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Nondestructive Observation of Microdefects in GaAs Wafers by Photothermal-Radiation Microscope

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Highly uniform GaAs wafers are needed for high speed ICs and optoelectronic ICs applications. The present GaAs wafer, however, includes various defects (dislocations, microdefects, etc.) which result in inhomogeneities of electrical properties and device performance. At present, there is no method of providing a simple rapid nondestructive means for evaluation of the defects in GaAs wafers.

In this report, we demonstrate that photothermal-radiation (PTR) microscope [1] can provide a nondestructive rapid means for observation of microdefects in GaAs wafers at room temperature. We measured PTR spectra (excitation energy vs. PTR signal) and PTR images to investigate nonradiative states due to the defects and spatial distribution of the defects, respectively.

Figure 1 shows a schematic diagram of the measurements of PTR spectra and PTR images. A tunable dye (HITC) laser (850$\sim$920 nm, $\sim$80 mW) excited with a Kr ion laser (red multiline, 5W) was used as a light source. The laser beam was chopped with a mechanical chopper ($\sim$330 Hz) and focussed on a spot of about 200 μm diameter at the sample surface. Thermal radiation emitted from the heated spot was detected with a photoconducting HgCdTe IR detector (NERC, MPC11-2-AD1) which is sensitive to the radiation in wavelength ranging from 8 to 13 μm. To normalize the PTR signals by irradiation-light intensity, we used a reflecting light from a beam splitter. We designed the experimental setup so that we could measure PL images at room temperature. A Kr ion laser (red multiline, $\sim$150 mW) was used as an excitation light source. The wavelength range of the final PL signal was from 0.83 to 0.96 μm.

Figure 2 shows PTR spectra of dislocated n-GaAs wafers (Si-doped, (100)-oriented, 1 $\sim$ 3x10^{-3} Ωcm, 300 $\sim$ 400 μm thick) with higher etch pit density ; EPD (10^4cm^{-2} < EPD < 10^5cm^{-2}) and lower EPD (< 10^4cm^{-2}). The bandgap energy of GaAs (1.43eV at room temperature) is indicated by Eg. The PTR spectra of the GaAs wafer with higher EPD has a peak at the wavelength of about 895nm. It is considered that the PTR peak is caused by the increase of optical absorption and nonradiative relaxation at defects.

Figures 3 and 4 show PTR image and PL image of a dislocated n-GaAs wafer, respectively. The PTR image was obtained by using excitation light at the wavelength of 895 nm. The time to get the PTR image was about 90 minutes. Dark area in Figs.3 and 4 indicate high intensity area of the signals. The increase of PTR signals in Fig.3 corresponds to the decrease of PL signals in Fig.4. The PTR signal gives direct imformation on the nonradiative process at defects (microdefects or dislocations) in GaAs wafers.

Figure 5 shows PTR spectra at 3 measuring points in an In-doped n-GaAs wafer (Si-doped, $\sim$1x10^{-3} Ωcm). The measuring points are indicated by A, B and C in X-ray

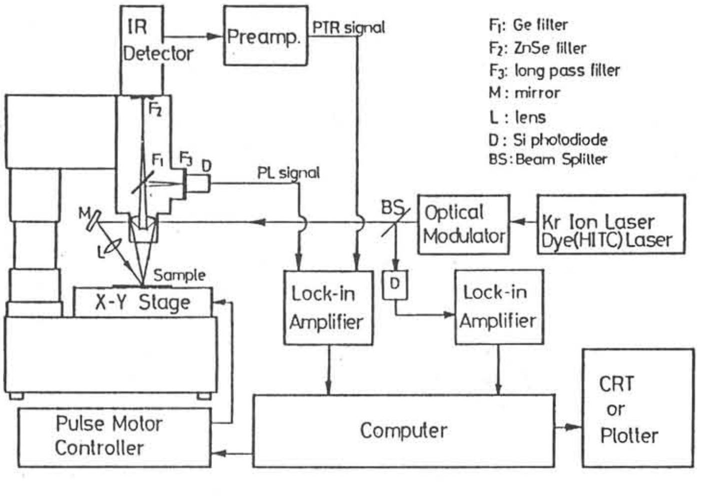

Fig.1

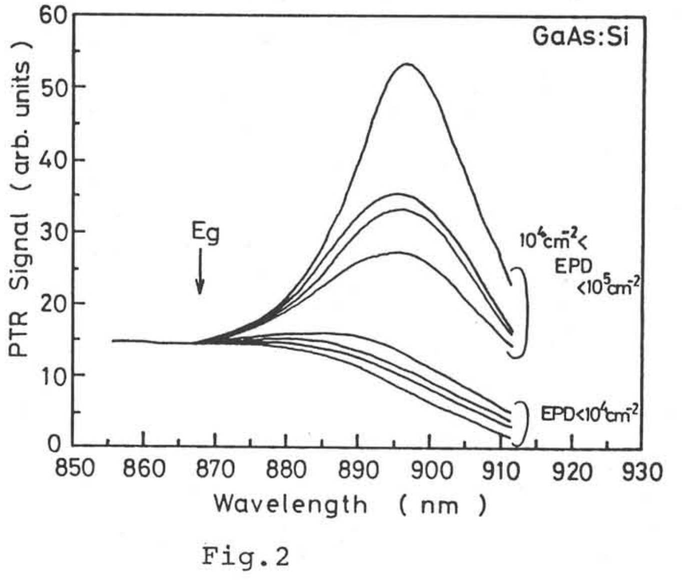

Fig.2

topograph (Fig.6). The point A and B are dislocated points and the point C is dislocation-free point. As shown in Fig.5, the PTR spectra at dislocation-free point (C) as well as dislocated points (A and B) have peaks at the wavelength of about 903nm. This result shows that the PTR peak in Fig.5 is caused by nonradiative states due to microdefects rather than dislocations. We found the discrepancy between the value of wavelength at the PTR peak in Fig.2 and that in Fig.5. The shift of the PTR peak from 895nm to 903nm seems to be caused by the change in the band gap energy of GaAs due to In-doping. We conjecture that the PTR peak ($\sim$ 895nm) in Fig.2 and the PTR peak ($\sim$ 903nm) in Fig.5 are caused by the same microdefects. It was reported that the mid-gap defect EL2 has shallow levels as well as deep levels [2]. There is a possibility that the PTR peaks in Figs.2 and 5 are caused by the shallow levels of microdefect EL2. To confirm the correlation between the PTR image and the distribution of EL2 defects, we will measure IR ($\sim$ 1μm) transmission topograph in near future.

Figures 7 and 8 show PTR image and PL image of the In-doped n-GaAs wafer, respectively. The PTR image in Fig.7 was obtained by using excitation light at the wavelength of 903nm. The PTR image (Fig.5) shows clear inhomogeneity of microdefect density which is not observed in X-ray topograph (Fig.6), in contrast to the indistinct PL image.

In summary, we have demonstrated that the present PTR microscope can provide a nondestructive rapid means for observation of microdefects in GaAs wafers at room temperature. Up to now, IR transmission topography has been proposed as a useful observation technique for the microdefects [3]. In the IR transmission topography, however, GaAs samples must be prepared with large thickness of 3$\sim$5 mm and both the surface must be polished. On the other hand, we could nondestructively evaluate GaAs wafers (300$\sim$400 μm) on the market with the present PTR microscope.

References

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[3] M. R. Brozel, I. Grant, R. M. Ware and J. D. Stirland: Appl. Phys. Lett. 42 (1983) 610.

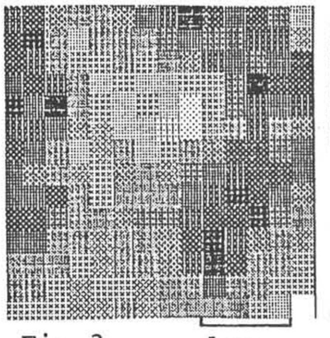

Fig.3 1cm

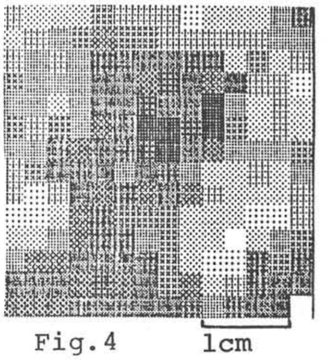

Fig.4 1cm

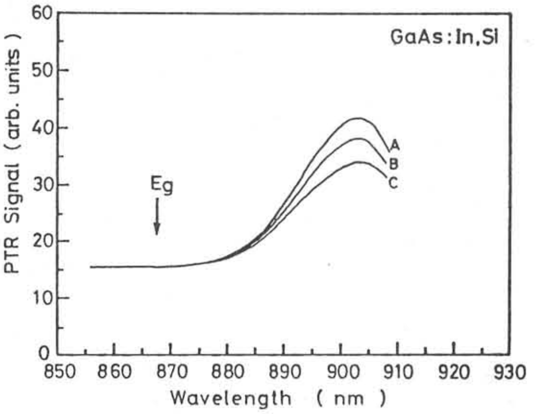

Fig.5

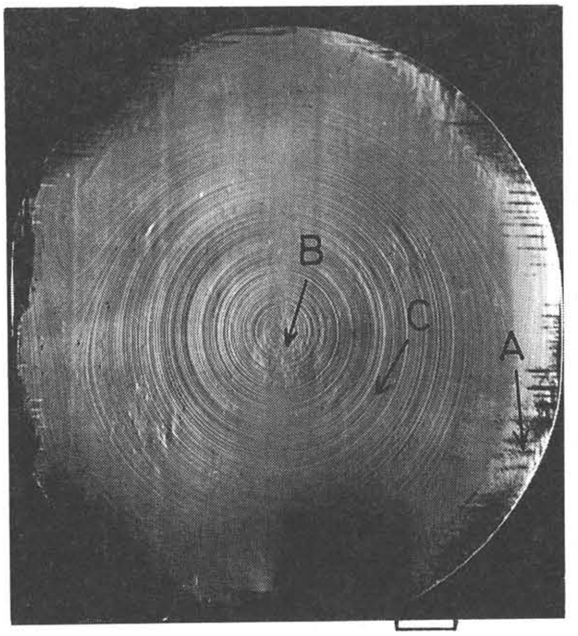

Fig.6 5mm

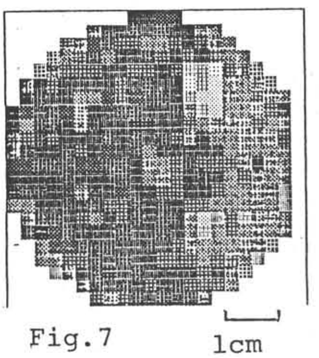

Fig.7 1cm

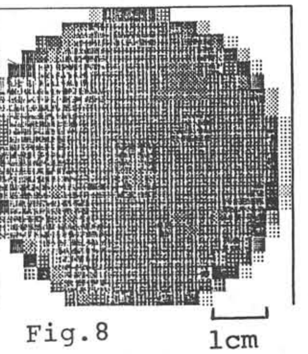

Fig.8 1cm