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B—1—3 Cathodoluminescence around Dislocations in an LEC-GaP Crystal

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Introduction The characterization of LEC-GaP crystals is very important to improve the efficiency of light emitting diodes, since various defects inherent to LEC crystals are reported to be strongly related to the green and/or red radiative recombination process. In this report we evaluate an LEC-GaP crystal by the cathodoluminescence (CL) method and the chemical etching method. The CL method has a great advantage in the evaluation of LEC crystals, because the CL signal directly reflects the radiative recombination process and because this method has the micron-sized spatial resolution. We investigate the luminescence properties in the vicinity of individual dislocation revealed by the etching method.

Experimental The sample used in this study was a <111> oriented, S-doped, LEC-GaP wafer with a carrier concentration of 3×10^{18} cm^{-3}. The etch-pit observations were performed on the $(\bar{1}\bar{1}\bar{1})$ P surface, which was mirror polished, pre-etched with chlorine-saturated methanol, and then preferentially etched with RC solution at 65°C for 4 min. The CL measurement was performed on the RC-etched $(\bar{1}\bar{1}\bar{1})$ P surface with an electron-probe microanalyzer which was modified to collect the emission light produced by electron-beam-excited recombination. An accelerating voltage of 30 kV and a specimen current of 1 μA were used in the measurement, and the electron beam measured about 2 μm in diameter. The emission light was analyzed with a grating monochromator and an S-1 type photomultiplier (RCA 7102). The electron beam was scanned two dimensionally on the sample surface, and the monochromatic emission intensity image was displayed on a cathode-ray tube.

Results and discussion The typical cathodoluminescence spectrum of the sample at room temperature is shown in Fig. 1. The photoresponse of the measurement system was not calibrated. The spectrum consists of two main bands; one is the green emission band (G-band) which has a peak at a wavelength of about 560 nm, and the other is the red emission band (R-band) which is rather broad and has a peak at about 710 nm. The local variations of the band shape and of the peak wavelength for the G- and R-bands were not recognized in the wafer. However, the intensities of the two bands change abruptly in the vicinity of dislocations. A strong correlation of intensity between the two bands was noticed in this area.

A typical example of the correspondence between the dislocations and the CL features is shown in Figs. 2 and 3. Figure 2 shows the optical photomicrograph of etch grooves and dislocation pits (D-pits). These etch grooves are believed to be attributed to dislocations lying on, or just under, the $(\bar{1}\bar{1}\bar{1})$ P surface. The back-scattered electron image of the same area of the wafer is presented in Fig. 3(a). The monochromatic CL intensity images of exactly the same area as in Fig. 3(a) are shown in Figs. 3(b) and (c). The CL intensity image at a wavelength of 560 nm which gives a peak of the G-band is shown in Fig. 3(b), where the whiter part corresponds to the stronger intensity part. Figure 3(c) shows the CL intensity image at 710 nm which gives a peak of the R-band. These two CL images show a striking contrast. The intensity of the G-band decreases in the vicinity of the dislocation grooves and the D-pits, whereas that of the R-band increases in the same region.

In the vicinity of dislocations it has been reported that impurities and micro-defects segregate at the dislocations, causing dark regions in photoluminescence[1] and electroluminescence.[2] This may explain the reduction of the intensity of the G-band around the dislocations. However, there has been no report on such an enhancement of the luminescence intensity around dislocations as in the case of the R-band. Further details of the recombination mechanisms for the G- and R- bands are now under investigation.

References 1) G.A. Rozgonyi et al.: Appl. Phys. Lett. 19 (1971) 153.
2) G.B. Stringfellow et al.: J. Electron. Mater. 3 (1974) 497.

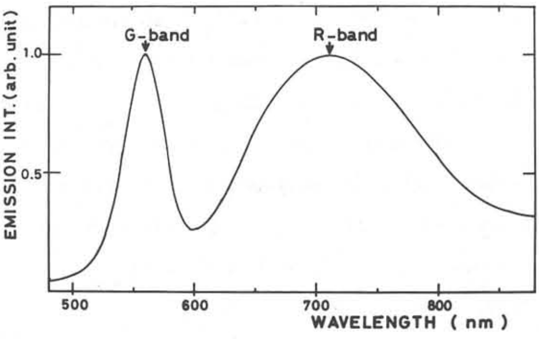

Fig. 1. Cathodoluminescence spectrum of an S-doped LEC-GaP crystal at room temperature.

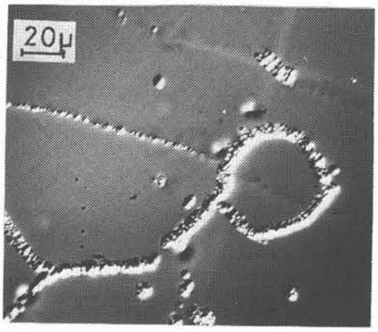

Fig. 2. Optical photomicrograph of etch grooves and D-pits on $(\bar{1}\bar{1}\bar{1})$ P surface of an LEC wafer.

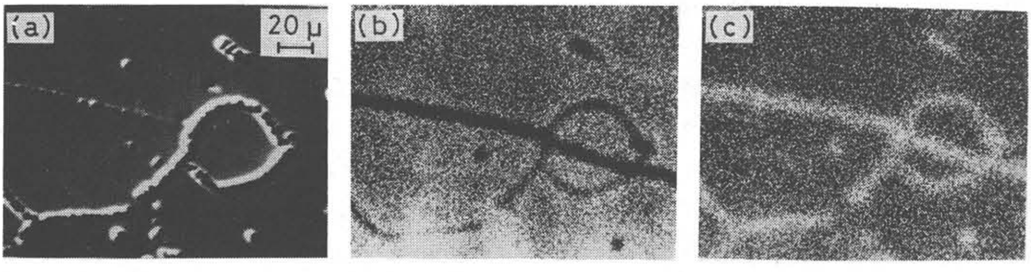

Fig. 3. Micrographs of an electron-probe microanalyses of the same area as in Fig. 2; (a) backscattered electron image; (b) monochromatic CL intensity image at 560 nm (G-band); (c) monochromatic CL intensity image at 710 nm (R-band).