesses were grown and their electrical conductivity was measured in the temperature range 100 - 300 K. Analysis of the results have been made using Mott's variable range hopping relation

Key words : Gallium phosphide, electrical conductivity, thin films

INTRODUCTION

Like amorphous silicon (a-Si) or germanium (a-Ge), amorphous III-V compound semiconductors can be obtained in the form of thin films by various methods : vacuum evaporation, cathode sputtering, plasma decomposition, flash evaporation etc. In the cases of silicon and germanium, the amorphous films have been very well studied and the importance of the deposition conditions in determining the film properties has been demonstrated in detail. For compounds, several difficulties arise from the necessity of controlling the film composition; indeed, an excess of one constituent with respect to stoichiometry is likely to modify the observed film properties and to obscure the analysis of the data. The optical and transport properties of amorphous GaAs, GaP films prepared by flash evaporation technique have been reported elsewhere [1,2]. The influence of deposition conditions on the film composition and on their initial d.c. electrical conductivity, taken as a characteristic parameter have been used to determine the best conditions for obtaining nearly stoichiometric samples by Gheorghiu et al [3]. In the present study GaP prepared by reaction of Ga with Zn_3P_2 has been used as source for the preparation of films by the electron beam evaporation technique and the results on electrical resistivity are analysed and reported.

EXPERIMENTAL METHODS

The source material GaP has been prepared by adopting the following procedure. Stoichiometric quantitites of specpure gallium metal 6N purity obtained from Electronic Enterprises, England and Zn_3P_2 5N purity were mixed thoroughly and transferred to a cleaned alumina boat. Since the gallium metal was in the liquid state and zinc phosphide was in the form of solid powder it took a long time for the thorough mixing of the two constituents and even after mixing for more than an hour some gallium metal remained separated from the Zn_3P_2. So during the reaction at 800°C the mixture was stirred continuously by making a separate attachement for this purpose. The temperature of the furnace was raised gradually until it reached 800°C. The reaction was continued in argon atmosphere for about 24 hours by maintaining the temperature at 800°C (± 5°C). At the end, the boat was removed and cooled to room temperature (RT) in about 15 minutes. The end product GaP (orange in colour) was then transferred to a beaker and concentrated hydrochloric acid was added to remove any unreacted zinc phosphide. This was done for a short time. The contents were then filtered, dried in an oven at 70 - 80 °C for about half an hour, and then transferred to a centrifuge, where it was placed for one hour to remove unreacted gallium metal. X-ray diffractogram of the powdered samples indicated only the sharp lines assignable to single phase GaP. Electron proble microanalysis indicated the presence of Ga and P in stoichiometric amounts.

Thin films of GaP were grown at R.T. on glass substrates by electron beam evaporation using the Hind Hivac Electron beam evaporator (under a vacuum of 10^{-6} Torr). The films were uniform and pores were not observed when viewed through a microscope. The thickness of the films was measured by the conventional weighing method. Films of different thicknesses in the range 2000 - 6000 Å were prepared and evaporated Au - alloy served as ohmic contact for conductivity measurements. Electrical conductivity was measured in the temperature range 100 - 300 K under a vacuum of 10^{-3} Torr using sandwich type of configuration. Two or three sets of films of same thickness were evaporated and their conductivity results varied within 5 %.

RESULTS AND DISCUSSION

The variation of d.c. conductivity as a function of temperature ($\ln\sigma$-vs T^{-1}) is shown in Fig.1 for GaP films of various thicknesses,

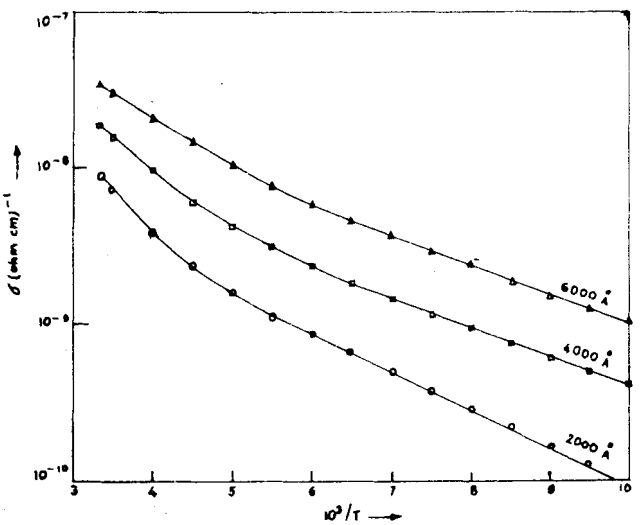

Fig. 1: Variation of D.C. conductivity of amorphous GaP films with temperature

(2000 - 6000 Å). The conductivity of these films is found to be very low and found to increase with thickness of the film. In this temperature range the conductivity is characterised by Mott's variable range hopping relation [4].

$$\sigma = A \exp(-T_o/T)^{1/4} \quad \ldots. (1)$$

where, $T_o = \dfrac{16\alpha^3}{K\, N(E_F)}$ ....(2)

with K as Boltzmann's constant and α^{-1} being a measure of the spatial extension of the wave function exp (αr) associated with the localised states, and N (E_F) is the density of states near the Fermi level. The value of α^{-1} is around 10A [5]. The values of T_o can be obtained from the slope of the plot in $\sigma\sqrt{T}$ vs $T^{-1/4}$ for GaP films of different thicknesses (Fig.2).

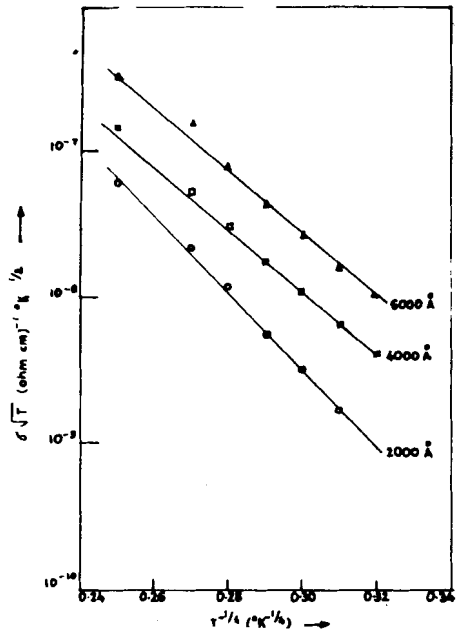

Fig.2: Plot of $\ln\sigma\sqrt{T}$ vs $T^{-1/4}$ for GaP films of different thicknesses

Using T_o and α^{-1}, the value of $N(E_F)$ can be calculated from eqn. (2). The values of T_o are, however, decreased with increasing thickness. This is because of the fact that in thick films there is a probability of transition from amorphous to polycrystallinity, since the magnitude of T_o/T represents the ratio of the characteristic disorder energy to thermal energy [6]. Its value is higher by two or three orders of magnitude as compared to polycrystalline films. The value of T_o and $N(E_F)$ (cf. Table I) are of the order of 10^7 and 10^{18} respectively, which are in good agreement with the results obtained by other workers for amorphous films [7 - 9].

Table I: Values of T_o and density of localised states near the Fermi level ($N(E_F)$)for GaP films of various thicknesses

Thickness (A)	T_o (° K) x 10^7	$N(E_F)$ x 10^{18}
2000	7	2.6
4000	5.25	3.5
6000	3.5	5.3

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