Solid State Communications, Vol. 76, No. 2, pp. 195–196, 1990.
Printed in Great Britain.

0038-1098/90 $3.00 + .00
Pergamon Press plc

COMPOSITION DEPENDENCE OF CATHODOLUMINESCENCE EMISSION OF $Al_xGa_{1-x}P$

P. Fernández, F. Domínguez-Adame and J. Piqueras

Departamento de Física de Materiales, Facultad de Físicas, Universidad Complutense, 28040 Madrid, Spain

and

G. Armelles

Centro Nacional de Microelectrónica, Consejo Superior de Investigaciones Científicas, Serrano 144, 28006 Madrid, Spain

(*Received* 31 *May* 1990 *by S. Amelinckx*)

Cathodoluminescence of $Al_xGa_{1-x}P$ has been investigated for x between 0.10 and 0.53. A band corresponding to the 610 nm band of pure GaP has been found to shift to higher energies with increasing x. The position of a red band centred at 690 nm is independent of x.

THE $Al_xGa_{1-x}P$ ALLOYS present interest for optoelectronic devices in the visible region because the band gap increases by increasing the Al content and the emission peaks shift toward higher energies. Luminescence [1–5] and electroreflectance [6, 7] techniques have been used to study the optical transitions of these alloys as a function of x, but their optical properties are in general scarcely known. Previous luminescence works refer mainly to the dependence of the green emission peak position on the alloy composition. Sonomura *et al.* [3] found that the energy gap and the green band electroluminescence emission peak vary linearly to the high energy side as the Al concentration increases. The luminescence spectra from GaP show bands in the green and red regions that are often observed under different excitation conditions. The bands are composite in character and the appearance of specific peaks depends on the defect or doping structure. In particular a peak at about 610 nm is observed in annealed GaP [8]. After some treatments the 610 nm emission can appear as the main luminescence band replacing the near band edge luminescence at about 560 nm [9]. In the present work cathodoluminescence (CL) is used to study the influence of Al content on the mentioned 610 nm band and on the 700 nm emission band of GaP. The composite character of the latter band has been previously studied by photoluminescence [8] and CL [10]. The possible spectral shift of these bands would be related to the shift of band gap value of $Al_xGa_{1-x}P$ alloys as a function of x.

n-type samples of $Al_xGa_{1-x}P$ were grown by metalorganic chemical vapor deposition (MOCVD) on (0 0 1) n-type substrates. The thickness of epitaxial layers was 5 μm. The parameter x ranged from 0.1 to 0.53. The Al content was determined by electron probe microanalysis. The samples were also characterized by double crystal X-ray diffraction. The full width at half maximum (FWHM) of the alloys peaks ((0 0 4) reflection) are about 32.7″ which clearly indicates a good crystalline quality (the GaP substrate has a FWHM of 28.2″). The samples were observed in the emissive and CL modes in a Cambridge S4-10 scanning electron microscope. Low temperature (173 K) spectra were recorded by means of a light guide feeding the light to an Oriel 78215 computer controlled monochromator. In cases of low signals, spectra representing the average of a high number of measurements are readily obtained. The spectra were corrected to include the system spectral response.

The spectra obtained from all the observed samples present several low intensity peaks in the green-yellow band, below 600 nm. An intense broad band centered at about 700 nm is also observed. When the spectra are recorded under the normal observation conditions of the SEM, with the electron beam focused on the sample the mentioned peaks in the green region are detected. However, with a defocused beam the intensity of the red band increases and peaks in the region 500–600 nm are not resolved. The increase of the red CL emission by defocusing the electron beam has been previously observed in GaP [11]. In order to study both, green and red bands of the $Al_xGa_{1-x}P$ alloys defocused and focused electron beams were used. Due to the large scale differences, spectra below and above 600 nm are separately represented in the following figures. Figure 1 shows the spectrum below 600 nm of the alloy with $x = 0.30$.

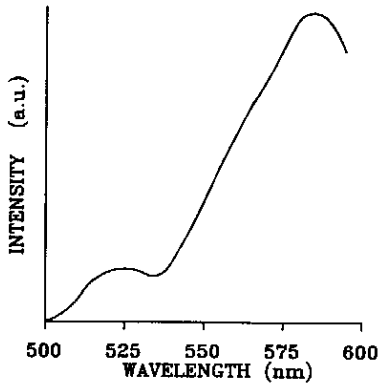

Fig. 1. Green-yellow CL spectrum obtained by focusing the electron beam onto the sample ($x = 0.30$).

The arrowed peak appears at 585 nm in this sample. The peak energy has been found to increase linearly with x as Fig. 2 shows. Extrapolation to $x = 0$ shows that this band hereafter called green-yellow band corresponds to the 610 nm band of GaP mentioned above. The equation of straight line of Fig. 2 is $E = 2.03 + 0.38x$ (eV). Figure 3 shows the spectrum above 600 nm of the alloy of $x = 0.3$. The peak position of the deep level band (690 nm) has been found to be independent of x. Comparison of the CL intensity of all the samples has shown that the increase of x leads to a slight reduction of the green yellow and red emission bands. The CL images of the samples do not show structural features, as for instance dislocations, that could cause the observed reduction.

The variation of the green-yellow band with x observed here is close to the variation of the near band gap edge described in [3] which was found in the same work to be parallel to the change of the band gap energy with x. The 610 nm emission of GaP is attributed

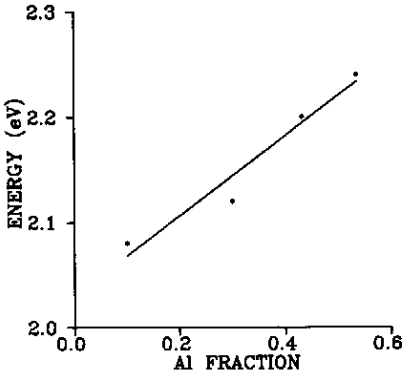

Fig. 2. Composition dependence of the green-yellow band position.

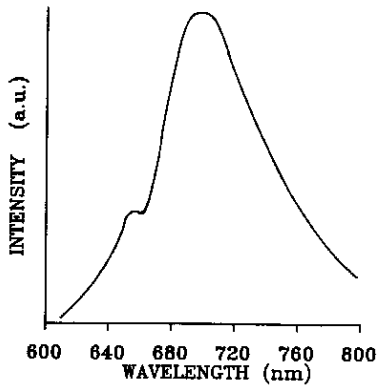

Fig. 3. Red emission spectrum obtained with a defocused electron beam ($x = 0.30$).

[8, 9] to annealing induced defects. Assuming that the position of the energy level associated to these defects is not composition dependent, the observed spectral shift as a function of x would be a direct consequency of the increase of energy band gap with x. On the contrary, the red band cannot be related to any band gap changes although its intensity has been found to depend on x.

Acknowledgements — This work has been partially supported by the Comisión Interministerial de Ciencia y Tecnología (Project PB86-0151).

REFERENCES

1. H. Sonomura, T. Nanmori & T. Miyauchi, *Appl. Phys. Lett.* **22,** 532 (1973).
2. R. Bindemann, K. Buchheiser, G. Kühn & A. Zehe, *Phys. Status Solidi (a)* **24,** K 189 (1974).
3. H. Sonomura, T. Nanmori & T. Miyauchi, *Appl. Phys. Lett.* **24,** 77 (1974).
4. H. Sonomura, K. Tanaka & T. Miyauchi, *J. Appl. Phys.* **50,** 6344 (1979).
5. O.N. Ermakov, R.S. Ignatkina, A.P. Karatsyuba, V.P. Sushkov & V.F. Aksenov, *IEEE Trans. Electron. Devices* **ED-30,** 268 (1983).
6. J.M. Rodríguez, G. Armelles & P. Salvador, *J. Appl. Phys.* **66,** 3929 (1989).
7. D.P. Bour, J.R. Shealy, A. Kasendzov & P. Pollak, *J. Appl. Phys.* **64,** 6456 (1988).
8. J.M. Dishman, D.F. Daly & W.P. Knox, *J. Appl. Phys.* **43,** 4693 (1972).
9. F. Domínguez-Adame, J. Piqueras & N. de Diego, *Solid State Commun.* **67,** 665 (1988).
10. F. Domínguez-Adame & J. Piqueras, *Mat. Chem. and Phys.* **21,** 539 (1989).
11. F. Domínguez-Adame, J. Piqueras, N. de Diego & J. Llopis, *J. Appl. Phys.* **63,** 2583 (1988).