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B-3-3 Photoluminescence Observation of Defects in Silicon

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Two simple, rapid and nondestructive methods of evaluating defects in silicon were developed. These methods are based on the photoluminescence (PL) measurements at room temperature; i.e., a PL profile measurement and a PL topography[1)] (PL pattern observation). PL profile measurement reveals the macroscopic defect distribution, such as swirl defects. On the other hand, PL topography provides information about microscopic defects, e.g. dislocations and stacking faults.

PL profile measurements were carried out by using a Perkin-Elmer E-1 grating spectrometer and an RCA 7102 photomultiplier. A cw Ar ion laser with a maximum output of 1 W at 5145 Å was used to optically excite the samples. The laser beam focused on the sample to a spot approximately 50 μm in diameter was scanned on the samples. PL topographs were taken with a combination of an infra-red vidicon TV camera (Hamamastu, C158), an IR-transmitting filter and a conventional optical microscope by scanning the focused laser beam (200 μm in diameter) on the surface of the sample.

Figure 1 shows the PL profile for a neutron transmutation doped (ND) crystal corresponding to swirl pattern. Photomacrograph of the sample which was Sirtl etched after PL measurement is also shown in Fig. 1. Here it can readily be seen that the PL intensity is high at the low defect density region and vice versa. Since swirl defects are identified as dislocation loops and agglomerates of silicon self-interstitials,[2)] which have many dangling bonds, it is quite possible that they act as non-radiative recombination centers at room temperature. The usefulness of this method was also demonstrated by observing the gettering effects. The details will be presented.

The correlation between the PL topograph and the defects was examined by preferential etching. Stacking faults and dislocations were found to be observed as dark spots in PL topograph as in GaAs-GaAlAs double heterostructure crystals.[3,4)] A comparison of the PL topograph results and the defects delineated by 3 min. Wright etch in an oxidized n-type wafer is shown in Fig. 2. All dark spots in the PL topograph correspond to etch figures indicated by triangles. Among them, surface stacking faults which produce an etch figure similar to an extended partial disk, correspond to deep dark spots in the PL topograph. On the other hand, etch mounds in Fig. 2 (c) correspond to dim dark spots in the PL topograph. An additional 5 min. Wright etch revealed these defects as full loops, which are due to bulk stacking faults. It was also demonstrated that dislocations introduced in the cource of LSI fabrication could be nondestructively observed by PL topography.

In conclusion, a combination of a PL topography and a PL profile measurement is shown to provide a simple, rapid and nondestructive method of evaluating defects in silicon, which are introduced during crystal growth and wafer processing.

1) R. Ito et al., Japan. J. Appl. Phys. 12, 1272 (1973)

2) H. Föll et al., J. Crystal Growth 40, 90 (1977)

3) R. Ito et al., J. Quantum Electron. QE-11, 551 (1975)

4) S. Kishino et al., Appl. Phys. Letters 27, 207 (1975)

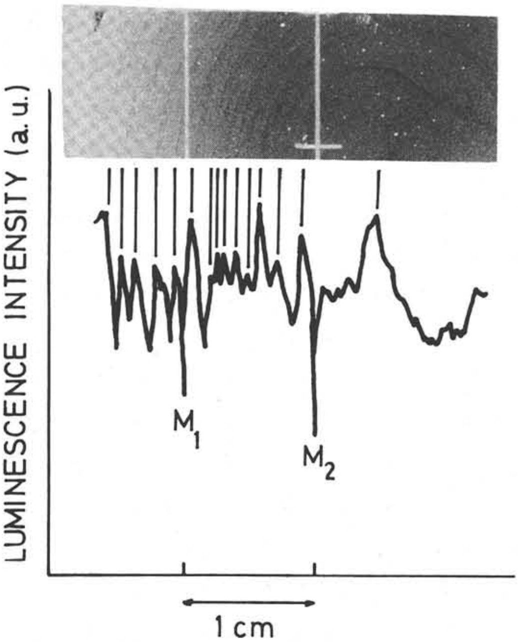
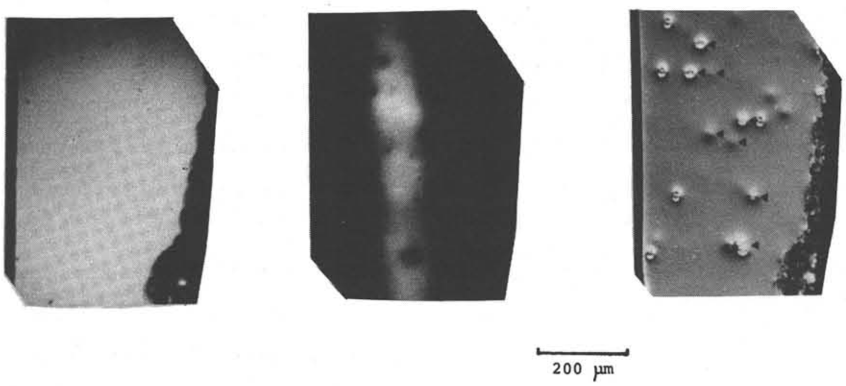


Fig. 1 PL profile of an FZ ND crystal corresponding to swirl pattern. Photomacrograph shown above was taken after 3 min. Sirtl etch. A focused laser beam was scanned on the lowest part of the photomacrograph. M_1 and M_2 are markers.



(a) PHOTOMICROGRAPH OF THE SURFACE

(b) PHOTOLUMINESCENCE TOPOGRAPH

(c) DIFFERENTIAL INTERFERENCE CONTRAST PHOTOMICROGRAPH OF THE SURFACE AFTER WRIGHT ETCH

Fig. 2 Correlation between PL topograph and stacking faults in an oxidized silicon wafer. Defects indicated by triangles closely correspond to dark spots in PL topograph.