PHOTO-DIELECTRIC INVESTIGATION OF p-GALLIUM ARSENIDE

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The complex dielectric constant of gallium arsenide sample was studied in the frequency range 0·3 to 30 MHz, subjected to Photo-excitation. The model proposed by Dutt and Nicholls for after glow plasma seems to be in agreement with the experimental results. The relaxation time and damping constants have been estimated.

The change in the dielectric constant of a semiconductor, subjected to a radiation of suitable wavelength, is explained either in terms of the increase in the number of dipoles on illumination, as done by Roux[1] in the case of ZnO or in terms of Maxwell-Wagner effect due to photoconduction in the grains of the sample, as done by Uchida[2] in the case of ZnS doped with copper and chlorine. In the present work the dielectric properties of p-GaAs sample subjected to ultraviolet illumination are reported. This type of investigation appears to be interesting, as dielectric methods have proved to be a powerful tool for studying the relaxation processes in the semiconductors[3]. A knowledge of ϵ as a function of ω provides us more information about the properties of electron-hole gas in the semiconductor than its simple dielectric response, where ϵ represents the complex dielectric constant, and ω the angular frequency.

Gallium arsenide is a material having high mobility of charge carriers and wider band gap. High mobility leads to high electrical conductivity and wider band gap is suitable for high temperature operations. Thus this material is used in many opto-electronic and solid state microwave devices used in defence. Hence a study of it with frequency is very important.

EXPERIMENTAL

Thin wafer of GaAs was used as dielectric material sandwitched between two conducting plates, one being of transparent conducting glass, (prepared by special technique) so that the sample could be illuminated from a 300 watt ultraviolet lamp (wavelength 365 millimicron). Carrier concentrations were changed by interposing calibrated light attenuators between the source and the sample. The capacitance and the loss factor (tan δ) were measured as a function of frequency in the range 0·3 MHz to 30 MHz at 300°K, using a Schering bridge E10-2. The real and imaginary parts ϵ' and ϵ'' respectively of the complex dielectric constant ϵ of the sample were determined by the following formulae,[4]

$$\epsilon' = \frac{1}{C_0}\left(\frac{C_{\text{read}}}{1 + \tan \delta^2} - C_{\text{cable}}\right) \tag{1}$$

and

$$\epsilon'' = \frac{C_{\text{read}}}{C_0} \times \frac{\tan \delta}{1 + \tan \delta^2} \tag{2}$$

where C_{read} is the value of the capacitance of the imperfect capacitor read by the bridge, tan δ the loss factor of the imperfect capacitor obtained by the bridge measurements, C_{cable} is the capacitance of the connecting cable and C_0 the capacitance of the imperfect capacitor without dielectric.

RESULTS AND DISCUSSIONS

The plot of ϵ' and ϵ'' as a function of frequency for GaAs sample for different attenuations is shown in

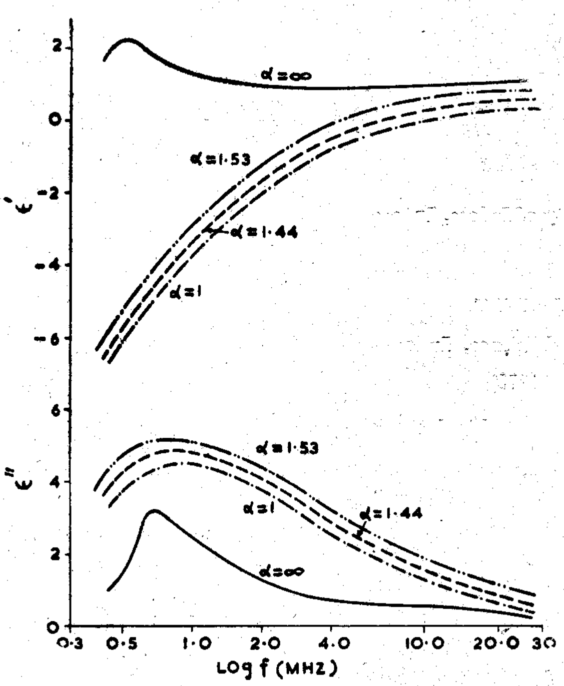

Fig. 1. It is observed that the dielectric constant becomes negative below 4 MHz explaining that the electron-hole gas in the sample exhibits a plasma-like behaviour. The point of zero crossing of ϵ' increases with light intensity. In this region of zero crossing the expected peak of ϵ'' is shifted little to the left probably due to collisions present in the plasma. The treatment of the plasma as free electron gas[5] giving $\epsilon'' = \frac{\omega_p^2}{\omega^2 + \nu^2} \times \frac{\nu}{\omega}$ where ω_p is the plasma frequency, and ν the collision frequency, does not predict any peak in the behaviour of ϵ''. Again if one considers this as a free electron gas subjected to a restoring force $\omega_p^2 x$, where x is the displacement of the electrons[6], ϵ'' will be modified to

$$\epsilon'' = \frac{\omega_p^2}{\omega} \times \frac{\nu}{\nu^2 + \left(\omega - \frac{\omega_p^2}{\omega}\right)} \tag{3}$$

exhibiting a peak in the dispersion of ϵ'' with frequency. At point, $\omega = \omega_0$, corresponding to zero value of ϵ' The relaxation time τ is given by[5]

$$\tau = \frac{\epsilon_0}{\omega_0 \, \epsilon''(\omega_0)} \tag{4}$$

The estimated values of relaxation times in this particular case lie between 11 n. sec. to 12 n. sec. for high density to low density of charge carriers.

The damping constant δ for Landau damping has been determined from the relation[7]

$$\delta = -\left[\frac{\partial \epsilon'}{\partial \omega}\right]^{-1} \epsilon''(\omega_0) \quad \text{neper/sec.} \tag{5}$$

The estimates of δ come out in the range 1×10^7 to 6×10^7 neper/sec. for high density to low density of charge carriers.

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