Designation: F 95 – 89 (Reapproved 2000)

Standard Test Method for Thickness of Lightly Doped Silicon Epitaxial Layers on Heavily Doped Silicon Substrates Using an Infrared Dispersive Spectrophotometer[1]

This standard is issued under the fixed designation F 95; 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.

INTRODUCTION

In editions of this test method published through 1987, the title and scope of the method required that the epitaxial layer and substrate be of the same conductivity type. This requirement was dropped, allowing the epitaxial layer and substrate to be of opposite conductivity type in the revision first published in 1988, subject to the continuing requirements of minimum allowed resistivity of the epitaxial layer and maximum allowed resistivity of the substrate. This same revision changed specifications on dispersive instruments from wavelength values to wave number values, where appropriate. A brief description of the theory of this test method is given in Appendix X1.

Automated test systems, utilizing Fourier-Transform Infrared Spectrophotometry (FT-IR) are widely used for epitaxial layer thickness measurements. Because such instruments are normally supplied with proprietary software for measurement analysis, detailed procedures for the use of such instruments are not included in this test method. However, for information purposes, estimates of single instrument repeatability and multiinstrument reproducibility, based on a 1986/1987 multilaboratory comparison of FT-IR instrument measurements are given in Note 6 and Appendix X2.

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1. Scope

1.1 This test method[2] provides a technique for the measurement of the thickness of epitaxial layers of silicon deposited on silicon substrates. A dispersive infrared spectrophotometer is used. For this measurement, the resistivity of the substrate must be less than 0.02 Ω·cm at 23°C and the resistivity of the layer must be greater than 0.1 Ω·cm at 23°C.

1.2 This technique is capable of measuring the thickness of both *n*- and *p*-type layers greater than 2 μm thick. With reduced precision, the technique may also be applied to both *n*- and *p*-type layers from 0.5 to 2 μm thick.

1.3 This test method is suitable for referee measurements.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

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

E 932 Practice for Describing and Measuring Performance of Dispersive Infrared Spectrophotometers[4]

F 84 Test Method for Measuring Resistivity of Silicon Slices with an In-Line Four-Point Probe[5]

3. Terminology

3.1 *Definitions:*

[1] This test method is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.06 on Silicon Materials and Process Control.

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[2] DIN 50437 is an equivalent method. It is the responsibility of DIN Committee NMP 221, with which Committee F-1 maintains close technical liaison. DIN 50437. Testing of Inorganic Semiconductor Materials: Measurement of the Thickness of Silicon Epitaxial Layers by the Infrared Interference Method, is available from Beuth Verlag GmbH Burggrafenstrasse 4-10, D-1000 Berlin 30, Federal Republic of Germany and Vol 10.05.

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

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

[5] *Annual Book of ASTM Standards*, Vol 10.05.

3.1.1 *epitaxial layer—in semiconductor technology*, a layer of semiconductor material having the same crystalline spacing as the host substrate on which it is grown.

3.1.2 *index of refraction*—the relative index of refraction is defined by Snell's law as the ratio of the sine of the angle of incidence to the sine of the angle of refraction. The angles are measured between the surface normal and the infrared beam. The value of this index for the wavelength range from 6 to 40 μm is 3.42 relative to air for silicon having resistivity greater than 0.1 Ω·cm.

3.1.3 *interface*—the boundary between the substrate and the epitaxial layer as determined by this technique.

3.1.4 *substrate—in semiconductor technology*, a wafer that is the basis for subsequent processing operations in the fabrication of semiconductor devices or circuits.

3.1.4.1 *Discussion*—The devices or circuits may be fabricated directly in the substrate or in a film of the same or another material grown or deposited on the substrate.

4. Summary of Test Method

4.1 The reflectance of the specimen is measured as a function of wave number using an infrared spectrophotometer. The reflectance spectrum of a suitable specimen exhibits successive maxima and minima characteristic of optical interference phenomena. The thickness of the epitaxially deposited layer is calculated using the wave numbers of the extrema in the reflectance spectrum, the optical constants of the layer and the substrate, and the angle of incidence of the infrared beam upon the specimen.

5. Apparatus

5.1 *Double-Beam Infrared Spectrophotometer*—This apparatus shall utilize monochromatic infrared light of known and variable wave numbers. This light shall be reflected from the specimen and the reflectivity shall be recorded as a function of wave number. It is essential that the wave numbers indicated by the apparatus be carefully calibrated. Calibration accuracy shall be determined in accordance with Practice E 932E 932, using polystyrene lines at 1601.6 and 648.9 cm^{-1}. The calibration accuracy shall be 0.05 μm. The useful range of wave number is 1670 to 250 cm^{-1}. The precision and thickness capabilities stated in Section 11 were established using data in the range 900 to 300 cm^{-1}. In general, thinner specimens require a broader wavelength range than thicker ones.

5.2 *Specimen Holder*— The specimen holder shall be so constructed that no damage can be inflicted by the holder on the epitaxial layer.

5.3 *Masking Aperture*— The size of the masking aperture shall be such as to restrict the illuminated area on the specimen surface to a value sufficiently small to eliminate the effect of thickness fluctuations, without impairing detection of the reflected light. The masking aperture shall be constructed from a nonreflecting material such as matte-surface graphite.

6. Test Specimen

6.1 The specimen surface shall be highly reflective, free from large-area imperfections, and free of passivating layers except native oxides. The specimen surface may be cleaned prior to measurement by any technique which does not affect the specimen polish or the layer thickness.

7. Preparation of Apparatus

7.1 Establish the maximum allowable scan speed as follows:

7.1.1 Choose a specimen with a substrate resistivity between 0.008 and 0.02 Ω·cm, (see Scope) and an epitaxial layer of such thickness that an observable minimum occurs at a wave number less than 400 cm^{-1}.

7.1.2 Choose a suitable masking aperture.

7.1.3 Place the specimen on the instrument and record the spectrum of a minimum wave number less than 400 cm^{-1} using the slowest scan speed available.

7.1.4 Record the position of the minimum.

7.1.5 Increase the scan speed in steps and record the position of the minimum for each scan speed.

7.1.6 Allowable scan speeds are those which show a shift of the minimum of less than ± 1 cm^{-1} relative to the position of the minimum as determined at the slowest scan speed.

8. Procedure

8.1 Handle the specimen carefully to avoid surface damage to the thin epitaxial layer.

8.2 Place the specimen over the aperture mask to expose the desired location to the beam.

8.3 Obtain a reflection spectrum similar to that shown in Fig. 1. Do not attempt a calculation of layer thickness if the peak amplitude to noise amplitude ratio is less than five.

NOTE 1—The interference pattern may be obscured or illegible if the

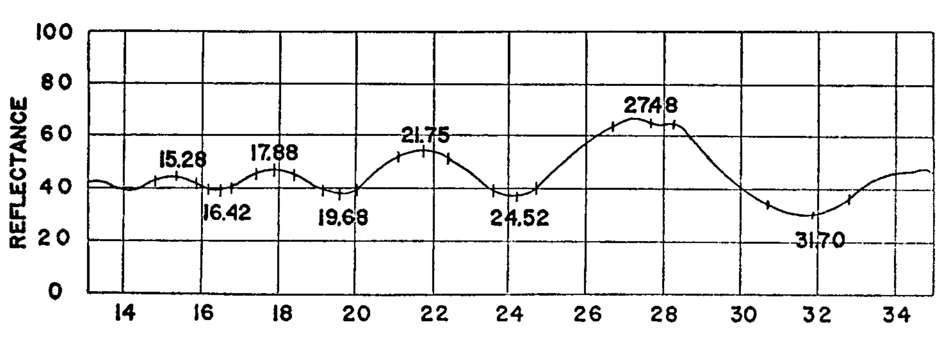

FIG. 1 Typical Reflection Spectrum for n-Type Specimen