short note

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reprinted from

physica status solidi

phys. stat. sol. 36, K21 (1969)

Subject classification: 14.3.2; 12; 13.4; 16; 20.3; 22.2.1

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Effect of Hydrostatic Pressure on the Spectral Photoresponse and Spontaneous Emission from Gallium Arsenide p-n Junctions

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This paper is part of a systematic study of the effect of pressure on the physical properties of semiconductors (1, 2) and semiconductor p-n junctions (3). It is shown for the first time from optical measurements of the spectral photoresponse and spontaneous emission that the zinc acceptor level shifts with pressure relative to the valence band.

Diodes were fabricated by zinc diffusion (20 to 30 μm deep) into a tellurium-doped ($n = 2x10^{18}$ cm^{-3}) (111)-oriented slice. In order to take the photoresponse spectrum of p-n junctions, the exciting irradiation was produced from the exit slit of a spectrometer normally to the emitting surface in the plate parallel to the p-n junction plane. Photoresponse and emission spectra were taken with the same diode. To estimate the surface recombination conditions on the spectral photoresponse all diodes had parallel sides cleaved and optically polished. No differences in the spectra for the two methods of preparing the emitting surface were observed.

The pressure was generated in a specially constructed optical high-pressure vessel in which previous p-n junction emission studies on indium phosphide were carried out (3).

Fig. 1 shows the spectra of photoresponse and those of spontaneous emission of gallium arsenide p-n junctions for several hydrostatic pressures at 293 ^{o}K.

The solid curve in Figs. 1 and 2 represents photoresponse and the dashed line spontaneous emission. As can be seen in Fig. 1, with increasing pressure the peak energy of the spectral photoresponse and of spontaneous emission shifts to shorter wavelenghs. The figure also shows a change of the spectral photoresponse structure, namely, with increasing pressure a higher asymmetry is observed. According to our measurements, the peak energy of the photoresponse and of the spontaneous emission line varies linearly with pressure (Fig. 2). The pressure coefficients are

a) for the spontaneous emission line

$$(\partial h\nu_{max}/\partial P)_{293^oK} = (11.1 \pm 0.3)\times10^{-6} \text{ eV/bar}$$

b) for the spectral photoresponse

$$(\partial h\nu_{max}/\partial P)_{293^oK} = (9.7 \pm 0.3)\times10^{-6} \text{ eV/bar} .$$

The effect of pressure on the spectral photoresponse of GaAs p-n junctions was not investigated earlier.

We have also investigated the effect of pressure on the I-U characteristics of GaAs diodes with various dopings. It should be noted that the shift in the forward-bias voltage with pressure is in good agreement with that of the peak of the spontaneous emission line with pressure (Fig. 2).

The pressure coefficient for the spontaneous emission line coincides with that given in (4) within the limits of experimental error. However, Feinleib et al. only studied the effect of pressure on the spontaneous emission which is due to the transition of electrons from the conduction band to an acceptor level, and they could not draw any definite conclusions about the impurity level behaviour under pressure. Comparing the pressure coefficients for spontaneous emission and optical absorption, the authors pointed out that the pressure effect is mainly due to that of the energy gap and the pressure coefficients can almost certainly be accepted as close.

The uniaxial stress dependence of photolumi-

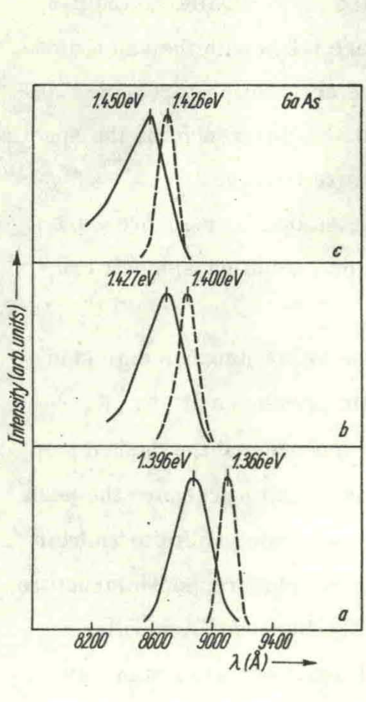

Fig. 1. Pressure effect on photoresponse and spontaneous emission from GaAs p-n junctions
a) P = 1 bar, b) P = 3100 bar, c) P = 5400 bar

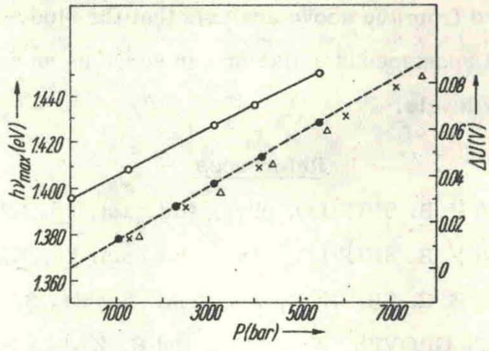

Fig. 2. Shift of the peak energy of the photoresponse and spontaneous emission line and shift in the forward-bias voltage at constant current of 3 mA against pressure.

1. Shift of the peak energy

   o - photoresponse, • - spontaneous emission line.

2. Shift in the forward-bias voltage

   Δ - $n = 1.1\times10^{16}$ cm^{-3}, × - $n = 4.7\times10^{17}$ cm^{-3}

nescence in GaAs was investigated by Bhargava and Nathan (5). They observed two lines: line A does not involve an acceptor level but line B does. In the low-stress region the peak shift with stress is larger for line B than for line A. However, in the discussion the authors concluded that the stress dependence of lines A and B have qualitatively similar behaviour.

Price (6) theoretically predicted the dependence of the acceptor ionization energy on uniaxial stress.

In our investigation the influence of hydrostatic pressure on the spectral photoresponse (band-to-band transition) and spontaneous emission (transition band-to-acceptor level) were simultaneously studied. Without pressure the difference between the peak energy of these lines (Fig. 1a) is equal to 0.03 eV, which coincides with the zinc acceptor level in GaAs. The pressure coefficient for the spontaneous emission line is larger than the coefficient for the spectral photoresponse. This fact suggests that with increasing pressure the zinc acceptor level should shift relative to the valence band with the coefficient

$$(\partial E_A / \partial P)_{293^oK} = (-10.6 \pm 0.5)\times10^{-7} \text{ eV/bar} .$$

It can be assumed from the above analysis that the study of the pressure effect on photoresponse and spontaneous emission can serve as an experimental technique for studying impurity levels.

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(Received July 21, 1969)