Designation: F 358 – 83 (Reapproved 2002)

# Standard Test Method for Wavelength of Peak Photoluminescence and the Corresponding Composition of Gallium Arsenide Phosphide Wafers [1]

This standard is issued under the fixed designation F 358; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the techniques used to determine the wavelength of the photoluminescence peak and the mole percent phosphorus content of gallium arsenide phosphide, GaAs $_{(1x)}P_x$.

1.2 Photoluminescence measurements indicate the composition only in the illuminated region and only within a very short distance from the surface, a distance limited by the penetration of the radiation and the diffusion length of the photo-generated carriers, as contrasted to X-ray measurements which sample a much deeper volume.

1.3 This test method is limited by the surface preparation procedure to application to epitaxial layers of the semiconductor grown in a vapor-phase reactor on a flat substrate. It is directly applicable to *n*-type GaAs $_{(1x)}P_x$ with the wavelength, $\lambda_{PL}$, of the photoluminescence peak in the range from 640 to 670 nm, corresponding to mole percent phosphorus in the range from 36 to 42 % ($x$ = 0.36 to 0.42). The calibration data provided for the determination of $x$ from $\lambda_{PL}$ is applicable to material doped with tellurium or selenium at concentrations in the range from $10^{16}$ to $10^{18}$ atoms/cm$^3$.

1.4 The principle of this test method is more broadly applicable. Other material preparation methods may require different surface treatments. Extension to other dopants, doping ranges or composition ranges requires further work to relate $\lambda_{PL}$ to the phosphorus content as determined by X-ray measurements of the precise dimensions of the unit cell upon which the calibration data are based. It is essential that calibration specimens have uniform composition in the volume sampled.

1.5 This test method is essentially nondestructive. It requires a light etching of the sample to be measured. The removal of a layer of material approximately 0.5 to 1.0 µm in thickness is required. This etching does not degrade the specimen in that devices can still be fabricated from it.

1.6 This test method is applicable to process control in the preparation of materials and to materials acceptance.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazard statements are given in Section 7.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 1125 Test Methods for Electrical Conductivity and Resistivity of Water[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[3]

E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near-Infrared Spectrophotometers[4]

2.2 *SEMI Standard:*

C1 Specifications for Reagents[5]

## 3. Summary of Test Method

3.1 The photoluminescence spectrum is recorded for the wavelength range from 600 to 750 nm and the wavelength, $\lambda_{PL}$, at which maximum luminescence occurs is determined by means of a graphical construction. The phosphorus content is then determined by means of a calibration curve relating $\lambda_{PL}$ to the amount of phosphorus as determined by X-ray measurement of the precise dimension of the unit cell.

## 4. Interferences

4.1 The apparent position of the photoluminescence peak can be distorted by the spectral response characteristics of the detection system, and, in particular, by the spectral response of the photomultiplier. Therefore, the detector to be used for measurements on a specific range of alloy compositions should be chosen so that the corresponding range of $\lambda_{PL}$ falls in a region where the detector response is changing slowly.

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[1] This test method is under the jurisdiction of Committee F01on Electronics and is the direct responsibility of Subcommittee F01.15 on Compound Semiconductors.

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[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.06.

[5] Available from Semiconductor Equipment and Materials Institute, 625 Ellis St., Suite 212, Mountain View, CA 94043.

4.2 The presence of strong background radiation and, in particular, of background radiation which changes rapidly with wavelength can displace the apparent position of the photoluminescence peak. Users should, therefore, assure themselves that the background radiation is small by replacing the sample with a mirror and scanning through the wavelength range of interest. The resulting trace should be a small fraction of the photoluminescence signal.

4.3 Since the energy of the band gap of most semiconductors, and of GaAs $_{(1x)}P_x$ in particular, varies with temperature, the measurement of $\lambda_{PL}$ can be perturbed if the incident power density from the illuminator is high enough to locally heat the specimen. Users of this technique should, therefore, assure themselves that they are not using too high a power density by measuring $\lambda_{PL}$ as a function of incident power, by using neutral density filters or other means. There should be no variation if the power level is low enough; $\lambda_{PL}$ will shift to longer wavelengths with increasing power if power is excessive.

## 5. Apparatus

5.1 *For Specimen Preparation*—Chemical laboratory apparatus such as plastic beakers, plastic-coated tweezers suitable for use with acids, and adequate facilities for handling and disposing of acids and their vapors must be provided.

5.2 *For Measurement of Specimen Photoluminescence* (see Fig. 1):

5.2.1 *Light Source*, a 200-W mercury or xenon arc lamp, a laser, or other source, with suitable filtration and focusing lens to illuminate the specimen with radiation at a wavelength shorter than 600 nm with a total incident energy of at least 1 mW in an area 1 $mm^2$ or less.

5.2.2 *Specimen Support*—A holder that can support the specimen in such a position that the incident radiation strikes it in a position that can be viewed by the collection optics of the monochromator. The holder should not damage the surface of the specimen and preferably should not touch the surface. It should also allow the controlled movement of the specimen in its own plane so that the luminescence of a desired portion of the specimen can be measured.

5.2.3 *Collection Optics*—A system of lenses and filters arranged to image the illuminated region of the specimen onto the entrance slits of the monochromator. It is important that the illuminating radiation be kept out of the monochromator either by filtration or by positioning of the specimen with respect to the illuminating radiation so that the specularly reflected rays do not enter the collection system, or both. Fig. 1 shows a schematic diagram of a system in which the effects of the reflected illumination are minimized by suitable positioning.

5.2.4 *Monochromator*, designed to operate in the 600 to 750-nm wavelength range with wavelength accuracy and repeatability of 0.5 nm as determined in accordance with Practice E 275.

5.2.5 *Detector*—A photomultiplier tube with constant or slowly varying spectral sensitivity throughout the range of interest.

NOTE 1—In the absence of data to the contrary, a variation of no more than 10 % in sensitivity in any 10-nm region of the spectral range of interest as determined from the manufacturer's published sensitivity curves for the tube shall be deemed acceptable.

5.2.6 *Detector Electronics*—Electronics capable of supplying the high voltage required by the photomultiplier and of detecting and amplifying the anode current from the photomultiplier so that it can drive the chart-recorder electronics.

5.2.7 *Detection System Sensitivity*—The detection system, consisting of collection optics, monochromator, detector, and detector electronics, should be capable of responding to a luminescence signal of $10^{-6}$ mW/nm or less as calculated from the following equation:

$$B = Sf^2/(WmTDG)$$

where:

- $B$ = luminescence signal, mW/nm,
- $S$ = minimum detectable signal at the output electronics, typically 10 times the detector dark current, mA,
- $f$ = the lesser of the speeds (f numbers) of the collection optics or the monochromator,
- $W$ = monochromator bandwidth, nm,
- $m$ = efficiency of the grating (assume $m = 0.5$ in the absence of other data),
- $T$ = mean transmission of the filters between the specimen and the monochromator in the band from 640 to 670 nm,
- $D$ = mean detector sensitivity, mA/mW, and

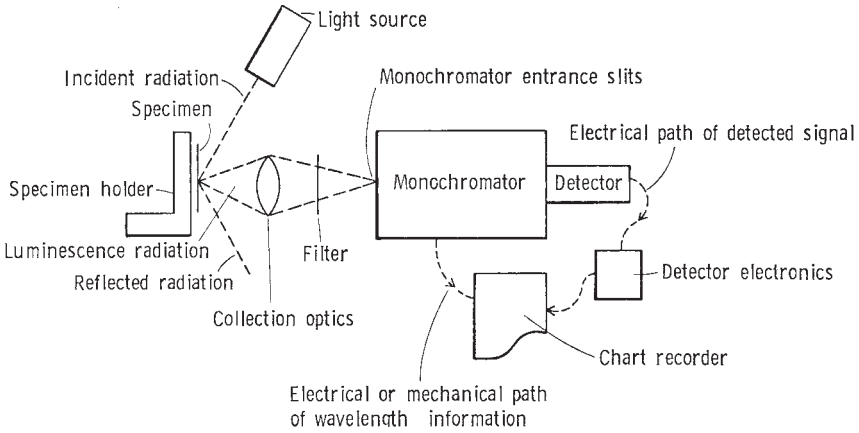


**FIG. 1 Schematic Diagram of Photoluminescence Apparatus**