J. PHYS. SOC. JAPAN **20** (1965) 1958

Franz-Keldysh Effect in Silicon P-N Junction

Yoshihiro HAMAKAWA*, Taneo NISHINO** and Jiro YAMAGUCHI*

Department of Engineering Science, Faculty of Engineering** Osaka University, Osaka*

(Received June 28, 1965)

A shift of the optical absorption edge toward longer wave length under high electric field has been observed in several semiconductor materials[1)-3)] and was explained by the theories derived individually by Franz[4)] and Keldysh[5)]. More recently, Frova and Handler[6)] have measured the Franz-Keldysh effect by using the space charge region of germanium P-N junction.

The purpose of this note is to report briefly a result of the effect in silicon P-N junction.

The samples used in this study were phosphorus-diffused P-N junction on a P-type silicon wafer of about 10Ω−cm resistivity, having a dimension of approximately 5×5 mm², and 300 microns thick. A monochromatic light beam chopped at 1000 cps was made to fall on the junction plane. The electric field was applied across the junction and parallel to the incident light beam. The transmitted light through the sample was detected by a PbS photocell and the signal was amplified by a tuned amplifier.

Figure 1 shows the transmitted light intensity versus photon wavelength for several reverse bias voltage at room temperature. As is seen from the figure, the absorption edge is shifted about 100Å toward the long wavelength side by the app lication of electric field of the order of 10^4V/cm. The relation between the transmitted light intensity I and the absorption coefficient $\alpha(E)$ is approximately given as follows,

$$\frac{I(E=0)-I(E)}{I(E=0)}=\int_0^d \alpha(E)dx \qquad (1)$$

where d is the effective width of the depletion layer and E is the electric field strength.

By accounting the electric field dependences of $\alpha(E)$[5)] and depletion region in diffused junction[7)], we can rewrite eq. (1) as the form,

$$\frac{I(E=0)-I(E)}{I(E=0)}=A V^{5/3} \qquad (2)$$

where A is a constant and V is the applied reverse bias voltage.

In Fig. 2 we show $\frac{I(E=0)-I(E)}{I(E=0)}$ versus $V^{5/3}$ for several wavelength.

Although above treatment by use of the formula for the direct transition is the simplest one, the experimental results are in qualitatively good agreement with the theoretical predictions. Although it is desirable that, in the case of silicon, a more detailed discussion should be made by taking into account of phonon-assited indirect process, unfortunately, any theoretical approaches about the electric field dependence of the absorption coefficient for the indirect transitions are not yet performed.

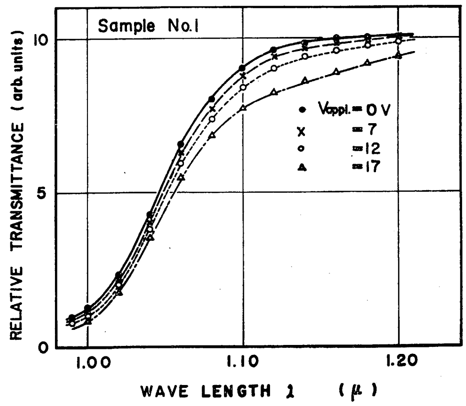

Fig. 1. Relative transmitted light intensity at various reverse bias voltages.

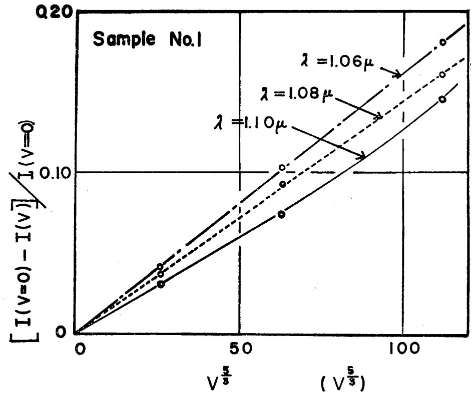

Fig. 2. Relative transparency versus $V^{5/3}$ as a parameter of wavelength near the absorption edge.

We wish to express our thanks to Mr. K. Kimura of Hayakawa Electric Co., Ltd. for providing the samples and to Prof. S. Narita for his useful discussion.

References

1) T. S. Moss: J. appl. Phys. **32** Suppl. (1961) 2136.
2) V. S. Vavilov and K. I. Britsyn: Soviet Physics-Solid State **2** (1960) 1746.
3) R. Williams: Phys. Rev. **117** (1960) 1487.
4) W. Franz: Z. Naturforsch. **13a** (1958) 484.
5) L. V. Keldysh: Soviet Physics-JETP, **7** (1958) 788.
6) A. Frova and Handler: Appl. Phys. Letters **5** No. 1 (1964) 11, Phys. Rev. **137** (1965) A1857.
7) K. G. Mackay: Phys. Rev. **94** (1954) 877.