IBM

TWO-WAVELENGTH (2-λ) IN-SITU L104B ELLIPSOMETER

SUPPLEMENTAL INSTRUCTIONS

Gaertner Scientific Corporation
1201 West Wrightwood Avenue, Chicago, IL, 60614
SUPPLEMENTAL INSTRUCTIONS  TWO-WAVELENGTH (2-λ) IN-SITU L2W04B.830 ELLIPSOMETER

INTRODUCTION

This supplemental instruction, on colored sheets included in the standard (single-wavelength) L104B manual, is for a two-wavelength (2-λ) In-Situ L2W04B.830 Ellipsometer with two lasers: a diode laser that operates in the infrared region, which is from 770 to 850 nanometers. But most of these lasers operate at 830 nm. The standard laser for the single-wavelength L104B is a helium-neon one at 633 nm. There is a wavelength selector lever (W) on the side of the analyzer module. The red (633 nm) laser beam is selected when selector W is out, and the infrared (diode) laser beam is selected when the lever is in. The diode laser has its own power supply with a key-operated ON/OFF power switch and digital current display. The current should be between 55 and 65 milliamperes and should not change more than one milliampere. See the associated connection diagram of the 2-λ In-Situ Ellipsometer instead of Figure B1 in the Installation section (Appendix B) of the L104B manual.

LASER SAFETY

Because the laser operation is Class IIIb for the two-wavelength L104B Ellipsometer, the warning logotype on the polarizer says "DANGER" (see the attached colored Laser Safety sheet) instead of "CAUTION" (for Class II) as shown on the white (page vi) Laser Safety sheet in the standard manual. Then disregard the white Laser Safety sheet.

LASER RETARDATION

At the end of this manual should be instructions for the GPIO, GPIB and VGA Plus card assemblies. Page 2 and Figure 2 concern red and infrared laser retardation and show DIP switches on the GPIO card. The diode laser retardation is less than 90.

ANGLES OF INCIDENCE

If a special L104SA Support is included with this ellipsometer, this support has angle of incidence detents for 30°, 45°, 50° and 70° for measurements. There is also a detent at 90° for adjustments.

SOFTWARE

The standard program for the L104B is GC4A. For the L2W04B.830, the standard program is 2GC4A. The difference between the two programs is that the 2GC4A allows the user a choice of the two wavelengths. For the polarizer and analyzer components on the L104SA, the 2-λ STD (2STD) program is included plus the optional 2-λ single-point programs that were ordered. The 2GC6A, for example, is the 2-λ version of the GC6A program.
ATTACH CABLE TO THE DIODE LASER POWER SUPPLY WITH THE BLACK CAP UP

Figure B1 2-λ In Situ Ellipsometer L104B Interconnection Diagram.
DESCRIPTION

TWO-WAVELENGTH L104B ELLIPSMETER

LIGHT (ROTATING AND CHANGING IN AMPLITUDE AS THE DRUM ROTATES)

ELLIPTICALLY POLARIZED LIGHT

SAMPLE

CIRCULARLY POLARIZED LIGHT (+90° COMPENSATOR IN THE LIGHT PATH)

+90° COMPENSATOR IN THE LIGHT PATH

LINEARLY POLARIZED LIGHT

POLARIZER PRISM

DEPOLARIZER

RED LASER

BEAM COMBINER

PULSAR DRUM (MANUALLY TURNED)

CIRCULARLY POLARIZED LIGHT

SHUTTER

DIODE LASER

ATTENUATOR

RED FILTER

DIFFUSER

IR FILTER

PHOTODETECTOR

ANALYZER DRUM (ROTATES IN AUTOMATIC)

ANALYZER MODULE

POLARIZER MODULE

*The LED meter is not on either arm.

Figure 1A. Two-Wavelength L104B In-Situ Optical System Functional Diagram
GOVERNING REGULATION

The 2-\(\lambda\) L104B Ellipsometer has a helium-neon and a diode laser light source. The accessible radiation does not exceed two milliwatts and, therefore, is classified a Class IIIb laser product as defined by 21CFR 1040.10. Appropriate WARNING Logotypes and Certification and Aperture labels are attached to the ellipsometer components to alert users and service personnel of the presence of laser radiation during operation.

WARNING Logotype.

Affixed to the laser housing and reads: Visible and/or invisible laser radiation - avoid direct exposure to beam.

APERTURE Label.

Affixed to the exit aperture of the polarizer module and reads: AVOID EXPOSURE. LASER RADIATION IS EMITTED FROM THIS APERTURE.

CERTIFICATION Label.

Attached to the electronic unit front panel left side and reads: THIS LASER PRODUCT COMPLIES WITH DHEW/BRH RADIATION PERFORMANCE STANDARDS 21CFR SUBCHAPTER J.

CAUTION

Use of controls or adjustments or performances of procedures other than those specified herein may result in hazardous radiation exposure.
1. The compensator fast axes have been precisely set to the polarizer.

2. With the stop block clamped in the up position and the solenoid de-energized, the No Comp opening is centered.

3. When the solenoid is energized, the $+90^\circ$ compensator is pulled to the center.

4. With the stop block lowered and clamped in the down position, the $+45^\circ$ compensator is centered.
USER MANUAL

IN-SITU AUTO-GAIN ELLIPSOMETER L104B

GAERTNER SCIENTIFIC CORPORATION
1201 W. Wrightwood Avenue, Chicago, IL, 60614
WARRANTY

ALL OF THE OPTICAL, MECHANICAL AND ELECTRICAL COMPONENTS OF THE L104B IN-SITU ELLIPSOMETERS, INCLUDING THE LASERS, ARE WARRANTED FOR ONE YEAR FROM THE DATE OF DELIVERY. ANY DEFECTS IN THE MATERIAL OR WORKMANSHIP WILL BE CORRECTED BY GAERTNER AT NO COST. SHIPPING CHARGES, TRAVEL AND LODGING COSTS INCURRED BY THE SERVICE PERSONNEL ARE NOT COVERED BY THIS WARRANTY. THE WARRANTY ON DEFECTS IN MATERIAL OR WORKMANSHIP FOR THE COMPUTER EQUIPMENT SUPPLIED WITH THE L104B IN-SITU ELLIPSOMETERS APPLIES FOR 90 DAYS FROM THE DATE OF DELIVERY. THE COMPUTER MANUFACTURER WILL, AT ITS OPTION, REPAIR OR REPLACE EQUIPMENT THAT PROVES DEFECTIVE DURING THE WARRANTY PERIOD. REPAIRS NECESSITATED BY THE MISUSE OF THE EQUIPMENT, INCLUDING THE USE OF SOFTWARE OR INTERFACING NOT SUPPLIED BY GAERTNER, ARE NOT COVERED BY THIS WARRANTY. NO OTHER WARRANTY IS EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, IMPLIED WARRANTY OF MERCHANTABILITY AND SUITABILITY FOR A PARTICULAR PURPOSE. GAERTNER SHALL NOT BE LIABLE FOR THE CONSEQUENTIAL DAMAGES.
This manual contains a description and installation, operation and maintenance instructions for the In Situ, Auto Gain Ellipsometer L104B, designed and manufactured by Gaertner Scientific Corp., Chicago, Illinois.

The ellipsometer analyzes the effects of the reflection of the polarization of light directed upon the surface of materials, to acquire measurement data identifying properties critical to quality control. The interpretations of the data yield the optical constants of the material or, if the material surface is film-covered, the thickness and optical constants of the film. Once initiated by the operator, analysis and measurement are automatic, utilizing a programmed, desktop computer interfaced with the ellipsometer. Parameters are entered by the operator, using the computer keyboard. Queries requiring operator/computer interaction and actual measurement data are displayed on the computer viewing screen. Measurement data may be printed for permanent record.

The ellipsometer instrument package includes the computer interface cable and a set of software programs, supplied on either cassette or disc depending upon the type of computer used for measurement.

Program instructions supplement the information in the User Manual, and are included in Appendix A. Data entry requirements are identified in each set of program instructions.

The L104B installation instructions are in Appendix B.
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GOVERNING REGULATION

The L104B Ellipsometer has a helium-neon laser light source. The accessible radiation does not exceed one milliwatt and, therefore, is classified a Class II laser product as defined by 21CFR 1040.10. Appropriate WARNING Logotypes and Certification and Aperture labels are attached to the ellipsometer components to alert users and service personnel of the presence of laser radiation during operation.

WARNING Logotype.

Affixed to the laser housing and reads: LASER RADIATION. DO NOT STARE INTO BEAM.

APERTURE Label.

Affixed to the exit aperture of the polarizer module and reads: AVOID EXPOSURE. LASER RADIATION IS EMITTED FROM THIS APERTURE.

CERTIFICATION Label.

Attached to the electronic unit front panel left side and reads:

THIS LASER COMPLIES WITH DHEW/CDRH RADIATION PERFORMANCE STANDARDS 21CFR SUBCHAPTER J.

CAUTION

Use of controls or adjustments or performances of procedures other than those specified herein may result in hazardous radiation exposure.
AC POWER PLUGS

Great Britain, Cyprus, Nigeria, Rhodesia and Singapore

Australia and New Zealand

Eastern and Western Europe, Saudi Arabia, and United Arab Republic

UL Approved for the U.S., Canada, Japan, Mexico, Philippines and Taiwan

UL approved for the U.S.

Switzerland

NOTE: All plugs are for single-phase power and are viewed (above) from the connector end. The prongs are:

- L = Line or active conductor, also called "live" or "hot." The insulation is black.
- N = Neutral or identified conductor. The insulation is white.
- E = Earth or safety ground. The insulation is green.

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L104B ELLIPSMETER

1.0 SPECIFICATIONS

Electrical power(Vac): 3-wire, 115V, 50/60Hz (std); 100V, 220V, 230V, or 240V are available
Fuse: 3/4 ampere, slow blow
Light source: Helium-neon laser; 632.8 nm wavelength
Power output on sample: Less than 0.9 milliwatt, CDRH Class II
Optical compensator: +90° fixed orientation
Polarizer/analyzer drums: 360°, graduated at 1° intervals with 10-part vernier (0.1°)

Electronic unit

Outline dimensions: 5-1/2x13x17 in. (14x33x43 cm)
Weight: 18 lbs (8.2 kg)
Interface cable to computer: 6-1/2 ft (1.98 m)

Polarizer module

Weight: 12 lbs (5.7 kg)
Laser cable to electronic unit: 6 ft (1.83 m)

Analyzer module

Weight: 12 lbs (5.7 kg)
Interface cables to electronic unit: 6 ft (1.83 m)
Shipping weight: 55 lbs (25 kg)

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2.0 ABBREVIATIONS AND SYMBOLS

<table>
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<th>Definition</th>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>$N_f$</td>
<td>Real value of refractive index for film being measured</td>
<td>AMPL</td>
<td>Amplifier</td>
</tr>
<tr>
<td>$K_f$</td>
<td>Extinction value of refractive index for film being measured</td>
<td>AS</td>
<td>Autoset</td>
</tr>
<tr>
<td>$N_s$</td>
<td>Real value of refractive index for substrate</td>
<td>A/AUTO</td>
<td>Automatic</td>
</tr>
<tr>
<td>$K_s$</td>
<td>Extinction value of refractive index for substrate</td>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>$\phi$</td>
<td>(PHI) Angle of incidence</td>
<td>DET</td>
<td>Detector</td>
</tr>
<tr>
<td>$\psi$</td>
<td>(PSI) Amplitude ratio as determined by measurement</td>
<td>EBT</td>
<td>Encoder-buffer-turn off</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>(DELTA) Phase difference as determined by measurement</td>
<td>LED</td>
<td>Light-emitting diode</td>
</tr>
<tr>
<td>$A/D$</td>
<td>Analog-to-digital</td>
<td>LSB</td>
<td>Least significant bit</td>
</tr>
<tr>
<td>ADJ</td>
<td>Adjust</td>
<td>M/MAN</td>
<td>Manual</td>
</tr>
<tr>
<td>AEC</td>
<td>Analyzer to Electronic Chassis</td>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>W/O</td>
<td>Without</td>
<td>mm</td>
<td>Nanometer</td>
</tr>
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PCTL  Peripheral Control
PD    Photodetector
PFLG  Peripheral flag
P/O   Part of
PWR   Power
RECT  Rectifier
EBT   Encoder-buffer-turn off
LED   Light-emitting diode
LSB   Least significant bit
M/MAN Manual
SPLY  Supply
STD   Standard
SW    Switch
W/O   Without

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3.0 PRINCIPLES OF OPERATION

The L104B In Situ Ellipsometer should be used with a vacuum chamber so that, for example, periodic film and refractive index measurements can be made during a film build-up on a substrate.

3.1 Optical System (Reference Figure 1A)

Ellipsometric measurements involve illuminating the surface of a sample wafer with monochromatic light of known wavelength and polarization and then analyzing the polarization state of the reflected light. The light is projected along a fixed path or angle of incidence (ϕ). The L104B should have a precise, fixed setting of an angle of incidence, which is most often at 70°.

For the measurements, the angle of reflection is always the same angle as the angle of incidence. (Since the two angles are always equal, it is usual to refer to both angles as angles of incidence.) With the angles thus set, their respective optical axes intersect the vertical center line of the plane of incidence at the same point. The vertical position of the sample stage is adjusted such that the point of intersection of the incidence and reflective optical axes occurs on the surface of the material sample situated on the stage, and that the sample surface is normal to the vertical centerline of the plane of incidence. This ensures that the light exiting the polarizer aperture is reflected from the sample surface upward into the entrance aperture of the analyzer.

A low-power (Class II) laser-light source is employed; a helium-neon laser having a beam wavelength of 632.8 nm. The 632.8 nm (red) laser is in the line of the optical axis, and the beam is projected directly through a combining beam splitter. From the prism, the beam is directed to a mirror which, in turn, deflects the beam such that it is reflected off the combining beam splitter onto the optical axis. A depolarizer and shutter assembly, with the wavelength selector controlled by the operator, selects and depolarizes the laser beam.

The resulting circularly polarized beam is then passed through a polarizer module. In passing through the polarizer, beam polarization is converted from circular to linear. This constant-intensity, linearly-polarized beam is then converted to one of circular polarization if a quarter-wave compensator is inserted in the optical path, or remains linear if the compensator is withdrawn from the optical path. The insertion and withdrawal of the +90° compensator is automatic, under computer program control. The resultant beam, with or without the +90° compensator in its path, is then projected upon the surface of the sample wafer.

The reflected light, with its polarization altered by the optical properties of the sample, passes through a rotating analyzer prism (in a rotating drum) and is then sensed by a photodetector which, in turn, converts the light energy into an electric current proportional to the intensity of the reflected light passing through the analyzer. An interference filter between the analyzer and photodetector blocks all of the wavelengths other than that of the laser beam, thus eliminating the effects of ambient illumination.
DESCRIPTION

ELLiptically polarized light

Linearly polarized light (rotating and changing in amplitude as the drum rotates)

Narrow-band filter

Angular of reflection

Analyzer prism

Analyzer drum (rotates in automatic)

Photodetector

Analyzer component

Polarizer component

Circularly polarized light (+90° compensator removed)

90° compensator in the light path

Linearly polarized light

Polarizer prism

Circularly polarized light

+90° compensator in the light path

Polarizer drum (manually turned)

Depolarizer

Red laser

*The LED meter is on the electronic unit (not on either component.)

Figure 1A. L104B In Situ Optical System Functional Diagram

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Figure 1B  L104B Ellipsometer Side View
Figure 1C L104B Ellipsometer,
Figure 15 Alignment prisms, standard ($\phi = 70^\circ$, underlined in the table) and optional.
Figure 1E  This is the standard Mounting Collar for both L104B Ellipsometer Modules.
4.0 DETERMINATION OF PSI AND DELTA

The state of polarization of the beam is determined by the relative amplitude (amplitude ratio) and the relative phase shift (phase difference) between the two component plane waves resolved from the electric field of the beam. If the phase difference between the components is either 0° or 180°, the beam is linearly polarized. All other phase differences result in elliptical polarization. When a monochromatic beam of polarized light strikes the surface of a sample, the reflection of the light causes a change in the relative phases of the component plane waves and a change in the ratio of their amplitudes. An angle DELTA (Δ) is defined as a change in phase difference. An angle PSI (Ψ) is the arctangent of the factor by which the amplitude ratio changes. The phase difference (Δ) and the amplitude ratio (Ψ) thus characterize the elliptically polarized light reflected from the sample surface. These parameters are used to calculate the optical constants of bare surfaces and, if film covered, the thickness and refractive index of the film. The refractive index (N_f) is used to determine the physical composition of the film and to establish the magnitude of the period, i.e., the thickness interval between the repeating of ellipsometric readings.

Using measurement data obtained from the two sets of light intensity readings, the computer calculates DELTA for each set. The DELTA selected, to achieve optimum accuracy in computation of optical constants and film thickness, is based on the following criteria:

- Within 45° of 0° or 180°, use DELTA obtained with compensator in the laser light path.
- More than 45° from 0° or 180°, use DELTA obtained without compensator in the light path.

PSI is always obtained from the measurements with the compensator removed from the optical path.
5.0 IN SITU ELLIPSEOMETER MAIN SECTIONS

There are three principle sections to the L104B In Situ Ellipsometer (supplied by GSC:) the polarizer and analyzer modules and the electronic unit.

5.1 Polraizer Module

This module consists of the polarizer component mounted on the alignment mechanism. See the right side of Figure 1B.

Polarizer Component

Laser Assembly The monochromatic light source is a helium-neon laser (at 6328Å) with a built-in, quarter-wave depolarizer and is mounted on the polarizer component along the axis of incidence. The depolarizer is oriented to achieve maximum circular polarization of the laser beam.

Polarizer Prism. This prism, in the polarizer module arm, is a Glan-Thompson calcite prism that converts the circularly-polarized light from the laser to linearly polarized light. Any given angle of prism orientation from 0° to 360° can be set by manually rotating the drum containing the prism inside. The angle of the drum can be set to within tenths of a degree by setting a number in whole degrees (indicated on the drum) just below zero (0) on the 0-to-1 vernier scale and then aligning a graduation on the vernier scale to one on the drum scale. For automatic measurements, the polarizer is fixed at exactly 45° by means of a locking screw inserted into a detent on the crum.

+90° Compensator. The compensator assembly is installed at the optical output end of the polarizer prism, and contains a mica, quarter-wave plate oriented at +90°. When this wave plate is inserted into the optical path of the laser beam, the linearly polarized light emitted from the polarizer is converted to circularly polarized light. When withdrawn from the optical path of the incident beam, the linearly polarized light emitted from the polarizer remains unchanged.

Beam Attenuator. The beam attenuator, at the output aperture of the polarizer module, is a manually operated slide device to either block the incident beam or to allow the beam to pass to the sample surface. Note that the correct label would be "beam blocker." However, the Center for Devices and Radiological Health (of the U.S. Food and Drug Administration) calls it a "beam attenuator."
5.2 Analyzer Module

This module consists of the analyzer component mounted on the alignment mechanism. The module contains the photodetector and the circuitry for evaluating the laser light reflected by the sample and then sends that information to the computer. See the left side of Figure 1B.

Analyzer Component

Analyzer Prism. The analyzer drum (with a prism inside) is mounted on the analyzer component along the optical axis of the laser light reflected from the sample. The analyzer is similar to the polarizer in that it is a Glan Thompson prism inside a rotating drum. During automatic operation (the Mode switch at 'A') the analyzer drum is rotated under control of a drive motor. Encoder and optical switch assemblies on the analyzer drum shaft are slotted so that light passes at discrete intervals of the analyzer prism rotation, from LED's to phototransistors which then generate the pulses used during the measurement process.

Filter. A narrow-band, 632.8 nm optical interference filter is installed at the analyzer output, and is used to block all wavelengths except that of the laser beam.

Detector and Switch Assembly. This unit is inside a cover and is next to the interference filter. It has a solid-state photodetector that produces an output current proportional to the intensity of the light out of the analyzer prism; a current-to-voltage converter/preamplifier; analog output amplifier; and three-position Mode toggle switch:

- The Manual (M) left position is for alignment and calibration.
- The AutoSet (AS) middle position is for setting up for measurements.
- The Automatic (A) right position is for automatic measurements.

5.3 Electronic Unit

This box has the solid-state circuitry that controls and powers the ellipsometer operation. It also has the LED meter on the front. There are also seven test points and two trimpots for servicing. Parts of this unit would be of concern of only qualified service personnel. See subsection 3.2 in the Service section (4) of this instruction.

LED Meter. This meter is in the middle of the front panel of the unit. The front and rear of which are shown in Figure B2 (Appendix B.). The meter is used in the setups for measurement. The meter displays the output of the photodetector (in the analyzer) by a string of red dots. When a small green lamp on the right end of the LED scale comes on, there is an "over-range" condition. A green light at the left end of the scale shows a negative output from the analyzer; and in that situation, contact GSC.

Power Switch and Emission Lamp. On the right side of the front panel are the key-operated on/off switch and the emission indicator lamp (to turn on when the laser is on.)
6.0 ALIGNMENT PRISMS

Figure 1C (view B-B) shows an alignment prism, which is suspended with the base of the prism in a plane parallel with the measurement plane (Figure 1B.) There are optional prisms. See the table in Figure 1D.

7.0 REFERENCE SAMPLES

Two silicon oxide reference samples consisting of a silicon substrate wafer with a single-layer, silicon oxide film (with thicknesses accurately set.) A 580Å (58 nm) film thickness wafer and a 780Å (78 nm) wafer. A data printout is supplied with the ellipsometer. The sample wafers are for reference checks upon the initial receipt of the ellipsometer and periodically thereafter, using the standard transparent (nonabsorbing) film program.

8.0 VACUUM CHAMBER

Chamber Windows. The vacuum chamber is supplied by the customer. The windows should not be quite perpendicular to the optical path so as to avoid creating reflections along the optical path. The windows must be free of birefringence.
9.0 OPTIONAL ACCESSORIES

9.1 L104S In Situ Support

One In Situ Support provides a fixed, 70° incidence angle mounting for the L104B polarizer and analyzer modules, allowing them to be used separately from the in situ reactor or chamber. Polarizer and analyzer alignment mechanisms are secured to the mounting collars which remain on the modules for use on both the Support and the in situ chamber. The Support, with L104B modules in place, functions similar to the Gaertner L116B. But the Microspot Optics that are optional for the L116B ellipsometer are not used on the L104B or on the L104S. See Figure 4H in the Service section (4), which identifies the polarizer and analyzer components.

9.2 L104SA In Situ Support

This In Situ Support is more versatile than the L104S (above) in that it permits the L104B Ellipsometer modules to be used separately from the In Situ reactor or chamber and at different angles of incidence. This support has a Sample Monitor Assembly with a microscope having a power of 39 and a 150 mm diameter table that can be tilted slightly. The In Situ chamber alignment mechanisms remain in place, and the user need only remove the polarizer and analyzer components. Each component consists of a mounting bracket which incorporates the polarizer or analyzer, and the tilt and pivot pins. These components may then be mounted on stainless-steel platforms attached to the adjustable arms of the support. The components are located on the platforms by their tilt/pivot pins and attached by hex head screws. The L104SA with polarizer and analyzer components in place functions identical to the Gaertner L116. Figure 4H in the Service section (4) identifies the polarizer and analyzer components.

9.3 LRS232

This option enables the user to send or receive serial data via an interface with RS-232C compatible equipment such as a large-scale computer, data terminal and modems. Included are interface cable, modified software and program User Instructions. Contact Gaertner for details on specific data communication specifications.
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1.0 OPTICAL/MECHANICAL ALIGNMENT

1.1 Introduction

Optical Axis and Angle of Incidence  The polarizer and analyzer components have been factory-preset to be concentric and parallel to the optical axis. By definition, the optical axis is a line established by the laser when the beam is concentric with the aperture pinholes of the polarizer and analyzer components. The angle of incidence is properly set when the laser beam reflected from the face of the alignment prism is concentric to the polarizer aperture pinhole, as in view A-A of Figure 1C.

Measurement Area  The area measured will be at the center of the measuring plane when the laser spot is centered, passing through the face of the alignment prism. (See view B-B of Figure 1C.) See Figure 1D for the standard and optional prisms.

Concentricity Conditions  The analyzer module is concentric to the optical axis when the laser beam is concentric to the 1 mm aperture pinhole (see view C-C, Figure 1C,) and parallel when the beam reflections are imaged at the polarizer aperture pinhole (reference view D-D, Figure 1C.) A stationary laser spot originates from the front of the analyzer prism, and should be positioned by adjustment so it is about 6 mm from the centerline of the analyzer aperture pinhole (as shown in view D-D). As the analyzer drum rotates (Mode switch at A,) a second laser spot orbits around the stationary spot, extinguishing twice during each revolution of the analyzer drum.

Module Mounting  The polarizer and analyzer modules incorporate alignment mechanisms, with provision for mounting flange attachment to the vacuum chamber.

Clamp Plate Adjustment  When the clamp plate screws (Figure 1B) are loosened, the components are adjustable in horizontal and vertical planes, using a 5/32-inch hex key.

1.2 Alignment Prism

CAUTION

ALWAYS have the laser off or the beam attenuator (the right side of Figure 1B) closed whenever there is no prism or sample in the access opening of the chamber.
1.0 OPTICAL/MECHANICAL ALIGNMENT (continued)

1.2 Alignment Prism (continued)

In Figure 1B, the alignment prism must be mounted with the base of the prism in the measurement plane, rotatable about the vertical axis and centered in the access opening of the chamber. The base of the prism clears an opening specified in the table under Figure 1D. Install the prism with the center of one of the faces facing the aperture of the polarizer module.

1.3 Alignment Concept

Centering Screws. Two pairs of opposed centering screws in planes P (pivot) and T (tilt) enable horizontal and vertical alignment of the optical axis with reference to the alignment prism, using a 3/16-inch hex key. (Refer to Figure 1C.)

Centering Screw Adjustment. Centering screws in planes P and T are adjusted equally to provide maximum adjustments (horizontal and vertical) of ±1/4-inch. The plane T centering screws control the angular tilt at the aperture pinhole pivot point in plane P. Tilt is ±6° at the center of lateral adjustment with only ±3° of tilt remaining at the lateral adjustment extremes.

1.4 Alignment Procedure

Loosen the horizontal and vertical clamp plate screws for both the polarizer and analyzer modules sufficiently to allow turning of the centering screws by hand for coarse adjustment, yet maintaining sliding surfaces in contact. As the alignment progresses, the clamp plate screws can be tightened and the final alignment accomplished, using 3/16-inch hex keys.

NOTE

To start, the centering screws should be set at about the middle of their adjustment ranges.
1.0 OPTICAL/MECHANICAL ALIGNMENT (continued)

1.4 Alignment Procedure (continued)

a. Direct the laser beam into the alignment prism.

b. Check the position of the beam reflection (ring of light) from the prism, as observed at the polarizer aperture pinhole (view A-A of Figure 1C.)

c. The alignment prism can be rotated about its vertical axis to minimize horizontal misalignment. Readjust the polarizer module as needed to center the laser spot at the prism face (view B-B of Figure 1C) and the polarizer aperture (view A-A).

d. Check the laser spot (ring of light) relative to the analyzer aperture pinhole (view C-C of Figure 1C.)

NOTE

Lateral adjustment of the analyzer module can be made and/or a combination lateral and angular adjustment of the polarizer module.

e. Repeat the above until the requirements of views A-A through C-C, Figure 1C are met.

f. Observe the reflections from the analyzer prism. Tilt the analyzer module by adjusting the plane T centering screws until the reflection is as shown in view D-D, Figure 1C.
2.0 CALIBRATION

The axis of polarization of the polarizer and analyzer prisms must be in precise positions relative to the measuring plane. A 3 inch or 100 mm diameter, 580Å film thickness calibration wafer is supplied for checking and adjusting the axis of polarization. The polished surface is coated with a silicon dioxide film, thickness about 580Å. Delta is 90°, permitting an accurate setting at 70° angle of incidence. The wafer may be used for other angles of incidence, but with a loss of setting accuracy.

2.1 Checking the Axis of Polarization

Place the 580Å calibration wafer with the polished side down and in the measuring plane.

2.1.1 Polarizer Check

a. Remove the polarizer drum clamping screw (a knurled hex screw.) Use a 3/32" hex key.

b. Set the analyzer drum at exactly 90°. Set the Mode switch to M.

c. Connect a voltmeter (set to 10 or 20V, dc) between the red and black (ground) test jacks.

d. Rotate the polarizer drum around 0° to obtain a minimum indication on the voltmeter, and search for a minimum. The correct minimum should occur at 0.00°.

e. Disconnect the voltmeter unless it will be used in the next subsection.

2.1.2 Analyzer Check

a. Set the polarizer drum at exactly 90°. Set the Mode switch to M.

b. Connect a voltmeter (set to 10 or 20V, dc) between the red and black (ground) test jacks.

c. Rotate the analyzer drum around 0° to obtain a minimum indication on the voltmeter, and look for a minimum. The correct minimum should occur at 0.00°.

d. Disconnect the voltmeter.
2.2 Axis of Polarization Adjustment

This adjustment is made by rotating the modules about the optical axis relative to their mounting collars.

2.2.1 Adjustment of the Modules

This adjustment is made by loosening the three locking screws (see Figure 1B) just enough to rotate the modules about the optical axis while maintaining contact between the module and the mounting collar. Then use the opposed adjust screws shown in view E–E of Figure 1C, which provide an adjustment range of ±4°.

NOTE

Use the 3/16" hex key for loosening the locking screws and the 5/32 hex key for the rotational adjustment.

2.2.2 Polarizer

a. Set the polarizer drum right at 0.00° and the analyzer drum right at 90°. Set the mode switch to M.

b. First observe the LED meter on the electronic unit, and rotate the polarizer module relative to the mounting collar for a minimum indication. Then observe the voltmeter, and adjust to its minimum.

c. As needed, adjust the polarizer module tilt plane (Plane T) centering screws (Figure 1B) to keep the laser beam aligned at the analyzer pinhole (view C–C in Figure 1C.)

d. Check the adjustment per subsection 2.1.1. If the check shows an error on the polarizer drum greater than 0.05°, repeat steps c and d (above.)

e. Tighten three locking screws (see Figure 1B.)
2.2 Axis of Polarization Adjustment (continued)

2.2.3 Analyzer

a. Set the polarizer drum at exactly 90.0° and the analyzer drum at exactly 0.00°. Set the mode switch to M.

b. First, observe the electronic unit LED meter, and rotate the polarizer module relative to the mounting collar for a minimum indication. Then observe the voltmeter, and adjust for its minimum.

c. As needed, adjust the polarizer module tilt plane (Plane T) centering screws (Figure 1B) to keep the laser beam aligned at the analyzer pinhole (view C-C in Figure 1C.)

d. Check the adjustment according to subsection 2.1.2. If the check shows an error on the analyzer drum greater than 0.05, repeat steps c. and d., above.

e. Tighten three locking screws (see Figure 1B.)
Figure 2A  The diagram shows the two photodetector trimpots inside the cover on the end of the analyzer module. The Zero Offset trimpot is closer to the center of the opening, but farther back.

2.3 PD Amplifier Gain

Turn off the computer before following this procedure. This procedure is the same as subsection 2.2 in section 4 (Service.) Some assistance may be needed from service personnel.

a. Place the 780Å sample with the polished side down and in the measuring plane.

b. Connect the cables to the electronic unit, and turn it on. (Don't connect the computer cable.)

c. Open the beam attenuator, and set polarizer drum at 45°.

d. Set the mode switch to A. Rotate the analyzer drum for a maximum on the LED meter at around 80° for a 70° angle of incidence.

e. For the PD gain adjustment, remove the black cap from PD cover. This trimpot is in Figure 2A.

f. Adjust the Gain trimpot for 94 ±2 on the LED meter. Turn the trimpot CW to increase the gain.

g. Reinstall the black cap on the cover.
3.0 MEASUREMENT PROCEDURE

With the In-Situ Ellipsometers, there are more variables concerning the samples in vacuum chambers than on the tables and stages on other Gaertner instruments. The following are more in the form of suggestions rather than instructions.

3.1 Automatic Motor Turnoff

An automatic turnoff of the rotating analyzer motor is provided to prolong its life. The motor will automatically turn off about five minutes after the last measurement.

Characteristics

1. If the ellipsometer is on with the computer off and the mode switch is set to A, the analyzer drum will rotate once and stop.

2. If both the ellipsometer and the computer are on and the mode switch is set to A, the analyzer drum will rotate for five minutes before auto turn off.

3. When stopped, the motor will automatically turn on when a measurement is initiated, and successive measurements will extend the five-minute interval.

3.2 Turn-on and Warmup

   a. Connect the ellipsometer and the computer. (See the Installation instructions, Appendix B.)
   b. Close the beam attenuator (PUSH TO CLOSE) to block the beam, and set the Mode switch to AS.
   c. On the right side of the electronic unit, turn the key-operated power switch ON. The emission indicator lamp should turn on.
   d. Allow at least a 15-minute warmup.
   e. Open the beam attenuator (PULL TO OPEN), and proceed with the measurements.
3.2 Turn-on and Warmup (continued)

NOTE

When performing the following procedure, there is excessive scatter in the film thickness readings (of more than 5%), refer to subsection 2.4 (Motor Speed) in section 4 (Service.)

Although measurements can be made after a 15-minute ellipsometer warmup, the stability of the laser improves over several hours of operating time. If the ellipsometer is used several times a day, it is recommended that the laser operate continuously, including overnight, but not on weekends. Keep the beam attenuator "closed" when the ellipsometer is not in use. Keep the Mode switch at AS.

WARNING

To avoid the hazard of exposure to the laser beam reflection, the beam attenuator must be "closed" when the analyzer module is not attached to the vacuum chamber or when a sample or alignment prism is not in the proper position in the chamber.

Valid measurements are dependent upon the selection of a program applicable to the sample being measured, and the correct use of the computer by the operator. The standard program supplied with the ellipsometer and other programs which can be used with the L104B are available by a special order.

The polarizer and analyzer modules should not need readjustment between measurements on a series of samples if all of the samples in a given lot are plane-parallel, of about equal sample thickness, and no dust particles or other foreign matter are deposited on the surface of the table.
3.3 Loading the Program

a. Load the program software into the computer. (See Appendix A.)

b. Place sample under test in the chamber, and proceed with the measurements. Be sure that the alignment is proper, according to the alignment part of this section (2.)

c. Set the Mode switch to A.

d. Proceed with the measurements by initiating data entry according to the program in Appendix A.

At the completion of the measurement sequence, set the Mode switch to AS; and remove the sample from stage. Insert the next sample, and realign the modules as necessary. Set the Mode switch to A, and proceed with the measurements of the next sample.
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1.0 USER MAINTENANCE

The user maintenance instructions are operator-level procedures for routine maintenance.

2.0 CLEANING AND LUBRICATION

Interior cleaning of the L104B (i.e., the detector and switch assembly, monitor assembly and instrument power supply) is not needed. These units are designed to prevent the entry of foreign matter. Put the dust cover on the ellipsometer when it is not being used. Exposed optical surfaces may be cleaned with a camel-hair brush or clean, dry compressed air (under 5 psi). All other external surfaces may be wiped clean using a soft, lint-free cloth. If a solvent is needed, a cloth dampened with wood or isopropyl alcohol is recommended. Periodic lubrication is not required.

3.0 CHECKING THE AXIS OF POLARIZATION

The axis of polarization of the polarizer and analyzer prisms must be in precise positions relative to the measuring plane. A 3 inch or 100 mm diameter 580Å calibration wafer is supplied for checking and adjusting the axis of polarization. The polished surface is coated with a silicon dioxide film, thickness about 580Å. Delta is 90°, permitting an accurate setting at 70° angle of incidence. The wafer may be used for other angles of incidence, but with a loss of setting accuracy.

Place the 580Å calibration wafer with the polished side down and in the measuring plane.

3.1 Polarizer Check

a. Remove the polarizer drum clamping screw (this is a knurled hex screw.)

b. Set the analyzer drum at exactly 90°. Set the Mode switch to M.

c. Connect a voltmeter (set to 10 or 20V, dc) between the red and black (ground) test jacks.

d. Rotate the polarizer drum to around 0°, and search for a minimum. The correct minimum should be at 0.0°.

e. Disconnect the voltmeter unless it will be used in the next subsection.
3.0 CHECKING THE AXIS OF POLARIZATION (Continued)

3.2 Analyzer Check

a. Set the polarizer drum at exactly 90°. Set the Mode switch to M.

b. Connect a voltmeter (set to 10 or 20V, dc) between the red and black (ground) test jacks.

c. Rotate the analyzer drum around 0° to obtain a minimum indication on the voltmeter, and search for a minimum. The correct minimum should occur at 0.00°.

d. Disconnect the voltmeter.
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1.0 TROUBLE ANALYSIS

This should be done by qualified service personnel. The L104B Ellipsometers should have long-life, trouble-free operation. In the event of a malfunction, symptoms are readily traceable by the use of built-in test jacks and intermediate check points. Fault isolation involves trouble-shooting to isolate the cause of failure only to a component or assembly readily removable for further fault isolation and repair or replacement. During automatic operation, a malfunction is usually characterized by no measurement data, inconsistent measurements, or operator-induced errors.

Instructions are not included for the replacement of laser assemblies and polarizer/analyzer optical or precision electro-mechanical components. Contact Gaertner Scientific about the repair or replacement of these items.

1.1 Measurement System

During automatic operation, the analyzer drum (Figure 1B) turns at a speed regulated by a closed-loop, motor speed control system. See Figure 4A. Motor pulses originating at discrete intervals from an encoder are amplified and applied to the input of a motor speed controller. Within the encoder, the pulses are derived from a phototransistor circuit activated by a light emitting diode (LED). The actual motor speed is determined by a frequency-to-voltage conversion of the input. This voltage is compared to an externally preset reference voltage. The result of the comparison controls the duty cycle of the pulse width modulated motor drive output stage, closing the system negative feedback loop. This, in turn, maintains motor speed constant. A "stall timer" feature prevents motor burn-out in case of an extended mechanical jam.

Intensity readings of the reflected light, as sensed by the photodetector, are taken at 5° intervals during the rotation of the analyzer, beginning at 0° and ending at 355°. The readings are taken in the dual mode, sequenced under program control via the input from the computer. One set of readings (72 data points during the analyzer rotation) is taken with the compensator inserted in the optical path. The other set of readings is taken with the compensator removed from the optical path.

The output current of the photodetector is converted to an analog voltage that varies sinusoidally in amplitude and proportional to the intensity of the light passing through the analyzer. The analog output is amplified and applied to the input of an analog-to-digital (A/D) converter. A zero offset adjustment in the photodetector circuit is factory preset to ensure optimum accuracy in measurement, especially for very thin films. After each set of readings, the maximum analog output is checked by the computer software. If measurement accuracy can be improved by changing the gain, the CTL 1 input logic will switch the gain range and a repeat set of readings will be taken. A logic "0" closes the switch, decreasing the gain; a logic "1" opens the switch, increasing the gain.
Figure 4A Measure System Functional Diagram
**Figure 4B** Typical Pulses During the Measurement Cycle

*The STORE DATA pulses will not appear with some makes of computers.*
1.1 Measurement System (continued)

A reference pulse originating from an optical switch and present between 356° and 359° of analyzer rotation, initiates the measurement cycle. The reference pulse is derived from a phototransistor circuit activated by a LED. If a peripheral control (PCTL) signal from the computer is present during the period of the reference pulse, indicating that the computer is ready to accept a reading, a timer is activated (turned on). For the first set of readings, count pulses starting at the 0° position of analyzer rotation trigger the A/D converter to accept the photodetector analog output. The count pulse is derived from a phototransistor circuit activated by a LED in the encoder, in the same manner as previously described for the motor pulse. Approximately 30 microseconds later, allowing time for A/D conversion, a peripheral flag (PFLG) signal is sent to the computer, indicating a reading is ready for the computer.

The reading, in 12-bit digital format, is then accepted by the computer. The cycle is repeated for each subsequent count pulse, occurring every 5°, until 72 readings have been processed and stored by the computer. The next reference pulse resets the timer and terminates the measurement cycle.

Under program control, the compensator position is changed and a second set of 72 readings is taken in the same manner as previously described. An external A/D offset adjust is factory preset to set zero light level of the A/D conversion such that measurements are insensitive to changes in gain of the photodetector output, ensuring minimum distortion.

Insertion and withdrawal of the compensator is by means of a solenoid-actuated, mechanical slide. When a "control zero" (CTL 0) signal from the computer is applied to a switching transistor circuit on the compensator control board, the solenoid is energized to insert the compensator in the optical path. When the CTL 0 signal is removed, the solenoid is deenergized to withdraw the compensator from the optical path.

1.2 Test Jacks

Seven color-coded test jacks (including a common ground) are on the lower-right side of the front panel of the electronic unit. See the front view of the electronic unit in Figure B2 (Appendix B.) These test jacks are useful in trouble-shooting to identify symptoms of malfunction and to isolate faults without first requiring access to the interior of the ellipsometer. These test points (with a trimpot on each end) are identified as follows:
1.2 Test Jacks (continued)

RED ORANGE YELLOW BLACK GREEN BLUE BROWN

A/D PD REF COUNT GROUND PFLG PCTL MOTOR MOTOR
OFFSET OUTPUT PULSE PULSE PULSE SPEED CONTROL

ADJUST

Figure 4C These are seven test jacks and two trimpots on the L104B electronic unit front panel.

NOTE

Logic 1 is less than one (1) volt. Logic 0 for reference, count and motor pulses is greater than 4.0 volts. Logic 0 for PCTL and PFLG is greater than 3.0 volts.

• PD Output This is the final photodetector/amplifier output. It is sinusoidal with an amplitude of up to 10V, peak to peak and a period of 180° of the analyzer rotation.

• Ref Pulse This occurs between 356° and 359° of analyzer drum rotation. These pulses are always present, as long as the drum is rotating (in automatic, with the Mode switch at A.) Logic 1 initiates the automatic measurement cycle if the logic 1 PCTL (peripheral control) signal is also present from the computer.

• Count Pulse These pulses occur within 1/2° of the analyzer drum position readings and are evenly divisible by five, between 0° and 355° of the analyzer rotation. Logic 1 triggers an A/D converter to accept the photodetector output during the measuring cycle.

• Ground This is the common ground for any measurement at each test jack and check point.
1.2 Test Jacks (continued)

- PFLG These pulses are the logic 1 peripheral flag signals to the computer (only during the measurement cycle) and occur about 30 microseconds after the leading edge of each count pulse. They indicate that a reading is ready for the computer. The pulses end at trailing edge of count pulse.

- PCTL This is the logic 1 signal from the computer (which starts the measurement cycle.) The signal tells the system that the computer is ready to accept readings. When coincident with the reference (ref) pulse, a timer is activated to permit the measurement cycle.

- Motor Pulse These pulses occur 1/2° to 1-1/2° after each count pulse.

Typical outputs at these test jacks (except the PD output) are shown in figure 4B. The use of an oscilloscope with a high-persistancy screen or a storage cathode-ray tube would display the waveforms clearer because of the slow sweep across the screen when the reference pulses are observed. An oscilloscope with two or more traces is needed to compare the pulses. It may be necessary to use the oscilloscope's external trigger on the reference pulse for a more stable pulse display.

1.3 Troubleshooting

Table 1 (on the page after the next figure) lists symptoms of malfunctions, possible causes and corresponding actions relative to fault isolation. The symptoms are listed in a sequence generally reflecting the operating procedure; i.e., premeasurement setup and measurement procedure. As a troubleshooting guide, the listing assumes all dc power supplies are operative and no discontinuity in wiring. Certain fault isolation actions are keyed to intermediate check points A1 to A4. The check points are shown in Figures 8 and 9 and are just below the photodetector board in the detector/switch assembly section of the analyzer module. Remove the detector/switch assembly cover for access to these four check points.
Figure 4D  These are the four Check Points (A1 to A4) with A1, A3 and A4 shown in Figure 4A. In order to observe the waveform or measure the voltage, carefully pull out the appropriate connector just enough to carefully insert a sharp probe (with the common probe at the black test jack.)
## TABLE 1. TROUBLESHOOTING GUIDE

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>POSSIBLE CAUSE</th>
<th>FAULT ISOLATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>No power to the ellipsometer (Key switch at ON)</td>
<td>No line voltage</td>
<td>Verify that the ellipsometer power cord is seated in an ac power outlet.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check the fuse; replace if defective. It is .75A, slow blow (Figure 4G.)</td>
</tr>
<tr>
<td>Emission indicator does not illuminate at power turn-on</td>
<td>Lamp burned out</td>
<td>Replace the lamp. If the problem is still present, the instrument power supply transformer or monitor assembly transformer may be at fault.</td>
</tr>
<tr>
<td>No light is emitted from the polarizer aperture</td>
<td>The Beam attenuator is closed</td>
<td>Check the position of the attenuator; if it is closed, PULL TO OPEN IT.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Defective laser or laser power supply Needs the replacement/alignment of a laser or removal of instrument power supply for repair (contact Gaertner).</td>
</tr>
<tr>
<td>No LED meter reading during the sample stage alignment (Mode switch at AS)</td>
<td>No PD output (verify at red test jack on electronic chassis)</td>
<td>If the PD output is correct, the LED meter may be defective. If the PD output is incorrect, the PD board may be defective. Remove the PD board for analysis/replacement.</td>
</tr>
</tbody>
</table>
### TABLE 1. TROUBLESHOOTING GUIDE (continued)

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>POSSIBLE CAUSE</th>
<th>FAULT ISOLATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>The analyzer drum does not rotate (Mode switch is at A.)</td>
<td>There is no motor drive output (assumes no motor-bind condition.)</td>
<td>Rotate the analyzer drum, and observe the brown test jack motor pulse output (Figure 4C.) If it is proper, the motor board may be defective.</td>
</tr>
<tr>
<td><strong>OR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The analyzer drum races with the Mode switch at A.</td>
<td></td>
<td>If the motor pulse is incorrect, observe the encoder output at check point A1 (Figure 4D.) If the pulse is correct at A1, the EBT board may be defective. Also check the auto-turnoff circuit on the EBT.</td>
</tr>
</tbody>
</table>

**NOTE**

If the EBT board or motor board is found to be defective, remove the electronic chassis for further fault isolation, repair or replacement.
<table>
<thead>
<tr>
<th>Symptom</th>
<th>Possible Cause</th>
<th>Fault Isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No binary (A/D) data output (all zeros)</td>
<td>The measurement cycle is not initiated</td>
<td>Reset and reload the program. Initiate the measurement. If the symptom persists, observe the reference pulse output at the orange test jack. If it is present, verify that the PCTL logic 1 (0 to 1V) is proper at the blue test jack. If the PCTL voltage is correct, the cycle timer may not have turned on. Remove the electronic chassis for trouble analysis of logic board. If the PCTL is incorrect, the problem may be in the computer or cable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the reference pulse output is not present (above) at the orange test jack, observe the reference pulse output at check point A3, Figure 4D. If the pulse is present, the Mode switch may be defective. (The Mode switch must be at λ.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the reference pulse output is not at A3, the optical switch may be defective (contact Gaertner).</td>
</tr>
<tr>
<td>SYMPTOM</td>
<td>POSSIBLE CAUSE</td>
<td>FAULT ISOLATION</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>No binary data (A/D output (continued)</td>
<td>No PD output conversion</td>
<td>Observe the count pulse output at the yellow test jack. If the pulses are present, check the PFLG pulses at the green test jack. If the PFLG pulses are not present, the logic board may be defective. If the PFLG pulses are present, the trouble may be in the computer or the interface cable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the count pulses are not present at the yellow test jack, observe the signal at check point A4 (Figure 4D.) If the pulses are present, the EBT board may be defective. Remove the electronic chassis for analysis/ repair.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If the signal is not present at A4, the encoder may be defective (contact Gaertner.)</td>
</tr>
<tr>
<td>Inconsistent or inaccurate measurements</td>
<td>Mechanical misadjustment</td>
<td>Verify that the polarizer drum is secured at 45°. Verify that the polarizer/analyzer settings are in precise agreement. Recheck the vertical position of the polarizer-analyzer module.</td>
</tr>
</tbody>
</table>
### TABLE 1. TROUBLESHOOTING GUIDE (continued)

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>POSSIBLE CAUSE</th>
<th>FAULT ISOLATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconsistent or inaccurate measurements (continued)</td>
<td>Irregularity of count pulses</td>
<td>Refer to the count pulse measurement procedure (on the next page.)</td>
</tr>
<tr>
<td></td>
<td>Analyzer drum speed of rotation</td>
<td>Refer to the motor speed adjustment procedure.</td>
</tr>
<tr>
<td></td>
<td>Loss of dual mode operation (the solenoid is not activated to insert the +90° compensator into the optical path.)</td>
<td>This requires the verification of the CTL 0 logic 1 (0 to 1V) at the input of the instrument power supply. If the voltage is 3 volts or more, the trouble is in the computer or the computer interface. If the voltage is less than one volt, the compensator control board may be defective. The output voltage to the solenoid should be 21 to 24.5V dc steady state while CTL 0 is at logic 1 (to energize the solenoid, with the compensator &quot;in&quot;). If the voltage is not correct, remove the power supply for further analysis. If the voltage is proper, then the solenoid is in an &quot;overheated&quot; condition or defective.</td>
</tr>
</tbody>
</table>
1.4 Count Pulse Measurement

a. Place the Mode switch at A, and stop the drive motor by a gentle pressure of the hand on the analyzer drum. Then set the analyzer drum to 359°.

b. Use an oscilloscope to display the count pulses at the yellow test jack (Figure 4C) while manually rotating the analyzer drum slowly. The first count pulse should start within ±1/2° of 0° and have a duration of no less than 0.4° or greater than 1.2°. During the period of the pulse, the voltage should be less than 0.2 volt, and jump to at least 4 volts at the end of the pulse. The pulse should repeat at 5° intervals of the analyzer rotation (a total of 72 pulses during one revolution of the drum). Incorrect pulses indicate a possible encoder defect.

c. To start the automatic analyzer rotating, momentarily set the Mode switch at AS and then at A.

2.0 ADJUSTMENTS

These adjustments should be made by only service personnel.

These adjustments are to be made on the two trimpots inside the PD cover. See Figure 4E. The PD Zero Offset, LED Meter and PD Gain adjustments are preset at Gaertner, but may require readjustment if the photodetector board is replaced.

NOTE

Check the PD Zero Offset adjustment before adjusting for the LED meter.

2.1 PD Zero Offset

This adjustment can be made by removing the black plug from the side of the PD cover.

a. Close the beam attenuator to block the laser light, and set the Mode switch at AS.

b. Connect the measuring probe of a voltmeter (that reads 10 or 20V, dc) to the PD Output (red) test jack (and the common probe to the black common jack in Figure 4C). Adjust the Zero Offset trimpot Figure 4E as needed so that the voltmeter reads 0.0 volts, dc.

c. Disconnect the voltmeter, and reinstall the plug in the PD cover unless the gain trimpot adjustment is next.
Figure 4E  The diagram shows the two photodetector trimpots inside the cover on the end of the analyzer module. The Zero Offset trimpot is closer to the center of the opening, but farther back.

2.2 PD Amplifier Gain

Turn off the computer before following this procedure.

a. Place the 700Å sample with the polished side down and in the measuring plane.

b. Connect the cables to the electronic unit, and turn it on. (Don't connect the computer cable.)

c. Open the beam attenuator, and set polarizer drum at 45°.

d. Set the mode switch to A. Rotate the analyzer drum for a maximum on the LED meter.

e. For the PD gain adjustment, remove the black cap from PD cover. The trimpot is in Figure 4E.

f. Adjust the Gain trimpot for 94 ±2 on the LED meter. Turn the trimpot CW to increase the gain.

g. Reinstall the black cap on the cover.
2.3 LED Meter

Figure 4F  This diagram shows the two trimpots (FS and ZE) and the six voltage test points at the rear of the LED meter. The LED meter is shown in Figure 4G.

Follow steps a. and b. in subsection 2.2. Set the polarizer drum at 45° and the Mode switch to AS.

a. The LED display should show one to three red light dots for (zero reference.) If the meter does not, remove the electronic unit cover by removing two screws on each side of the unit.

b. Carefully adjust the ZE trimpot, Figures 4F and 4G, for two dots. Open the beam attenuator.

c. Connect a voltmeter common probe to the ground (black) test jack in Figure 4C, and connect the measuring probe to the PD Output (red) test jack. Slowly rotate the analyzer drum until the voltmeter reads 10V, dc.

d. Adjust the FS trimpot as needed so that the LED meter reads 100 (as the voltmeter reads 10V.)

e. Disconnect the voltmeter, and reinstall the cover on the electronic unit.
Figure 4G This is the inside of the electronic unit.
2.4 Motor Speed

This adjustment is just to the right of the brown (motor pulse) test jack (Figure 4C.) The motor speed control trimpot is preset at the factory, but may require a fine adjustment if the electronic chassis is replaced, to ensure accurate measurements of very thin films. A silicon substrate with silicon oxide film of about 200Å (20 nm) is recommended for this adjustment.

a. With a sample in place, check the adjustments of the polarizer and analyzer modules according to the alignment procedure in Section 2.

b. Load and run the standard film program (with fixed $N_f$ of 1.46) to get several thickness measurements. See Appendix A.

c. Adjust the trimpot, searching for a point giving the minimum scatter in the readings.

NOTE

Avoid changes in motor speed that produce excessive vibration.

d. If the measurements vary less than 3 to 5Å (.3 to .5 nm) and the upper end of the laser is quite vibration free (touch it lightly,) the motor speed is proper.

e. If the measurement variations are still greater than 5Å, contact Gaertner.

f. When the adjustments are complete, the motor should run very smoothly.

2.5 A/D Offset Adjust

If the electronic chassis is replaced, the A/D Offset trimpot is preset at the factory on the new chassis. This trimpot should thus not require realignment by the customer.
3.0 COMPONENT REMOVAL FOR REPAIR/REPLACEMENT

The removal and replacement or reinstallation instructions are limited to qualified service personnel. These instructions apply to components requiring either direct replacement or lower-level fault isolation and repair. Removal of components other than those covered herein should be performed by only Gaertner personnel.

3.1 Polarizer and Analyzer Components

It becomes necessary to replace lasers after thousands of hours of service. Thus, the customer should remove the polarizer component from the alignment mechanism and return it to Gaertner for the installation of a new laser. In the same manner, the customer may need to remove the analyzer component from the mechanism and return it (with or without the polarizer component) to Gaertner.

When returning the polarizer and analyzer components to Gaertner for service, all that is needed is to remove the polarizer component from its alignment mechanism and the analyzer component from its mechanism. Figure 4H (next page) identifies the two components, which are shaded.

3.1.1 Polarizer Component

a. Note that there are three screws (5/32 hex key) and a vertical clamp plate that secure the polarizer component to its alignment mechanism and that there are four (two top and two on the bottom) vertical centering screws (3/16 hex key.)

b. Loosen just the two top vertical centering screws on the polarizer module.

c. Remove the three screws that secure the vertical clamp plate and the polarizer component to the alignment mechanism.

3.1.1 Analyzer Component

a. There are three screws (5/32 hex key) and a vertical clamp plate that secure the analyzer component to its alignment mechanism and that there are four (two top and two on the bottom) vertical centering screws (3/16 hex key.)

b. Loosen just the two top vertical centering screws on the analyzer module.

c. Remove the three screws that secure the vertical clamp plate and the analyzer component to the alignment mechanism.
Figure 4H  This diagram shows the polarizer and analyzer components, which are shaded.
3.0 COMPONENT REMOVAL FOR REPAIR/REPLACEMENT (Continued)

3.2 Electronic Unit

Test Points and Sockets The lower right of the front panel has the seven colored test points and two trimpots (for servicing.) On the upper left of the front is the socket for the cable to the analyzer module. The other socket is for the GPIO cable to the computer.

Rear Panel This has the cable with the high voltage to the polarizer module, the fuse (3/4A, slow blow) and the ac line cord for 115V ac. The unit can be modified for 100, 220, 230 or 240V ac.

Internal Components The electronic unit contains the following:

- Motor board
- EBT board
- Logic board
- Analog-to-Digital (A/D) board
- +15V dc power supply for the A/D board and photodetector board
- +5V dc power supply for the A/D board, logic board and count board
- +10V dc power supplies (two 5V supplies in series) for the motor board

The electronic unit also has the instrument power supply containing the following:

- Laser power supply (about 2000V operating, 10,000V ignition)
- +5V dc power supply for the LED meter
- Compensator control board
- Multi-purpose transformer:
  115V ac for the monitor assembly
  115V ac for the instrument dc power supplies and laser power supply
  28V ac for the compensator control board
3.2 Electronic Unit (continued)

3.2.1 Instrument Power Supply

a. Turn off the computer and ellipsometer. Unplug the ellipsometer line cord from the ac outlet.

b. Remove the cover of the electronic unit by removing two screws on each side.

c. Remove the screw at each corner of the rear panel on the electronic unit. The rear panel is the power supply chassis. See Figure 4G.

WARNING

Use care in steps d and e. Up to 10,000 volts are in the 632.8 nm laser.

d. Separate the large white laser connectors on the cable between the laser and the laser power supply on the electronic unit rear panel.

e. Use a 1k to 2k resistor across the two-prong plug on the laser cable to discharge the voltage.

f. Remove the power supply after unplugging the following internal connectors:

   Power supply to the sample monitor assembly (9-pin)
   Power supply to the electronic chassis (4-pin)
   Power supply to the electronic chassis (3-pin)
   Power supply to the solenoid (2-pin)

7. To install an instrument power supply, reverse the procedure of steps a through f (with the power off and the line cord unplugged.)
3.0 COMPONENT REMOVAL FOR REPAIR/REPLACEMENT (Continued)

3.2.2 Electronic Chassis

Turn off the computer and ellipsometer. Unplug the ellipsometer line cord from the ac outlet.

a. Remove the cover on the electronic unit by removing two screws on each sides.

b. Remove the two screws attaching the top bracket to the sides (T in Figure 4G.)

c. The front panel lower left has the socket for the cable to the computer. Remove the two screws on the socket.

d. Remove the two screws on the test point block on the front panel lower-right.

e. For the power supply, disconnect the 3-pin and 4-pin electronic chassis interface wiring connectors. Disconnect the 24 pin DIP plug from the chassis.

f. Remove four screws E in Figure 4G. Carefully pull out the electronic chassis while lifting up the front panel.

g. Disconnect the cable assembly from the receptacle. (This disconnects the interface wiring associated with the detector and switch assembly.)

h. To replace or reinstall the electronic chassis, reverse the procedure of steps a through g (with the power off and the line cord unplugged.)

3.2.3 LED Meter Assembly

Turn off the computer and the ellipsometer. Unplug the line cords from the ac power outlet.

a. Remove two screws that attach the front of the LED meter to the front panel. These are the two larger screws that go through the screw holes on each side of the front panel meter opening.

b. Disconnect the LED meter cable from the 4-inch monitor-to-power supply extension cable connector, and remove the meter.

c. To replace or reinstall an LED meter assembly, reverse the procedure of steps a and b (with the power switch off and the line cord unplugged.)
3.0 COMPONENT REMOVAL FOR REPAIR/REPLACEMENT (Continued)

3.3 Photodetector Board

The removal of the photodetector board requires access to the detector and switch assembly. Perform the following:

a. Turn off the computer and ellipsometer. Unplug the line cord from the ac power outlet.

b. Remove the two screws that secure the Mode switch to the cover of the detector and switch assembly.

NOTE

In the next step, it would be a good idea to wrap some tape around the analyzer next to the edge of the cover to hold the cables in place. Then the reinstallation of the cover will not be so difficult.

c. Loosen the three screws that secure the cover. Pull the cover outward to remove it from the assembly.

d. Withdraw the switch assembly from the retainer slots, and disconnect the two black/white plugs from the receptacles above the photodetector board.

e. Remove the four screws that secure the photodetector board, and lift out the board carefully.

f. To install a photodetector board, reverse the procedure of steps b through e.
3.0 COMPONENT REMOVAL FOR REPAIR/REPLACEMENT (Continued)

3.4 Beam Attenuator

This procedure applies to both the removal and reinstallation (or replacement) of the beam attenuator. Perform the following:

a. Turn off the power to the computer and Ellipsometer, and pull their plugs from the ac outlets.

b. Using a 5/32-inch hex key, remove the two cap screws that secure the polarizer pin-hole plate to the inner support of the polarizer arm.

c. Pull the pin-hole plate from the support.

d. Remove the damaged beam attenuator from the slotted back surface of the plate, and install the new beam attenuator in the slot, and note that the orientation is the same as for the one removed. (The end with a hole faces the front.)

e. Install the pin-hole plate on the support, using the the locating pins as a guide and ensuring that the silver reference dots on the pin-hole and polarizer inner support are aligned.

f. Insert the two cap screws (removed in step b) into the holes in the pin-hole plate. Turn them until they are almost finger tight.

g. Check the plate and locating pins for firm seatings; and then tighten the screws, using a 5/32-inch hex key.

h. Slide the attenuator in and out to verify that there is no binding. (If it is too loose, bow the slide slightly.)

i. Adjust the polarizer-analyzer module for the verticle position according to the Sample Stage Alignment procedure (in Section 2.)
4.0 COMPUTER INTERFACE CABLE DATA

Computer interface cable data for the ellipsometers are in Table 2.

5.0 REPLACEMENT PARTS

A replacement parts list is in Table 3.


<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Input</th>
<th>Output</th>
<th>Logic Level</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 18, 24, 26, 43, 49</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 1</td>
<td>(MSB)</td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 5</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 6</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 7</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 8</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 9</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 10</td>
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<td>13</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 11</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>X</td>
<td>1</td>
<td>A/D, Bit 12</td>
<td>(LSB)</td>
</tr>
<tr>
<td>19</td>
<td>X</td>
<td>1</td>
<td>A/D Done</td>
<td>(reading ready)</td>
</tr>
<tr>
<td>44</td>
<td>X</td>
<td>1</td>
<td>Initiate measurement cycle*</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>X</td>
<td>0</td>
<td>Terminate measurement cycle*</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>X</td>
<td>1</td>
<td>Compensator in</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>X</td>
<td>0</td>
<td>Compensator out</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>X</td>
<td>1</td>
<td>Increase PD gain</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>X</td>
<td>0</td>
<td>Decrease PD gain</td>
<td></td>
</tr>
</tbody>
</table>

*The Period of the measurement cycle is one revolution of the analyzer drum, with the duration settable from 0.25 to 1.5 seconds.

Logic level (TTL); Logic 1 = 0 to 1 volt; Logic 0 = 3 to 5 volts
## TABLE 3. L104B REPLACEMENT PARTS LIST

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>GSC Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic chassis (less housing)</td>
<td>10161-KB</td>
</tr>
<tr>
<td>Interface connector (chassis)</td>
<td>A-7108-E-118b</td>
</tr>
<tr>
<td>Mating connector (cable)</td>
<td>A-7108-E-118a</td>
</tr>
<tr>
<td>Test jack</td>
<td>708-E-127 (specify color)</td>
</tr>
<tr>
<td>Instrument power supply</td>
<td>10026-KF</td>
</tr>
<tr>
<td>Meter and cable assembly</td>
<td>10257-21</td>
</tr>
<tr>
<td>Photodetector board</td>
<td>10257-10E</td>
</tr>
<tr>
<td>Mode switch (includes cables and connectors)</td>
<td>10257-30</td>
</tr>
<tr>
<td>Beam attenuator</td>
<td>10026-21</td>
</tr>
<tr>
<td>A/D offset potentiometer</td>
<td>7108-E-121</td>
</tr>
<tr>
<td>Motor speed potentiometer</td>
<td>7108-E-121</td>
</tr>
<tr>
<td>Emission Indicator lamp</td>
<td>10259-25-RE6</td>
</tr>
<tr>
<td>Lock switch (includes key)</td>
<td>7108-E-231A</td>
</tr>
<tr>
<td>Ellipsometer fuse, 3/4 amp, slow blow</td>
<td>B-7108-E-138A.750</td>
</tr>
<tr>
<td>Transformer, emission Indicator</td>
<td>7108-E-230A</td>
</tr>
<tr>
<td>Cable, monitor power supply extension</td>
<td>10259-23</td>
</tr>
<tr>
<td>Laser Assembly (632.8 nm)</td>
<td>C-10026-20F</td>
</tr>
</tbody>
</table>
APPENDIXES
L104SA IN SITU SUPPORT

(For L104B Only)

Gaertner Scientific Corporation

1201 West Wrightwood Avenue, Chicago, IL, 60614
SINGLE- AND TWO-WAVELENGTH L104B ELLIPSOMETERS

1.0 DESCRIPTION

The In Situ Support (Support) permits the single-wavelength (1-λ) or two-wavelength (2-λ) L104B Ellipsometer to be used separately from the customer's In Situ reactor or chamber. The In Situ chamber alignment mechanisms may remain in place, and the user need only remove the polarizer and analyzer components. Each component consists of a mounting bracket (see Figure 2A) which includes the polarizer or analyzer, and the tilt and pivot pins. These components may then be mounted on the platforms attached to the adjustable arms of the support. The components are mounted on the platforms by their tilt/pivot pins and secured by hex head screws. The L104SA with the single-wavelength polarizer and analyzer components in place functions the same as the Gaertner L116 Ellipsometer.

NOTE

If the L104SA is ordered with the L104B, the polarizer and analyzer components will be factory installed and aligned on the L104SA.

2.0 COMPONENT REMOVAL

2.1 Removal of Components From the Support (Reference Figure 2A)

- Turn off electronic unit, and disconnect the polarizer and analyzer components from it.
- Position and clamp the Support arms at a 90° angle of incidence.
- Loosen setscrews PP and PA. Loosen only the upper setscrews TP and TA. This step applies to both the polarizer and analyzer components.
- Uniformly loosen the three hex head screws on each component until it can be removed. The hex head screws remain captive in the Support arms.
L104SA IN-SITU SUPPORT

2.0 COMPONENT REMOVAL (Continued)

2.2 Removal of the Components from the Chamber

Perform the following while referring to Figure 1B (1-λ) of the L104B manual, 7109-C-292 or Figure 1B of the two-wavelength supplement (2-λ).

- Turn off electronic unit and disconnect polarizer and analyzer components from it.
- Remove the three screws from the vertical clamp plate (of both components). Hold the component, and loosen only the upper plane T and P centering screws. The components may then be removed.

3.0 INSTALLATION AND ALIGNMENT OF COMPONENTS ON THE SUPPORT

3.1 Installation

Apply the following steps to both components, referring to Figure 2A of this instruction:

- Position the component so that the tilt and pivot pins mate with their respective holes on the platform.
- Uniformly tighten the captive hex head screws (7/16 wrench) until the lockwashers are sufficiently compressed to allow a sliding movement of the component with respect to the platform.

3.2 Preliminary Alignment

Before aligning, firmly clamp the adjustable arms at a 90° angle of incidence. Check that the polarizer drum is set to 45°. Connect the cables to the electronic unit, and turn it on. Do not connect the computer cable.

- Lower the sample table to make a clear path for the laser beam.
- Open the beam attenuator.
- Using 3/32-in. hex key, tighten the nylon tip setscrews PP and PA. This will minimize the clearances between pivot pins and their respective holes.
- Using 3/32-in. hex key, tighten setscrews TP and TA sufficiently to make contact with the tilt pins (T).
3.0 INSTALLATION AND ALIGNMENT OF COMPONENTS ON THE SUPPORT (Continued)

3.3 Polarizer Component Alignment

Adjust tilt setscrew TP to center laser beam on analyzer pinhole. If necessary, you can horizontally center the beam by adjusting the front or rear laser set screws, such as to move the beam inward by slightly loosening the front setscrew while slightly tightening the rear setscrew.

3.4 Analyzer Component Alignment

Adjust the analyzer tilt setscrew TA to position the reflected laser light from the analyzer pinhole at about 3 o'clock on the polarizer pinhole.

- Place the mode switch in Automatic (A). Stall the motor by a gentle pressure on analyzer drum.

- Rotate the analyzer drum to 45°. If the LED meter does not exceed 100 (full scale deflection), adjust the analyzer tilt using both setscrews TA for a maximum reading on the LED meter.

**NOTE**

See section 5.0 if the LED reading is less than 90 or more than 100.

3.5 Final Adjustment

- Tighten the hex head screws for both components, ensuring that the conditions of paragraphs 3.3 and 3.4 are met.

- Restart the motor by switching from A to AS, then back to A.
4.0 AXIS OF POLARIZATION CHECK AND ADJUSTMENT ON THE SUPPORT

NOTE
If the components have been removed from the chamber, it may be necessary to adjust the polarizer and analyzer drums.

- Clamp both arms at a 70° angle of incidence.
- Place the 580Å SiO$_2$ wafer on table, and adjust the table vertically for a minimum LED meter reading. Adjust the tilt of the table to level the sample.
- Place the mode switch at M.
- Connect a voltmeter to the red and black test jacks on the front of the electronic unit.
- Remove the polarizer drum clamping screw (this is a knurled hex screw normally clamping the drum at 45°).
- Open the beam attenuator.

The adjustment is made by loosening the two cap screws that hold the vernier part of the drum to the mounting bracket and then rotating the drum assembly about the optical axis. Loosen the cap screws just enough to allow the rotation of the vernier while keeping it in contact with the mounting surface. See Figure 2A.

4.1 Polarizer Check

a. Set the analyzer drum to exactly 90°.

b. Rotate the polarizer drum to near 0° for a minimum reading on the voltmeter, and search for the minimum. The correct minimum should be at 0.0°.
Polarizer Drum Adjustment

a. Set the polarizer drum at exactly 0.00°.
b. Loosen the polarizer vernier capscrews.
c. Rotate the vernier and drum together to obtain the minimum reading on the voltmeter.
d. Tighten the vernier capscrews and check the setting.

4.2 Analyzer Check

a. Set the polarizer drum at exactly 90°.
b. Rotate the analyzer drum to about 0° for a minimum reading on the voltmeter, and search for the minimum. The correct minimum should be at 0.00°.

Analyzer Drum Adjustment

a. Set the analyzer drum at exactly 0.00°.
b. Loosen the analyzer vernier capscrews.
c. Rotate the vernier and drum together for a minimum reading on the voltmeter.
d. Tighten the vernier capscrews and check the setting.

4.3 Polarizer Drum Setting

Set the polarizer drum to 45°. Insert the drum clamping screw, and tighten.
5.0 PHOTODETECTOR (PD) GAIN ADJUSTMENT

Because of the laser beam divergence, the laser beam may overpower the photodetector when the polarizer and analyzer components are transferred from their (usually) wide spacing outside the In Situ chamber to the 9-5/8-in. spacing of the L104SA. To adjust the PD gain, proceed as follows:

- Clamp both arms at a 90° angle of incidence.
- Set the polarizer drum at 45°.
- Place the mode switch at λ, and stall the motor.
- Set the analyzer drum to 45°.
- Open the beam attenuator.
- Connect the cables to the electronic unit, and turn it on. (Do not connect the computer cable.)
- Gain access to the photodetector (PD) gain trimpot by removing the black cap from the PD cover. The Gain trimpot is just below the access cover hole at about 6 o'clock. See Figure 5A (below) for the trimpot.
- Adjust the Gain potentiometer for 94±2 on the LED meter. Turn it CW to increase the gain or CCW to decrease it.
- Reinstall the black cap.

Figure 5A This shows the Gain (and Zero Offset) trimpot inside the PD cover on the end of the analyzer component. The Zero Offset trimpot is nearer the center of the opening, but farther back.
Top View (Installation & Alignment) with Polarizer & Analyzer @ 90°

Figure 2A
Ellipsometer Quick Software Guide

KEY:
- $\Phi$ = angle of incidence (usually set $70^\circ$; may be moved to e.g. $50^\circ$)
- $t_s$ = thickness of substrate
- $n_s$ = refractive index (real part) for substrate. A function of $\lambda$. Limits: 0 to 20.
- $k_s$ = imaginary part of refractive index for substrate (due to absorption: $\alpha = 2\pi k/\lambda$). A fcn of $\lambda$. Limits 0 to -20.
- $t_i$ = thickness of ith layer.
- $n_i$ = index of ith layer. A function of $\lambda$.
- $k_i$ = imaginary part of refractive index. Due to absorption: $\alpha = 2\pi k/\lambda$. A fcn of $\lambda$.
- $n_a$ = index of ambient (air: 1.00 = default).
- Oxide = silicon dioxide: SiO$_2$ ($n = 1.46 @ 6328\AA; n = 1.453 @ 8300\AA$)
- Nitride = silicon nitride: Si$_3$N$_4$ ($n = 2.00 @ 6328\AA; n = 2.00 @ 8300\AA$)
- Silicon = single crystal Si ($n = 3.875$ and $k_s = -0.018 @ 6328\AA$)

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Gaertner Name (subprograms referenced in the manual)</th>
<th>layer$_i$/substrate$_s$ (for films other than Si, SiO$_2$, Si$_3$N$_4$ it helps to know $n$ at 6328Å and 8300Å.)</th>
<th>User Input (for films &lt;400Å, $n_{film}$ should be fixed rather than calc.)</th>
<th>Data Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>2w2a</td>
<td>2SC6A, 2SC7A, 2SC2A, 2GC5A, 2SubCA</td>
<td>(SiO$_2$ or Si$_3$N$_4$)$_f$/Si$_s$ (SiO$_2$ or Si$_3$N$_4$)$_f$/Si$_s$ any$_f$/any$_s$</td>
<td>$(\Phi=70^\circ)$ fixed</td>
<td>t, n</td>
</tr>
<tr>
<td></td>
<td>(auto two $\lambda$ or two $\Phi$)</td>
<td>any$_s$</td>
<td>$\Phi$</td>
<td>t, n</td>
</tr>
<tr>
<td>2layerab</td>
<td>LGC9A</td>
<td>any$_f$/any$_f$/any$_s$</td>
<td>$\Phi$, $n_s$, $k_s$</td>
<td>$n_s$, $k_s$</td>
</tr>
<tr>
<td>(transparent or absorbing film)</td>
<td></td>
<td></td>
<td>$\Phi$, $n_s$, $k_s$, $n_2$, $k_2$, and $t_2$, ($n_1$ or $k_1$): or $n_1$, $k_1$:</td>
<td>$t_1$, ($n_1$ or $k_1$)</td>
</tr>
<tr>
<td>4layer</td>
<td>2GC8A4</td>
<td>$4*(any_f)/any_s$</td>
<td>$\Phi$, $n_s$, $k_s$, $n_2$, $n_3$, $t_3$, $n_4$, $t_4$, and $n_1$; or $t_2$:</td>
<td>$t_1$, $t_2$</td>
</tr>
<tr>
<td>(up to 4 transparent film layers)</td>
<td></td>
<td></td>
<td>$\Phi$, $n_s$, $k_s$, $n_a$, #rev,</td>
<td>$t_1$, $n_1$ or $\Psi$, $\Delta$; time sequence (&gt;1s/pt) or single point.</td>
</tr>
<tr>
<td>insitu</td>
<td>2GC4A</td>
<td>any$_f$/any$_s$</td>
<td>$\Phi$, $n_s$, $k_s$, $\Psi$, $\Delta$</td>
<td>t, n</td>
</tr>
<tr>
<td>(auto time seq, data logging)</td>
<td></td>
<td></td>
<td>$\Phi$, $n_s$, $k_s$, $\Psi$, $\Delta$</td>
<td>$n_s$, $k_s$</td>
</tr>
<tr>
<td>manual</td>
<td>GP5, SubP, SPrmanual</td>
<td>any$_f$/any$_s$</td>
<td>$\Phi$, $n_s$, $k_s$, $\Psi$, $\Delta$</td>
<td>t, n</td>
</tr>
</tbody>
</table>

For oxide thickness, the 2 wavelength option of 2w2a is probably the easiest. Make a habit of using the same wavelength (e.g. 830nm) first on each run.

ELLIPSOMETER OPERATION REVIEW (italics are to be typed on computer keyboard):
1. Powerup computer, monitor, ellipsometer electronics, diode laser.
2. Place sample on stage and adjust tilt to align + and x crosshairs in viewing microscope.
3. cd ellip (if desired, dir or ls for a listing of ellipsometer program directories).
4. cd 2w2a (or to other desired program directory).
5. auto; follow menus using function keys (e.g. 2w2a: DISP/WAVE/830nm (push in $\lambda$ selector tab on RHS of analyzer)<center> key/pull out $\lambda$ selector<center>/5 Å/50,000 Å/list.
6. END program, powerdown diode laser, ellipsometer electronics, monitor, and computer.

cgl 5/93
Two-Wavelength Standard Program (2STD) Instructions for use with
L2W15C.830, L2W16C.830, W25C.1.5 and L2W26C.1.5 Ellipsometers and
IBM PC and PS Series Computers

Gaertner Scientific Corporation
1201 West Wrightwood Avenue, Chicago, IL, 60614
# Appendix A

## STANDARD (2STD) Program

### TWO-WAVELENGTH
L2W15C.830, L2W16C.830, L2W25C.1.5 AND L2W26C.1.5 ELLIPSOMETERS
WITH IBM COMPUTERS

WITH HELIUM-NEON 6328A (RED) AND
7700 TO 8500Å (DIODE) OR 15230Å (HELIUM-NEON INFRARED) LASERS

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APPENDIX A

L2W15C.830/L2W16C.830 ELLIPSOMETERS
L2W25C.1.5/L2W26C.1.5 ELLIPSOMETERS

1.0 INTRODUCTION AND SET UP

There are two different types of infrared lasers.

**Diode Lasers**: These lasers have wavelengths between 7700Å (770 nm or 0.77 μm) and 8500Å are installed on the two-wavelength L115C and L116C Ellipsometers (Model Numbers L2W15C.830 and L2W16.830 respectively.) Most of the diode lasers operate at 8300Å.

**Helium-Neon (Infrared) Lasers**: These longer-wavelength infrared lasers are fixed at 15230Å (1523 nm or 1.23 μm) and are used on the L2W25C.1.5 and L2W26C.1.5 Ellipsometers.

Gaertner Ellipsometer program software is supplied on two types of discs for use on the IBM PC and PS Series Computers. The program software for the IBM computers are as follows:

- IBM PC and IBM PC XT Computers are supplied on discs compatible with a 360k-byte, 5-1/4" drive.
- The IBM PS/2 Models 25 and 30 are supplied on discs compatible with a 720k-byte, 3-1/2" drive.
- The IBM PC AT Computer is supplied on discs compatible with a 1.2M-byte, 5-1/4" drive.

1.1 WaferSkan Systems

**L2W15C.830**: This ellipsometer system is set up according to the two-wavelength supplement to the L115C/L116C manual. Disregard Figures 2B and 3D.

**L2W25C.1.5**: This ellipsometer system is set up according to Appendix B (Installation) of the L2W25C.1.5/L26C.1.5 manual. Disregard Figures B-2 and B-6.

1.2 Single-Point Systems

**L2W16C.830**: This ellipsometer system is set up according to the two-wavelength supplement to the L115C/L116C manual. Disregard Figure 2A.

**L2W26C.1.5**: This ellipsometer system is set up according to Appendix B (Installation) of the L2W25C.1.5/L26C.1.5 manual. Disregard Figure B-1.

*Diode lasers have wavelengths between 0.77 and 0.85 μm, but most are at 0.83 μm. The ellipsometer identification table will show the actual infrared wavelength (in micrometers.)

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1.3 Software Installation and Loading

Waferskan Systems

These ellipsometers have computers with hard discs, which have the standard and optional programs on that disc.

L2W15C.830: Refer to "Software Installation and Loading (L2W15C.830 only)" at the end of the two-wavelength supplement to the L115C/L116C manual.

L2W25C.1.5: Refer to "Software Installation and Loading (L2W25C.1.5 only)" at the end of Appendix B of the L2W25C.1.5/L26C.1.5 manual.

L2W26C.1.5 Single-Point Systems:

A computer such as IBM PS/2-25 (without a hard disc) needs to have the program disc inserted whenever the computer is turned on.

L2W16C.830: Refer to "Software Installation and Loading (L2W16C.830 only)" at the end of the two-wavelength supplement to the L115C/L116C manual.

L2W26C.1.5: Refer to "Software Installation and Loading (L2W26C.1.5 only)" at the end of Appendix B of the L2W25C.1.5/L26C.1.5 manual.

1.4 The Sample Table Vacuum and Alignment

L2W15C.830 and L2W16C.830: See "Sample Stage or Table Vacuum and alignment" near the end of the two-wavelength supplement to the L115C/L116C user's manual.

L2W25C.1.5 and L2W26C.1.5: Place a sample wafer with a film of a known thickness on the table. See the "Sample Table Vacuum and Alignment" subsection 1.3 and steps a. through l. in the Operation section of the L2W25C.1.5/L2W26C.1.5 manual.

a. Step m refers to the software loading instructions. Use the standard 2SC6A + 2SC7A + 2SC2A + 2GC5A + 2SubCA program (2STD.) Then use the Film subprogram (F1 key.)

b. Step n refers to the thickness data measurement. The data should also be within ±3A.
2.0 STANDARD PROGRAM (2SC6A + 2SC7A + 2SC2A + 2GC5A + 2SubCA.)

This is a two-wavelength (2–λ), single-layer, nonabsorbing (transparent) film program consisting of five subprograms. The screen will in less than one minute display a line in the lower left corner:

"SELECT KEY FROM BELOW AS DESIRED
1PRINT 2DISP"

If the printer is connected, on and to be used, press F1 (PRINT) otherwise press F2 (DISP). Then the main menu with the five subprograms is displayed:

"SELECT KEY FROM BELOW AS DESIRED
1FILM 2SPECIF 3SUBSTR 4TWOANG 52WAVE 6 7 8 9 10END"

Pressing F1 (FILM) selects subprogram 2GC5A, in which different angles of incidence can be used to evaluate a sample. See Figure A1.

Pressing F2 (SPECIF) selects subprogram 2SC6A in which oxide or nitride films are evaluated at only an angle of 70°. See Figure A2.

Pressing F3 (SUBSTR) selects subprogram 2SubCA, which evaluates bare substrates.

Pressing F4 (TWOANG) selects subprogram 2SC7A, which takes measurements at both 50° and 70° and determines the proper film thickness order.

Pressing F5 (2WAVE) selects subprogram 2SC2A, which takes measurements at both wavelengths and at 70° incidence angle and determines the proper film thickness order.

Pressing F10 (END) causes the program to exit so that another 2–λ program on another disc can be inserted and entered.

Note the display; and press key F1, F2, F3, F4 or F5 corresponding to the desired subprogram; i.e., film (2GC5A), specific (2SC6A), substrate (2SubCA), two angle (2SC7A) or two-wavelength (2SC2A). This is the main menu. After working with one of the five subprograms, the MENU key (F10) may be pressed, with the main menu back on the screen. Then you can work with one of the other four subprograms in the 2STD program.
APPENDIX A

2.0 STANDARD PROGRAM (2SC6A + 2SC7A + 2SC2A + 2GC5A + 2SubCA, Continued)

The next display at the bottom of the screen asks for a selection of the lasers in micrometers (μm):

"Select Wave Length( μmeter ): 10 6.33 21.523* 3 4 5 6 7 8 9 10."

Pressing F1 (red laser) causes this display:

"PULL OUT WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** <PRESS ENTER>._"  

Pressing F2 (infrared laser) causes this display:

"PUSH IN WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** <PRESS ENTER>._"

*The "1.523" shown is for the helium-neon infrared laser on the L2W25C.1.5 and L2W26C.1.5 Ellipsometers. For the L2W15C.830 and L2W16C.830 instruments, "0.830" appears in place of "1.523."

**Only the L2W25C.1.5 and L2W26C.1.5 instruments have a D lever on the polarizer arms. The L2W15C.830 and L16C.830 ellipsometers have only the W levers on the analyzer arms.

2.1 2GC5A, Film Subprogram

When the film subprogram is selected, these are the "Default Values" (left side of Figure A1, which is just before section 2.2):

- The red laser wavelength is 6328Å (633 nm or 0.633 μm).
- The longer (neon-helium) infrared laser wavelength is 15230Å (1523 nm or 1.523 μm).
- The shorter (diode laser) infrared wavelength is between 7700Å (770 nm or 0.77 μm) and 8500Å.
- Mode of measurement: Measure N and thickness
- Angle of incidence: PHI=70°
- Polarizer drum angle: POL=45°

There are also default values for the indexes of the silicon substrate, oxide layer and nitride layer. But these default values are different for every wavelength. The screen will display the individual default values.

7109-C-261B
2.1 2CC5A, Film Subprogram (continued)

The film subprogram menu functions are as shown (bottom of Figure A2):

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (PRINT or DISP)*</td>
<td>Pressing F1 while PRINT is on the screen's lower left causes the printer to automatically print solutions (if connected and on.) Then &quot;PRINT&quot; changes to &quot;DISP&quot; so that pressing F1 again does not let the printer print solutions.</td>
</tr>
<tr>
<td>F2 (SETUP)</td>
<td>This allows the setup of the input parameters.</td>
</tr>
<tr>
<td>F3 (SAMPLE)</td>
<td>The user enters identifying numbers and/or letters.</td>
</tr>
<tr>
<td>F5 (MEAS)</td>
<td>It calculates index N and thickness.</td>
</tr>
<tr>
<td>F9 (LIST)</td>
<td>It gives a listing of all of the possible thicknesses (periodic multiples).</td>
</tr>
<tr>
<td>F10 (MENU)</td>
<td>This returns the main menu to the screen, where the specific, substrate or two-angle subprogram can be selected.</td>
</tr>
</tbody>
</table>

*If you pressed F1 (for PRINT) at the beginning of this section (2.0), then "DISP" is by "1" in this menu so that you can deactivate the printer if you wish. But if you pressed F2 (DISP) at the beginning of this section, you can now activate the printer (which must be connected and on) by pressing F1 (PRINT) in the above menu.

When the F2 key (SETUP) in the above menu is pressed, the setup menu functions are as shown:

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (WL)</td>
<td>You can now select the other laser. If you chose 0.633 μm after selecting this subprogram, then &quot;1.523&quot; (or &quot;0.830&quot;) appears next to &quot;1&quot; so that the other wavelength can be used instead, and vice versa.</td>
</tr>
<tr>
<td>F2 (Nf)</td>
<td>This allows the film index Nf to be changed.</td>
</tr>
<tr>
<td>F3 (PHI)</td>
<td>You can change the angle of incidence.</td>
</tr>
<tr>
<td>F4 (EXPTHK)</td>
<td>You can change the expected thickness of the film.</td>
</tr>
<tr>
<td>F5 (POLRZR)</td>
<td>You can use a polarizer drum angle other than 45°.</td>
</tr>
<tr>
<td>F9 (ALL)</td>
<td>You can change any parameter including Ns and Ks.</td>
</tr>
<tr>
<td>F10 (EXIT)</td>
<td>This returns the above (film) menu to the screen.</td>
</tr>
</tbody>
</table>

**The "1.523" shown is for the helium-neon infrared laser on the L2W25C.1.5 and L2W26C.1.5 Ellipsometers. For the L2W15C.830 and L2W16C.830 instruments, "0.830" appears in place of "1.523."
2.1 2GC5A, Film Subprogram (continued)

<table>
<thead>
<tr>
<th></th>
<th>RED (HELIUM-NEON) LASER</th>
<th>INFRARED (DIODE) LASER</th>
<th>INFRARED (HE-NE) LASER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>633 nm</td>
<td>830 nm*</td>
<td>1523 nm**</td>
</tr>
<tr>
<td>FILM</td>
<td>Nf 50° 70°</td>
<td>Nf 50° 70°</td>
<td>Nf 50° 70°</td>
</tr>
<tr>
<td>OXIDE</td>
<td>1.46 2545 2832</td>
<td>1.453 3361 3745</td>
<td>1.444 6221 6945</td>
</tr>
<tr>
<td>NITRIDE</td>
<td>2.00 1713 1792</td>
<td>2.00 2246 2351</td>
<td>1.997 4129 4290</td>
</tr>
</tbody>
</table>

*The diode (infrared) laser is used only in the L2W15C.830 and L2W16C.830 Ellipsometers. The periods for diode lasers at other than 830 nm will be in proportion to the wavelength. At 820 nm, 3745 would be multiplied by .98795 to give 3700, since 820 divided by 830 is .98795.

**The helium-neon infrared laser is used only in the L2W25C.1.5 and L2W26C.1.5 Ellipsometers.

The periods for very thin films (less than 400Å thick) or films within 400Å of a periodic multiple, the sensitivity of the index measurement is very poor; therefore, accurate thickness measurements can be obtained only by fixing the value of the index (N) and then calculating the thickness. The two-angle program (2SC7A) finds the absolute thickness of thick films, based on the order or period from matched measurements at each angle.

As seen on these pages, it is very often important to know the periods of the silicon dioxide and/or silicon nitride films when making measurements. The table above gives the periods for oxide and nitride films at 50° and 70° with the red laser (at 6328Å), the infrared (diode) laser between 7700 and 8500Å and the infrared (helium-neon) laser at 15230Å.
2.1 2CC5A, Film Subprogram (continued)

If the OXIDE key (F5) is selected (for oxide films), the program automatically determines whether the index (N) should be fixed or measured. The same is true for nitride films if the NITRIDE key (F6) is selected. Hence, for either oxide or nitride film on a silicon substrate at 70° angle of incidence, the above keys are recommended.

NMEAS (F7) and NFXD (F8): The automatic fixing or measuring of the index (N) can be avoided, if desired, by using function keys (Nfxd) and (N Meas). These keys fix the index (N) and measure the index (N) respectively, regardless of sensitivity considerations, although sometimes answers may not be computed. For example: if attempting to measure the Index (N) of very thin films (under 100 Angstroms or 10 nm) it may not be possible to compute an answer. But, if the Index (N) is fixed, the thickness will be computed. One oxide film example of a display in the center of the screen is this (which appears in the center of Figure A1 while "Select optional from below" disappears:)

SAMPLE: xxx
THICK: 1051
Nf: 1.464
PSI: 44.48
DEL: 79.33

The LIST key (F9) gives (lower right of the screen) the thickness and the eight smallest thicknesses with a given period. One example is this (which appears in the lower-right part of Figure A1):

LISTING: (PERIOD= 2819Å)
1051 9508 17965
3870 12327 20784
6689 15146 23603

One nitride film example of a display (in the center of Figure A1) is this:

SAMPLE: nnn
THICK: 264
Nf: 1.986
PSI: 15.81
DEL: 106.07

The LIST key (F9) gives in the lower right of the screen the thickness and the eight smallest thicknesses with a given period. One example is this:

LISTING: (PERIOD= 1809Å)
264 5691 11118
2073 7500 12927
3882 9309 14736
GAERTNER 2SC6A+2SC7A+2SC2A+2SC5A+2SubCA AUTOMATIC ELLIPSOOMETRY PROGRAM FOR IBM PC

N_s = 3.850
K_s = -0.020
WL = 6328
N = 1.460
PHI= 70.00
POL= 45.00

Select option:
1PRINT 2SETUP 4SAMPLE 4 5MEAS 6LIST 7 8 9 10MENU

Figure A1 This is the screen display with the standard film subprogram Program Menu at the bottom. The red (6328Å) laser is shown.
2.2 2SC6A (Specific Subprogram)

With this subprogram, you can measure either oxide or nitride films at only 70°. These are the "Default Values" (left side of Figure A2, which is just before section 2.3):

- The red laser wavelength is 6328Å (633 nm or 0.633 μm).
- The longer (neon-helium) infrared laser wavelength is 15230Å (1523 nm or 1.523 μm).
- The shorter (diode laser) infrared wavelength is between 7700Å (770 nm or 0.77 μm) and 8500Å.
- Mode of measurement: Measure N and thickness
- Angle of incidence: PHI=70°
- Polarizer drum angle: POL=45°

There are also default values for the indexes of the silicon substrate, oxide layer and nitride layer. But these default values are different for every wavelength. The screen will display the individual default values.

The specific subprogram menu functions are as shown (bottom of Figure A2):

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (PRINT or DISP)</td>
<td>See the film subprogram (section 2.1) about this F1 key.</td>
</tr>
<tr>
<td>F2 (SAMPLE)</td>
<td>The user enters identifying numbers and/or letters.</td>
</tr>
<tr>
<td>F3 (OXIDE)</td>
<td>The thickness, index Nf, Psi and Delta of an oxide film are measured.</td>
</tr>
<tr>
<td>F4 (NITRIDE)</td>
<td>The thickness, index Nf, Psi and Delta of a nitride film are measured.</td>
</tr>
<tr>
<td>F5 (NMEAS)</td>
<td>It calculates index N and thickness.</td>
</tr>
<tr>
<td>F6 (NFXD)</td>
<td>The fixed index N can be changed.</td>
</tr>
<tr>
<td>F7 (LIST)</td>
<td>It gives a listing of all of the nine lowest periodic thicknesses.</td>
</tr>
<tr>
<td>F8 (WL)</td>
<td>The wavelength of the other laser can be used.</td>
</tr>
<tr>
<td>F10 (MENU)</td>
<td>This returns the main menu to the screen, where the specific, substrate or two-angle subprogram can be selected.</td>
</tr>
</tbody>
</table>

As seen on these pages, it is very often important to know the periods of the oxide and/or nitride films when making measurements. See the table in the film subprogram section (2.1) in the columns at only 70° with the red laser (at 6328Å) and either infrared laser.

For very thin films or films close to a periodic multiple, the sensitivity of the index measurement is very poor; therefore, accurate thickness measurements can be obtained only by fixing the value of the index (N) and then calculating the thickness. The two-angle subprogram (2SC7A*) can be used for more accurate film thickness measurements.
2.2 2SC6A (Specific Subprogram, continued)

The SAMPLE key (F2) permits you to assign identification letter(s) and/or number(s) to a sample.

If the OXIDE key (F3) is selected (for oxide films), the program automatically determines whether the index (N) should be fixed or measured. The same is true for nitride films if the NITRIDE key (F4) is selected. Hence, for either oxide or nitride film on a silicon substrate at 70° angle of incidence, the above keys are recommended.

NMEAS (F5) and NFXD (F6): The automatic fixing or measuring of the index (N) can be avoided, if desired, by using function keys (NFx) and (N Meas). These keys fix the index (N) and measure the index (N) respectively, regardless of sensitivity considerations, although sometimes answers may not be computed. For example: If attempting to measure the index (N) of very thin films (under 100 Angstroms or 10 nm,) it may not be possible to compute an answer. But, if the index (N) is fixed, the thickness will be computed. One oxide film example of a display in the center of the screen is this (which appears in the center of Figure A2):

```
SAMPLE:xxx
THICK:   Nf:    PSI:    DEL:
 1248    1.464   63.57    84.77
```

The LIST key (F7) gives (appearing in the lower right of the screen) the thickness and the eight smallest thicknesses with a given period. One example is this (which appears in the lower-right part of Figure A2):

```
LISTING: (PERIOD= 2819Å)
1248  9705  18162
4067  12524  20981
6886  15343  23800
```

One nitride film example of a display (which would be in the center of Figure A2) is this:

```
SAMPLE:nnn
THICK:   Nf:    PSI:    DEL:
 264     1.986   15.81   106.07
```

The LIST key (F7) gives in the lower right of the screen the thickness and the eight smallest thicknesses with a given period. One example is this:

```
LISTING: (PERIOD= 1809Å)
264  5691  11118
2073  7500  12927
3882  9309  14736
```
**Table: GAERTNER 2SC6A+2SC7A+2SC2A+2SC5A+2SubCA AUTOMATIC ELLIPSOMETRY PROGRAM FOR IBM PC**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ns</td>
<td>3.8500</td>
</tr>
<tr>
<td>KS</td>
<td>-0.0200</td>
</tr>
<tr>
<td>WL</td>
<td>6328</td>
</tr>
<tr>
<td>N</td>
<td>1.460</td>
</tr>
<tr>
<td>PHI</td>
<td>70.00</td>
</tr>
<tr>
<td>POL</td>
<td>45.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THICK:</th>
<th>Nf:</th>
<th>PSI:</th>
<th>DEL:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1248</td>
<td>1.464</td>
<td>83.57</td>
<td>84.77</td>
</tr>
</tbody>
</table>

Select option:

1PRINT 2SAMPLE 3OXIDE 4NITRDE 5NMEAS 6NFXD 7LIST 8WL 9 10MENU

**Figure A2:** This is the screen display with the specific subprogram Program Menu at the bottom. The F5 key (NMEAS) has been pressed, causing the four solutions to appear in the middle of the screen.

**NOTE:** In the above display, the printer has been deactivated. The have the printer operate, press F1 (PRINT), but the printer must be connected and on. Then "PRINT" will change to "DISP" so that the printer can be deactivated if or when desired. The 633 nm laser is shown on the screen.
2.3 2SubCA (Substrate)

Pressing F3 (SUBSTR) when the main menu is displayed (see section 2.0, "Standard Program," subprogram 2SubCA is selected so that the optical constants (PSI, DEL, real Ns and extinction ks) of a bare substrate can be evaluated. These constants are needed before making any film measurements. Pressing MENU (F10) enters the main menu.

The angle of incidence (70°) is selected automatically. Check that the polarizer drum is at 45°.

- Angle of incidence: PHI=70°
- Polarizer drum angle: POL=45°

Any one of the following can be selected by using the corresponding key:

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (DISP or PRINT)</td>
<td>See the F1 function key for the film subprogram (section 2.1)</td>
</tr>
<tr>
<td>F2 (PHI)</td>
<td>You can use an angle of incidence other than 70°.</td>
</tr>
<tr>
<td>F3 (POLRZR)</td>
<td>It allows the input of the polarizer drum setting (normally 45°) for the best overall sensitivity. By setting the polarizer drum close to the value of PSI, sensitivity and stability can be increased.</td>
</tr>
<tr>
<td>F4 (SAMPLE)</td>
<td>You may enter an alphanumerical sample identifying number.</td>
</tr>
<tr>
<td>F5 (MEAS)</td>
<td>It instructs the ellipsometer and computer to make a measurement with the given input parameters.</td>
</tr>
<tr>
<td>F6 (WL)</td>
<td>You can change to the other laser.</td>
</tr>
<tr>
<td>F10 (MENU)</td>
<td>This terminates the Substrate subprogram and returns the program to the main menu.</td>
</tr>
</tbody>
</table>

At φ = 70° with the 633 nm laser, one substrate produced these measurements (which appear in the middle of the screen):

\[
\text{SAMPLE:Sss} \\
Ns: 3.791 \quad Ks: -0.153 \quad \text{PSI: 9.99} \quad \text{DEL: 173.21}
\]
2.4 2SC7A (Two Angle)

The ellipsometric thickness measurement of transparent films is a periodic function. When using only one angle of incidence, the expected thickness of the film has to be known within a period. For SiO$_2$, a period is 2832Å (283.2 nm) at a 70° angle of incidence. If the thickness is not known to this accuracy, then measurements at two angles of incidence are needed to find the actual film thickness.

Pressing F3 (TWOANG) in the main menu selects subprogram 2SC7A*, which takes measurements at both 50° and 70° for the most accurate film thickness measurements. The computer asks that a sample serial number and/or letters be typed in and Enter pressed or just Enter is pressed for no number. Then the user selects Oxide (F1), Nitride (F2) or Nf (F3).

The Two Angle program requires the cooperation of the user (in changing the angle of incidence,) in taking measurements at 70° and 50° angles of incidence on Oxide or Nitride films on Silicon substrates, and determines the actual thickness of films. The thickness does not have to be known within a period; however, minimum and maximum possible thicknesses, such as 0 and 30000, have to be entered. An example of a display for an nitride film in the center of the screen is this (with the two-angle menu below):

```
SAMPLE:nnn
PHI=70
MATCHED THICKNESS: 265

PHI=50
268

1PRINT* 2SAMPLE 3OXIDE 4NITRIDE 5Nf? 6WL 7LIST 8PSIDEL 9 10MENU
```

*See section 2.1 (2GC5A) about the F1 key (PRINT or DISP.)
7109-C-279A

2GC9A and 2GC9A# Optional Automatic Program Instructions for use with
L2W16C.830 and L2W26C.1.5 Ellipsometers and
IBM PC and PS Series Computers

Gaertner Scientific Corp.
1201 West Wrightwood
Chicago, IL, 60614
APPENDIX A

OPTIONAL 2GC9A AND 2GC9A# SINGLE-POINT PROGRAMS

1.0 INTRODUCTION

These optional two-wavelength (2-λ), single-point measurement programs (2GC9A and 2GC9A#) are two-layer, absorbing-film programs for use with Gaertner L2W16C.830* and L2W26C.1.5 Ellipsometers and IBM computers.

Be sure to read the computer and the ellipsometer manuals. It would be beneficial to study the printer manual. Also, be sure to read the 2-λ Standard Program (2STD) instructions. If you have the RS-232 single-point system, read the 2-λ RS-232 Standard (single-point) Program (2STD#) instructions. Running some measurements would help, because this instruction makes many references to the 2STD instruction where the two operations are the same.

2.0 SET UP

See sections 1.0 (Introduction and Set Up,) 1.1 (Software Installation and Loading) and 1.2 (Sample Table Alignment) in the 2STD instructions. For 2-λ RS-232 systems, see the 2STD# Instructions.

3.0 SETTING THE PARAMETERS

Several seconds after computer power on, Figure A1 appears and offers four choices (options.) See the caption of the figure for an explanation of the choices.

3.1 The Program Menu

Pressing F1, F2, F3 or F4 (in the Calculation Menu in Figure A1) causes Figure A2 with the Program Menu at the bottom to appear on the screen. Actually, Figure A2 shows the 1.523 µm infrared laser selected, while Figure A3 shows the red laser selection.

a. Pressing F1 (when it says Print) in Figure A2 activates the printer, which must be connected and on (so that the printer will automatically print the measurement solutions.) At the same time, "Print" changes to "Disp" so that the printing can be deactivated when F1 is again pressed.

b. Press F2 (Sample) to assign an alphanumeric identification number to the sample wafer.

*The L2W16C.830 Ellipsometer has a helium-neon red laser (at 6328Å) and a diode infrared laser. The wavelength range of the diode laser is 7700 to 8500Å, but mostly at 8300Å.
GAERTNER 2GC9A AUTOMATIC ELLIPSOmetry PROGRAM

FOR IBM PC
TWO LAYER ABSORBING
(c) Copyright Gaertner Scientific Corp. 1988

Option 1 (f1) Calculates:  Option 2 (f2) Calculates:  Option 3 (f3) Calculates:  Option 4 (f4) Calculates:
Top Layer THK  Top Layer THK  Top Layer THK  Top Layer THK
Top Layer N  Layer 2 THK  Top Layer K
(Thin film)

<table>
<thead>
<tr>
<th>OPT 1</th>
<th>OPT 2</th>
<th>OPT 3</th>
<th>OPT 4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

Figure A1 This is the screen display that shows the four options that are in this two-wavelength (2->) single-point measurement program. Note that this program is for two film layers, either of which can be nontransparent (absorbing.) Note that Option 2 measures only the thickness of the top film layer and that "(Thin film)" implies that the film thickness is less than 400A or else within 400A of a periodic multiple* (in Option 2.) Option 3 measures the second-layer thickness instead of the top layer N in Option 1. Option 4 measures the top-layer index K (instead of the top layer N in Option 1.) For an RS-232 system, "2GC9A" at the top of the screen becomes "2GC9A#." 

*A periodic multiple means that a positive integer is multiplied by the period.
3.0 SETTING THE PARAMETERS (Continued)

3.2 Film Parameters

To change any Film Parameters, press F3 in Figure A2. The bottom of the screen shows this:
"Select film setup options:
1NsKs  2NfKf  3ExpThk  4Layers  5WL  6All  7  8  9  10Exit."

a. F1 (NsKs) allows changing the substrate indexes N and K.
b. F2 (NfKf) lets you change the film N and K.
c. F3 (ExpThk) permits a new film thickness to be entered.
d. F4 (Layers) allows the second layer thickness and indexes, Nf and Kf to be changed.
e. For F5 (WL), the screen asks for the laser to be used next, in micrometers (μm):
"Select Wavelength(μmeters)"
10.633 21.523* 3 4 5 6 7 8 9 10.*

Pressing F1 (red laser) causes this display:
"PULL OUT WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** (PRESS ENTER)"

Pressing F2 (Infrared laser) causes this display:
"PUSH IN WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** (PRESS ENTER)"

*The "1.523" shown is for the helium-neon infrared laser on the L2W25C.1.5 and L2W26C.1.5 Ellipsometers. For the L2W15C.830 and L2W16C.830 instruments, "0.830" appears in place of "1.523."

**Only the L2W25C.1.5 and L2W26C.1.5 instruments have a D lever on the polarizer arms. The L2W15C.830 and L2W16C.830 ellipsometers have only the W levers on the analyzer arms.

NOTE: Wavelength is actually an Instrument Parameter, but it is included with the Film Parameters so that you can also change the substrate indexes (N and K.) Note the differences between the default substrate indexes for silicon in Figures A2 and A3.

f. For F6 (All), all seven of the Film Parameters (in Figure A2) can be changed.
g. F10 (Exit) brings Figure A2 functions back.
OPTIONAL 2GC9A AND 2GC9A# SINGLE-POINT PROGRAMS

FILM PARAMETERS
Top Layer-Thick (exp): 0       Nf (exp): 1.444       Kf (fxd): 0.000
Layer 2 -Thick2 (fxd): 0       Nf2 (fxd): 0.000       Kf2 (fxd): 0.000
Substrate-Ns: 3.479           Ks: 0.0

INSTRUMENT PARAMETERS
Wavelength(A): 15230         Ambient: 1.000
Phi (Incidence angle): 70.00

Select option:
1Print 2Sample 3Film P 4InstrP 5Meas 6 7Setup 8* 9* 10End

*For the RS-232 instrument, "Ser1 P" appears for the F8 key. After a measurement is taken, "SEND" appears for the F9 key.

Figure A2 This screen display has the 2GC9A or 2GC9A# two-wavelength (2-λ), single-point Program Menu at the bottom. This display first appears with no solution in the middle of the screen. The screen initially shows the red laser wavelength (6328A) and the substrate N_s of 3.85 and K_s of .02 (as in Figure A3.) Here, the screen shows the 15230A infrared laser and N_s and K_s. Then pressing F2 allows a sample identification number to be typed in (with Enter pressed.) Pressing F5 causes a measurement to be made, with the results shown below the sample number. This causes F6 to become the List key. Then pressing F6 causes the first twelve periodic multiples representing thicknesses to be displayed, while "List" disappears.

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3.0 SETTING THE PARAMETERS (Continued)

3.3 Instrument Parameters

If you want to change any of the Instrument parameters, press F4 in Figure A2. The bottom of the screen changes to this:

"Select instrument setup options:
1_Wi  2_Phi  3_Ambient  4  5  6  7  8  9  10_Exit."

a. F1 (Wi) allows changing the lasers. See step 3.2e.
b. F2 (Phi) lets you change the angle of incidence.
c. F3 (Ambient) permits a new ambient value to be entered.
d. F10 (Exit) brings Figure A2 functions back.

4.0 TAKING THE MEASUREMENTS

Figure A2 shows the seven choices at the bottom, called the Program Menu functions. Note on the screen, there is no function for the F6 key.

a. If you press F5 (Meas.) a measurement is taken. The results are shown in the middle of the screen, as shown in Figure A3 (for Option 1 in Figure A1.) Now F6 is the List key.
b. If you press F6 (List,) the first twelve periodic multiples representing thicknesses are displayed (for any of the four options) just above the functions while the word "List" disappears. One listing example is this:

LISTING:(PERIOD= 2397 A)
750  7939  15129  22318
3146  10336  17525  24715
5543  12732  19922  27112
c. For Option 2 (Figure A1), "Psi calculated" and its value replace "Nf measured" and its value.
d. If Option 3 is chosen, "Layer 2 Thick" and its value replace "Nf measured" and its value.
e. If Option 4 is chosen, "Kf measured" and its value replace "Nf measured" and its value.
f. When you are through running measurements with this optional program, press F10 (End,) Then "A>" appears on the screen so that you can work with another program on another disc. Turn off the computer so that the discs can be changed.
OPTIONAL 2GC9A AND 2GC9A# SINGLE-POINT PROGRAMS

FILM PARAMETERS
- Top Layer-Thick (exp): 0
- Layer 2-Thick2(fxd): 0
- Substrate-Ns: 3.850

Nf (exp): 1.460  Kf (fxd): 0.000
Nf2(fxd): 0.000  Kf2(fxd): 0.000
Ks: -0.020

INSTRUMENT PARAMETERS
- Wavelength(A): 6328
- Phi(Incidence angle): 70.00
- Ambient : 1.000

SOLUTION
- Sample number:
  - Top Thickness(A): 750
  - Nf measured : 1.621
  - Psi : 33.85
  - Delta: 71.78

*For the RS-232 instrument, "Ser1 P" appears for the F8 key. After a measurement is taken, "SEND" appears for the F9 key.

Figure A4  This screen display shows the solutions to the measurement, which appear when the F5 key is pressed. The measurement was made with the red laser (6328 A.). Note that F6 has become the "List" key.
7109-C-281A

2GC8A4 and 2GC8A4# Optional Automatic Program Instructions for use with
L2W16C.830 and L2W26C.1.5 Ellipsometers and
IBM PC and PS Series Computers

Gaertner Scientific Corp.
1201 West Wrightwood
Chicago, IL, 60614
APPENDIX A

OPTIONAL 2GC8A4 AND 2GC8A4# SINGLE-POINT PROGRAMS

1.0 INTRODUCTION

These optional single-point measurement programs (2GC8A and 2GC8A#) are four-layer, nonabsorbing (transparent)-film programs for use with Gaertner L2W16C.830* and L2W26C.1.5 Ellipsometers and IBM computers.

NOTE: Sometimes the screen asks you to type in some specific characters. This instruction shows those characters in boldface and just after "type." Type in the characters, and press Enter.

Be sure to read the computer and the ellipsometer manuals. It would be beneficial to study the printer manual. Also, be sure to read the Standard Program (2STD) Instructions. If you have the RS-232 single-point system, read the RS-232 Standard (single-point) Program (2STD#) Instructions. Running some measurements would help, because this instruction makes many references to the 2STD instruction where the two operations are the same.

2.0 SET UP

See sections 1.0 (Introduction and Set Up,) 1.1 (Software Installation and Loading) and 1.2 (Sample Table Alignment) in the 2STD instructions. For RS-232 systems see the 2STD# instructions.

3.0 SETTING THE PARAMETERS

Several seconds after computer power on, Figure A1 appears and offers three choices (options.) See the caption of the figure about the choices.

3.1 The Program Menu

Pressing F1, F2 or F3 (Figure A1) causes Figure A2 to appear.

a. Pressing F1 (when it says Print) in Figure A2 activates the printer (which must be connected and on) so that it will automatically print solutions. At the same time, "Print" changes to "Disp." Then, pressing F1 deactivates the printer.

b. Pressing F2 (Sample) allows you to assign an alphanumeric identification number to the sample.

*The L2W16C.830 Ellipsometer has a helium-neon red laser (at 6328Å) and a diode infrared laser. The wavelength range of the diode laser is 7700 to 8500Å, but mostly at 8300Å.
GAERTNER 2GC8A4 AUTOMATIC ELLIPSOMETRY PROGRAM

FOR IBM PC

FOUR LAYER NONABSORBING

(c) Copyright Gaertner Scientific Corp. 1988

Option 1 (f1)       Option 2 (f2)       Option 3 (f3)
Calculates:         Calculates:         Calculates:

Top Layer THK       Top Layer THK       Top Layer THK
Top Layer N          Top Layer THK       Layer 2 THK

(Thin film)

OPT 1 2OPT 2 3OPT 3 4  5  6  7  8  9 10

Figure A1 This is the screen display that shows the three options that are in this single-point program. Note that this program is for four film layers, which are all transparent (nonabsorbing.) Note that Option 2 measures only the thickness of the top film layer and that "(Thin film)" implies that the film thickness is less than 400Å or else within 400Å of a periodic multiple.* In Option 3, the second layer thickness is measured instead of the top layer index N. For an RS-232 system, "2GC8A4#" at the top of the screen becomes "2GC8A4#.*

*A periodic multiple means that a positive integer is multiplied by the period.
3.0 SETTING THE PARAMETERS (Continued)

3.2 Film Parameters

If you want to change any of the Film Parameters, press F3 in Figure A2. The bottom of the screen changes to this:

"Select film setup options:
1NsKs  2Nf  3ExpThk  4Layers  5WL  6All  7  8  9  10Exit."

a. F1 (NsKs) allows changing the substrate indexes N and K.
b. F2 (Nf) lets you change the top film index N.
c. F3 (ExpThk) permits a new top film thickness to be entered.
d. F4 (Layers) allows the second, third and fourth layer thicknesses and indexes Nf to be changed.
e. For F5 (WL), the screen asks for the laser to be used next:

"Select Wavelength( μmeter )
10.633  21.523*  3  4  5  6  7  8  9  10."

• Pressing F1 (red laser) causes the screen to display the following:

"PUSH IN WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** <PRESS ENTER>._"

• Or pressing F2 (infrared laser) causes the screen to display the following:

"PULL OUT WAVELENGTH SELECTOR (W) AND DEPOLARIZER (D)** <PRESS ENTER>._"

*The "1.523" shown is for the helium-neon infrared laser on the L2W26C.1.5. For the L2W16C.830 (and the diode infrared laser,) "0.830" appears in place of "1.523."

**Only the L2W26C.1.5 has a D lever on the polarizer arm. The L2W16C.830 has only the W lever on the analyzer arm.

NOTE: Wavelength is actually an Instrument Parameter, but it is included with the Film Parameters so that you can also change the substrate indexes (N and K). Note the differences between the default substrate indexes for silicon in Figures A2 and A3.

f. For F6 (All), all seven of the Film Parameters (in Figure A2) can be changed.
g. F10 (Exit) brings Figure A2 functions back.
FILM PARAMETERS
Top Layer- Thick (exp): 0  Nf (exp): 1.444*
Layer 2 -Thick2(fxd): 0  Nf2(fxd): 0.000*
Layer 3 -Thick3(fxd): 0  Nf3(fxd): 0.000*
Layer 4 -Thick2(fxd): 0  Nf4(fxd): 0.000*
Substrate-Ns: 3.479*  Ks: 0.0*

INSTRUMENT PARAMETERS
Wavelength(A): 15230*  Ambient: 1.000
Phi(Incidence angle): 70.00

Select option:
1Print 2Sample 3Film P 4InstrP 5Meas 6 7Setup 8** 9** 10End

*For the L2W26C.830, the wavelength will be 8300(A) and the Ns, Ks, Nf and Kf will be generally different from the values above.

**For the RS-232 instrument, F8 has "Ser1 P." When a measurement is taken, F9 has "SEND."

Figure A2 This screen display has the 2GC8A4 or 2GC8A4# two-wavelength (2-λ), single-point Program Menu at the bottom. This display first appears with no solution in the middle of the screen. The screen initially shows the red laser wavelength (6328A) and the substrate Ns of 3.85 and Ks of -.02 (as in Figure A3.) Here, the screen shows the infrared laser wavelength of 15230A and the substrate Ns and Ks (and film indexes.) Then pressing F2 allows a sample identification number to be typed in (with Enter pressed.) Pressing F5 causes a measurement to be made, with the results shown below the sample number (Figure A3.) Then pressing F6 causes the first twelve periodic multiples representing thicknesses to be displayed, while "List" disappears.
3.0 SETTING THE PARAMETERS (Continued)

3.3 Instrument Parameters

If you want to change any of the instrument parameters, press F4 in Figure A2. The bottom of the screen changes to this:

"Select instrument setup options:
1. \( W \) 2. \( \Phi \) 3. Ambient 4 5 6 7 8 9 10. Exit."

a. F1 (W) allows changing the lasers. See step 3.2e.
b. F2 (Phi) lets you change the angle of incidence.
c. F3 (Ambient) permits a new ambient value to be entered.
d. F10 (Exit) brings Figure A2 functions back.

4.0 TAKING THE MEASUREMENTS

Figure A2 shows the seven choices at the bottom, called the Program Menu functions. Note on the screen, there is no function for the F6 key.

a. If you press F5 (Meas.) a measurement is taken. The results are shown in the middle of the screen, as shown in Figure A3 (for Option 1 in Figure A1). Now F6 is the List key.
b. If you press F6 (List), the first twelve periodic multiples representing thicknesses are displayed (for any of the three options) just above the functions while the word "List" disappears. One listing example is this:

```
LISTING: (PERIOD= 2800 A)
1039  9439  17839  26239
3839  12239  20639  29039
6639  15039  23439  31839
```
c. For Option 2 (Figure A1), "Psi calculated" and its value replace "Nf measured" and its value.
d. If Option 3 is chosen, "Layer 2 Thick" and its value replace "Nf measured" and its value.
e. When you are done with this program and want to exit, press F10 (End.) Then "A>" appears on the screen so that you can work with another program on another disc. Turn off the computer so that the discs can be changed.
FILM PARAMETERS
Top Layer-Thick (exp): 0  Nf (exp): 1.460
Layer 2 -Thick2 (fdx): 0  Nf2 (fxd): 0.000
Layer 2 -Thick2 (fxd): 0  Nf2 (fdx): 0.000
Layer 2 -Thick2 (fxd): 0  Nf2 (fdx): 0.000
Substrate-Ns: 3.850  Ks: -0.020

INSTRUMENT PARAMETERS
Wavelength (A): 6328  Ambient: 1.000
Phi (Incidence angle): 70.00

SOLUTION
Sample number:  
Top Thickness (A): 1039  Psi: 44.11
Nf measured: 1.470*  Delta: 78.69

*The "Nf measured" is for Option 1 in Figure A1. For the other three options, these are shown:
Option 2: "Psi calculated" is in place of "Nf measured."
Option 3: "Layer 2 Thick" is in place of "Nf measured."

**For the RS-232 instrument, F8 has "Sep L P." When a measurement is taken, F9 has "SEND."

Figure A3  This screen display shows the measurement solutions, which appear when the F5 key is pressed. The red laser (6328 A) was used. Note that F6 has become the "List" key.
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<td>4</td>
</tr>
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<td>8</td>
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</tbody>
</table>
1.0 PROGRAM LOADING INSTRUCTIONS

This program is for two-wavelength manual and auto-gain ellipsometers that are measuring single-layer films and bare substrates.

This Gaertner Ellipsometer program software is supplied on two types of discs for use on the IBM PC and PS Series Computers. Program software for the IBM PC and IBM PC XT Model Computers are supplied on discs compatible with a 360K bytes drive. Software for the IBM PC AT and PS/2 Model Computer is supplied on discs compatible with a 1.2M bytes drive.

Connect the ellipsometer system (with the computer and printer) as shown in the Installation section of the ellipsometer user's manual. Sometimes the ellipsometer user's manual has a supplement; in that case, the installation information may also be in the supplement.

NOTE: Whenever the screen asks you to type in something specific, the characters to be typed in are shown in boldface, followed by "and press Enter."

Insert the program disc into drive A, and turn on the computer. The program should boot automatically. If DOS is already loaded, place the program disc in the appropriate disc drive, i.e., 1.2M drive for programs using IBM PC AT and PS/2 or 360K drive for programs using IBM PC or IBM PC XT. For example, if a: is displayed on the screen, drive A is the default drive. If the program disc is compatible with drive A and inserted in drive A, then just type autost and press Enter. If program disc is compatible with drive B and inserted in drive B when "a:" is the default drive (displayed on the screen), then type b: autost and press Enter. The program will be loaded and start running.

The first screen display is shown in Figure A1, which asks whether or not the retardation shown (for the red laser) is correct. Just press Enter if it is. If it is not, type in the correct value (see the retardation values hand-written in below,) and press Enter. The retardation of the infrared laser may be typed in later in the Film subprogram. Your values for the retardation will not be stored when this program is terminated.

Ellipsometer Model Number_________________________ Serial Number________ AK

633 nm (red) laser retardation________ 830 nm (infrared) laser retardation________

Observe the display (Figure A2,) and press F1 or F2 for your subprogram; that is, Film (2GP5) or substrate (2SubP). Proceed to section 2.0 (Film measurements) or 3.0 (Substrate.)
<table>
<thead>
<tr>
<th>Retardation = 90.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence Angle =</td>
</tr>
<tr>
<td>Wavelength =</td>
</tr>
<tr>
<td>Ambient =</td>
</tr>
<tr>
<td>Expected Thick =</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUBSTRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ns(Fxd)=</td>
</tr>
<tr>
<td>Ks(Fxd)=</td>
</tr>
</tbody>
</table>

Enter Rotation (RETARD=90.0)?

**Figure A1** This is the first screen display of the 2GP5 + 2SubP program. You are asked to type in the correct retardation for the red laser if 90.0 is not correct.
RAERTNER 2GP5 + 2SubP MANUAL
ELLIPSOMETRY PROGRAM USING IBM PC

<table>
<thead>
<tr>
<th>Retardation</th>
<th>Incidence Angle</th>
<th>Wavelength</th>
<th>Ambient</th>
<th>Expected Thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.0</td>
<td>70.00°</td>
<td>6328Å</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUBSTRATE</th>
<th>Ns(Fxd)</th>
<th>Ks(Fxd)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.875*</td>
<td>-0.018*</td>
</tr>
</tbody>
</table>

Select option:
1Film 2SubStr 3 4 5 6 7 8 9 10 END

*These index values for a silicon substrate at 633 nm apply only to ellipsometers that also have an infrared laser (770 to 850 nm and 1.523 μm.)

**Figure A2** This is the second screen display with the default values shown. The user has the choice of making Film (F1) or Substrate (F2) measurements after checking that the parameters above for the red laser are all proper.
APPENDIX A

2.0 GP5 (Film) SUBPROGRAM

When the Film subprogram is selected (with F1 in Figure A2,) the following are "Default Values."

- Silicon substrate: \( N = 3.875; K = 0.018 \)
- \( SiO_2 \) film: Expected index, \( N = 1.46 \)
- Mode of measurement: Measure N and thickness
- Angle of incidence: \( \phi = 70^\circ \)

2.1 Film Subprogram Menu

The bottom of Figure A3 has the Film subprogram menu, and the function of each key is as follows:

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Print/Disp)</td>
<td>Pressing F1 when &quot;PRINT&quot; is shown causes the printer (which must be connected and ON) to automatically print the measurement solutions. Pressing F1 when &quot;DISP&quot; is shown deactivates the printer.</td>
</tr>
<tr>
<td>F2 (Setup)</td>
<td>You may type in values for any substrate, film and angle of incidence.</td>
</tr>
<tr>
<td>F3 (Oxide)</td>
<td>It automatically fixes or measures index N, depending upon the sensitivity for oxides.</td>
</tr>
<tr>
<td>F4 (Nitride)</td>
<td>This is the same as above except being for nitrides.</td>
</tr>
<tr>
<td>F5 (A1/P1)</td>
<td>You type in analyzer/polarizer readings or psi and delta.</td>
</tr>
<tr>
<td>F6 (PsiDel)</td>
<td>You may type in the psi and delta values.</td>
</tr>
<tr>
<td>F7 (N Fixd/N Meas)</td>
<td>&quot;N Fixd&quot; calculates only the film thickness with N fixed. &quot;N Meas&quot; calculates both the thickness and index.</td>
</tr>
<tr>
<td>F8 (Sample)</td>
<td>You may type in an alphanumeric sample identifying number.</td>
</tr>
<tr>
<td>F9 (List)*</td>
<td>The ten smallest possible film layers are shown.</td>
</tr>
<tr>
<td>F10 (EXIT)</td>
<td>This brings Figure A2 and its menu back to the screen.</td>
</tr>
</tbody>
</table>

*The List function appears only after a measurement was taken.
2.1 Film Subprogram Menu (Continued)

For very thin films or films close to periodic multiple, the sensitivity of index measurement is very poor and, therefore, accurate thickness measurements can be obtained only by fixing the value of the index (N) then calculating the thickness (press F6 when it has "N Meas.")

If the Oxide key (F3) is selected (for oxide films,) the subprogram lets you type in analyzer/polarizer readings or psi and delta values. The program then proceeds to automatically determine whether the index (N) should be fixed or measured. The same is true if the NITRIDE key (F4) is selected, for nitride films. Hence, for either oxide or nitride film on a silicon substrate the above keys (F3 and F4) are recommended.

The automatic fixing or measuring of the index (N) can be avoided, if desired, by using function F6 (N Fixd/N Meas) which toggles to fix the index (N) and measure the index (N) respectively regardless of sensitivity considerations, although sometimes answers may not be computed. For example: attempting to measure the index (N) of very thin films (under 100 Angstroms) may not be possible to compute an answer. However, if the index (N) is fixed, the thickness will be computed.

The A1/P1 key (F5) prompts the analyzer/polarizer entries. If Enter is pressed without any values typed in, psi and delta values can be typed in. After A1/P1 readings are typed in, A2/P2 readings should be typed in. The screen shows the ideal values for the A2/P2 readings. If the analyzer and polarizer readings are entered, default polarizer and analyzer values will be displayed. To use any default values, just press Enter. After one set of A2 and P2 values are entered, then a prompt to enter A1 will appear. If just Enter is pressed, the program will take the values entered. If more than one set of A1, P1, A2 and P2 values are to be averaged, then the sets of values can be entered at this stage.*

* "Rétardation=90.0?" will be displayed. Press Enter, and the calculating sequence will start automatically.
GAERTNER 2GP5 + 2SubP MANUAL
ELLIPSOMETRY PROGRAM USING IBM PC

| Retardation = 90.0 |
| Incidence Angle = 70.00° |
| Wavelength = 6328Å |
| Ambient = 1,000 |
| Expected Thick = 800 |

| A1 = 34.90 |
| P1 = 99.21 |
| A2 = 145.10 |
| P2 = 189.01 |

| SUBSTRATE Ns(Fxd)= 3.875 |
| Ks(Fxd)= -0.018 |

| Thick: 776Å |
| Nf(calc): 1.606 |
| Psi: 34.90 |
| Delta: 71.98 |

| LISTING (PERIOD = 2430Å) |
| 776 5636 10495 15355 20214 |
| 3206 8665 12925 17784 22644 |

Select option:
1Print 2Setup 3Oxide 4Nitride 5A1/P1 6PsiDel 7N_Fxd 8Sample 9List* 10EXIT

*The List key (F9) appears only after a measurement is taken. Then pressing F9 causes the ten thinnest possible film layers to be shown (on the left, above the menu.)

**Figure A3** This is the third screen display with the Film menu at the bottom. Then after measurements have been taken, those values appear. Sample values and a listing are shown. See section 2.0 about the functions of the keys in the Film subprogram menu.
2.0 GP5 (Film) SUBPROGRAM (Continued)

2.2 The Film Setup Menu

F2 is the Setup (F2) key in the Film Subprogram Menu, which has the following functions:

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Print/Disp)</td>
<td>See F1 in the above menu.</td>
</tr>
<tr>
<td>F2 (Retard)</td>
<td>This allows the proper value for each laser to be typed in.</td>
</tr>
<tr>
<td>F3 (Phi)</td>
<td>You can type in the angle of incidence if it is not 70°.</td>
</tr>
<tr>
<td>F4 (Waveln)</td>
<td>You can choose the other wavelength for measurements.</td>
</tr>
<tr>
<td>F5 (Ambent)</td>
<td>Lets you type in the proper ambient value.</td>
</tr>
<tr>
<td>F6 (ExpThk)</td>
<td>This is for typing in the expected film thickness.</td>
</tr>
<tr>
<td>F6 (Nf)</td>
<td>You may type in the expected or fixed index N.</td>
</tr>
<tr>
<td>F8 (Ns Ks)</td>
<td>You may type in the substrate indexes.</td>
</tr>
<tr>
<td>F9 (All)</td>
<td>You can change all of the above parameters.</td>
</tr>
<tr>
<td>F10 (EXIT)</td>
<td>This causes Figure A3 to return to the screen.</td>
</tr>
</tbody>
</table>

In Figure A1, you typed in the retardation for the red laser if the default value of 90.0 was incorrect. To type in the retardation for the infrared laser, press F4 (Waveln). Then press F2 for the 830 nm (infrared) laser. Then press F2 to check and change if necessary the infrared retardation. If you exit this program and reenter it later, the retardation values will have to be put in again.

The Setup menu permits you to type in the substrate index values, fixing or measurement of index (N), estimated value of index (N), angle of incidence (phi) and expected film thickness (in A). Default values for the above parameters will be displayed. Pressing Enter with no values typed in first, the defaults are to these values. Otherwise, other desired values (parameters) may be typed in. Press Enter after value is typed in.
3.0 SubP (Substrate) SUBPROGRAM

Pressing F2 in the menu of Figure A1 brings the Substrate Program Menu to the screen:

"Select option:
1Print 2Retard 3Phi 4Waveln 5Ambent 6A1/P1 7PsiDel 8Sample 9 10EXIT"

The default angle of incidence (70,00°) is selected first automatically. The A1/P1 functions are the same as the film program (GP5) and A1, P1, A2, P2 values or psi and delta values can be entered. Pressing the Film key enters film program 2GP5. The functions of the above keys are as follows:

<table>
<thead>
<tr>
<th>Key</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Print/Disp)</td>
<td>Pressing F1 when &quot;PRINT&quot; is shown causes the printer (which must be connected and ON) to automatically print the measurement solutions. Pressing F1 when &quot;DISP&quot; is shown deactivates the printer.</td>
</tr>
<tr>
<td>F2 (Retard)</td>
<td>This lets you type in the proper retardation value for each laser</td>
</tr>
<tr>
<td>F3 (Phi)</td>
<td>You can type in the angle of incidence if it is not 70°.</td>
</tr>
<tr>
<td>F4 (Waveln)</td>
<td>You can choose the other wavelength for measurements.</td>
</tr>
<tr>
<td>F5 (Ambent)</td>
<td>It lets you type in the proper ambient value between 1.00 and 2.00.</td>
</tr>
<tr>
<td>F5 (A1/P1)</td>
<td>This is for typing in analyzer/polarizer readings or Psi and Delta</td>
</tr>
<tr>
<td>F6 (PsiDel)</td>
<td>You may type in the psi and delta values.</td>
</tr>
<tr>
<td>F8 (Sample)</td>
<td>You may type in an alphanumeric sample identification number.</td>
</tr>
<tr>
<td>F9 (All)</td>
<td>You can change all of the above parameters.</td>
</tr>
<tr>
<td>F10 (EXIT)</td>
<td>This causes Figure A1 to return to the screen.</td>
</tr>
</tbody>
</table>
7109-C-320-R1
TWO-WAVELENGTH IN-SITU PROGRAM
FOR L2W04B.830 ELLIPSOMETERS
AND IBM PC/PS COMPUTERS

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  1.1 System Hook Up .................................................... 1
  1.2 Computers and Start Up .......................................... 1
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1.0 INTRODUCTION AND START UP

This program is for use with the IBM PC/PS computers with the two-wavelength (2-λ) L2W04B.830 In-Situ Ellipsometer. This program allows users to enter film or substrate parameters, instrument parameters, and monitoring parameters for 2-λ in situ measurements. Raw data may be stored or computed and outputted during the runtime process. Also, a time critical process may be selected which provides a continuous PSI and Delta output during runtime. A retrieve function will recall stored data for automatic computation; results will be displayed, printed and stored in an ASCII file.

NOTE: The 2-λ L104B (L2W04B.830) Ellipsometer always has a red laser (at 6328Å) and an infrared (diode) laser (between 7700 and 8500Å.) The most common infrared wavelength is 8300Å. The model number will indicate the actual infrared wavelength. For example, an ellipsometer with a 8200Å diode laser would have the model number of L2W04B.820.

Carefully study this instruction before making any measurements. The ellipsometer may be on and warming up (see 1.2.1.) Also study sections 1 (Description) and 2 (Set Up and Operation) and the 2-λ supplement of the L104B user's manual. Then read the computer and printer manuals.

1.1 System Hook Up

The L2W04B.830 Ellipsometer and computer system is connected according to the 2-λ supplement to the L104B user's manual.

1.2 Computers and Start Up

Gaertner Ellipsometer program software is supplied on two types of discs for use on the IBM PC and PS Series Computers. Program software for the IBM:

- PC and PC XT Model Computers is supplied on discs compatible with a 360K bytes 5-1/4" drive.
- AT computer is supplied on discs compatible with a 1.2M bytes 5-1/4" drive.
- PS/2 Model 25 and 30 Computers is supplied on discs compatible with a 1.2M bytes drive.

1.2.1 Ellipsometer

The ellipsometer should be on for 15 minutes, but 30 minutes would be better.
1.2.2 Computer System

NOTE: When you are prompted to type in specific characters, as in the following paragraph, those characters are in boldface and followed by "and press Enter."

Turn on the computer display unit if it has a power on/off switch. Turn on the printer. Insert the program disc into drive A, and turn on the computer. The program should boot automatically. If DOS is already loaded, place the program disc in the proper disc drive, i.e., 1.2M drive for programs using IBM PC AT and 720k for PS/2 or 360K drive for programs using IBM PC or IBM PC XT.

For example, if "A:\" or "A>" is displayed on the screen, drive A is the default drive (the drive that the computer selects when the computer is turned on.) The screen should show that A is the default drive. If there is some other letter than A, type a: and press Enter to make A the default drive. When the program disc is compatible with drive A and inserted into drive A, then just type autost and press Enter. The program will load and start running.

1.3 Menu Structure

The program is organized using a menu-driven, hierarchical structure. See the three charts in this appendix (A.) From the CRT-displayed function keys in the Program (Main) Menu, you may select the Film Measurement Menu or the Substrate Measurement Menu, each of which has its own group of menus. Most menus have an Exit function which causes a return to the next higher menu level.
1.0 INTRODUCTION AND START UP (Continued)

1.4 Program Menu

The Program Menu is the menu from which you may select the Film or Substrate Measurements.

"Select mode:
1Film  2SubCA  3  4  5  6  7  8  9  10End"

The above three keys are:

- F1 - (Film) Film Measurement Menu access. See 2.0.
- F2 - (SubCA) Substrate Measurement Menu access. See 3.0.
- F10- END. The prompt appears: "Exit Program (Y/N)?" The program will return to DOS so that you can load a different program if you press "Y" and Enter.

1.4.1 Wavelenth Selection

Pressing F1 (Film) causes

"Select wavelength
1633  2830" to be shown on the screen's bottom left. The F lever is on the analyzer's side.

- F1 - (633 nm) - The wavelength, N_S and K_S are changed to the 6328A values. Then you are asked to "PULL OUT FILTER (F) <PRESS ENTER>.

- F2 - (830 nm) - The wavelength, N_S and K_S are changed to the 8300A values. Then you are asked to "PUSH IN FILTER (F) <PRESS ENTER>.

1.4.2 Film or Substrate Measurements

After pressing F1 (red laser) or F2 (infrared laser,) setting lever F and pressing Enter, Figure A1 (next page) to be displayed. See 2.0 for the menu. However, pressing F2 (Subca) in the Program Menu (1.2) causes the wavelength choices (1.2.1) to appear. When you set the F lever and press Enter, Figure A2 is shown (the page after 3.0.)
FILM PARAMETERS
Ns: 3.850   Nf: 1.460   Expected Thickness (A): 0
Ks: -0.020   Fix Nf near origin (Monitor mode only): Yes

INSTRUMENT PARAMETERS
Retardation: 88.00   Polarizer Angle: 45.0
Number of Revolutions: 1   Wavelength (Å): 6328
Phi (Incidence Angle): 70.00   Ambient: 1.000

Select option: 1FilmP 2InstrP 3Monitr 4Retrv 5Print 6Sample 7* 8Meas 9* 10Exit

*For the F7 and F9 functions, see 2.0 (next page.)

Figure A1 This is the Film Measurements Menu for the two-wavelength L104B (L2W04B.830) In Situ Ellipsometer. The above default parameters are for the red (6328 Å) laser,
2.0 FILM MEASUREMENTS MENU

When the F1 key in the Program Menu (in 1.2) is pressed, a display as in Figure A1 appears. There would be Film Parameters Menu (for F1), an Instrument Parameters Menu (F2), the Monitor Menus (F3), the Retrieve Menus (F4) and the Measure Menu. F3 (Monitor) accesses the Data, Output, Store, Both, and Time Critical Menus.) Most menus have an Exit key (F10), which causes a return to the next higher menu level. You may select from the available operations, which are:

- **F1** - (Film P) - This accesses the Film Parameters Menu. See 2.1.
- **F2** - (Instr P) - This is the Instrument Parameters Menu access. See 2.2.
- **F3** - (Monitor) - This accesses the Monitor Menu. See 2.3.
- **F4** - (Retrv) - This is the Retrieve Menu access. See 2.4.
- **F5** - (Print or Disp) - This key alternates to select Print or Display.*
- **F6** - (Sample) - You may enter an alphanumerict identification number for the test sample.
- **F7** - (List) - This lists the nine smallest possible film thicknesses after the measurement. This key appears just after F8 is pressed (and a measurement is taken.)
- **F8** - (Meas) - Measure Menu access. See 2.5.
- **F9** - (Start) - This starts the automatic measuring sequence as set up using the Monitor Menu (see 2.3.) This key appears on the Film Measurements Menu after pressing the Exit key in the Monitor Menu.
- **F10** - (Exit) - The return is to the Program Menu in 1.2.

*When "Print" is displayed for F1, the printer is deactivated. To press F1, the printer must be connected and on. The pressing of F1 will cause the printer to automatically print measurement solutions. When "Display" is displayed for F1, the printer is activated (and must have been connected and turned on.) Then if you press F1, the printer will not automatically print.
2.0 FILM MEASUREMENT MENU (Continued)

2.1 Film Parameters Menu (Film Measurements Only)

When the F1 key in Figure A1 is pressed, this menu appears for selecting these film parameters:

- F1 - \((N_S/K_S)\) - This allows you to enter substrate constants, \(N_S\) and \(K_S\) (the boundaries are 0 to 20 for \(N_S\) and 0 to -20 for \(K_S\)).
- F2 - \((N_f)\) - This lets you enter the film refractive index (between 0 and 20).
- F3 - (Fix N, N Meas) - This key alternates between measuring \(N\) and letting you fix \(N\).
- F4 - (Exp Thk) - This lets you enter the expected film thickness (between 0 and 99,999\(\text{Å}\)).
- F7 - (Wave) - See the Wavelength Selection in 2.2.1.
- F8 - (All) - You can change all of the film parameters in sequence.
- F10 - (Exit) - The return is to the Film Measurement Menu (2.0.)
2.0 FILM MEASUREMENT MENU (Continued)

2.2 Instrument Parameters Menu (Either Film or Substrate Measurements)

From the Figure A1 F2 key (2.0) or the Figure A2 F2 key in 3.0, this menu selects the following instrument setup options:

- F1 - (Retard) - You can change the laser retardation. The default value is 88.0 for red and 70.0 for infrared.
- F2 - (Num Rev) - This allows you to enter the number of complete analyzer drum revolutions to be averaged (between 1 and 20.)
- F3 - (Phi) - You can change the angle of incidence.
- F4 - (Pol Ang) - You may change the angular setting of the polarizer drum. The default drum value is 45.00.
- F5 - (W1) - You may change to the other wavelength. If another laser is installed, then that wavelength can be typed in (between 2000 and 50,000Å.) See 2.2.1 (below.)
- F6 - (Ambent) - This allows you to change the ambient refractive index. The default value is 1.000 for a vacuum or air, and the boundaries are between 1.0 and 2.0.
- F10 - (Exit) - The return is to the Film Measurements Menu (2.0) if you selected F1 (Film) in 1.2 or the Substrate Measurement Menu (3.0.) If you selected F2 (Subcal) in 1.2.

2.2.1 Wavelength Selection - This is from the F5 key (W1,) above. Filter lever (F) is on the side of the analyzer component.

- F1 - (633) - The wavelength, N<sub>e</sub> and K<sub>e</sub> are changed to the 6328Å values. Then you are asked to "PULL OUT FILTER (F) < PRESS ENTER >."
- F2 - (830) - The wavelength, N<sub>e</sub> and K<sub>e</sub> are changed to the 8300Å values. Then you are asked to "PUSH IN FILTER (F) < PRESS ENTER >."
2.0 FILM MEASUREMENT MENU (Continued)

2.3 Monitor Menus

These menus (from the F3 key in Figure A1) permit you to select the desired method of monitoring instrument data.

- F1 - (Output) - This is the Output Menu - See 2.3.1 (below.)
- F2 - (Store) - This is the Store Menu. Follow the on-screen prompts. See 2.3.2.
- F3 - (Both) - This combines the Output and Store Menus. See 2.3.3.
- F4 - (Tcrit) - This is the Time Critical Menu. See 2.3.4.

2.3.1 Output Menu

You can set up the type of data and timing parameters for display/print output.

- F1 - (Data) - This is the Data Menu - See 2.3.1.1 (below.)
- F2 - (Mode) - This is the Mode Menu - See 2.3.1.2 (next page.)
- F3 - (Time) - This is the Time Menu - See 2.3.1.3 (next page.)
- F4 - (Origin) - This is for only film measurements with the dual mode. See 2.3.1.4.
- F10- (Exit) - The return is to the Film Measurement menu (see 2.0) or to the Substrate Measurement Menu (see 3.0,) whichever is appropriate.

2.3.1.1 Data Menu

This menu selects which measured data are to be calculated. You may select PSI and Delta (always outputted) (F1) or Thickness (F2). After this selection, the display returns to the Output Menu.
2.0 FILM MEASUREMENT MENU (Continued)

2.3.1.2 Mode Menu
This menu is for selecting the type of +90° compensator mode to be used for measurements.

- F1 - (N Comp) - The compensator is not in the light beam.
- F2 - (Comp) - The compensator is in the laser light path.
- F3 - (Dual) - The compensator is both in and out of the light beam.

2.3.1.3 Time Menu
This menu (key F3 in 2.6) sets up the timing of the measurements to be outputted.

- F1 - (Intvl) - This lets you enter the time interval between measurements. (The minimum interval will depend upon the rotating analyzer drum speed.)
- F2 - (Durtn) - This allows you to enter the time duration of the measurements up to 24 hours. (If the time duration is less than one minute, no colons are required in the time entry format.)
- F10 - (Exit) - The return is to the Output Menu.

2.3.1.4 Origin Menu
Pressing F4 in 2.3.1 displays this menu, which lets you type in the bounds for the thickness, psi, and delta. See Figure A2, which has the Origin Menu at the bottom. This menu has the following functions:

- F1 - (LoThk) You can change the thickness lower bound in angstroms.
- F2 - (LoPsi) You can change the Psi lower bound in degrees.
- F3 - (LoDel) You can change the Delta lower bound in degrees.
- F4 - (HiThk) You can change the thickness upper bound in angstroms.
- F5 - (HiPsi) You can change the Psi upper bound in degrees.
- F6 - (HiDel) You can change the Delta upper bound in degrees.
- F7 - (Depost) The film thickness will increase.
- F8 - (Etch) The film thickness will decrease.
- F10 - (Exit) The return is to the Output Menu. See 2.3.1.
**OUTPUT OPTION**
- Data: Thickness, Psi, Delta
- Mode: Dual

**TIME OPTION**
- Interval (hr:min:sec): 00:00:01
- Duration (hr:min:sec): 24:00:00

**ORIGIN BOUNDS (Period= 2832 )**
- Below Origin Thickness: 2700
- Below Origin Psi: 11.759
- Below Origin Delta: 214.689
- Film: Etching*

- Above Origin Thickness: 2900
- Above Origin Psi: 10.794
- Above Origin Delta: 159.757

**APPROXIMATE MINIMUM TIME INTERVALS FOR EACH MODE**
(Number of revolutions= 1)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Psi/Delta data Time Intervals (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-compensator</td>
<td>0.78</td>
</tr>
<tr>
<td>Compensator</td>
<td>0.78</td>
</tr>
<tr>
<td>Dual</td>
<td>1.27</td>
</tr>
</tbody>
</table>

Select origin bounds:

*The alternate display is "Film: Depositing" when F7 is pressed. Then, pressing F8 brings "Film: Etching" back.

Figure A2. This is an example of a screen display of the Origin Menu for the L2W04B.830 In-Situ Ellipsometer.

7109-C-320-R1  10
2.0 FILM MEASUREMENT MENU (Continued)

2.3.2 Store Menu

This menu (F2 in 2.3) permits storing measured raw (uncalculated) data. First set up the files:

- F1 - (Create) - This permits you to create a file on the disc.
- F2 - (Delete) - This lets you remove one or more files from the disc.
- F9 - (Cont) - This key appears on the menu after you created a file. Press it to continue to the Mode and Time menus (below.)
- F10 - (Exit) - The display returns to the Film Measurement Menu (2.0) or the Substrate Measurement Menu (3.0,) whichever is appropriate.

2.3.2.1 Mode Menu

This menu appears when F9 (Continue, above) and then F2 (Mode) are pressed. See 2.3.1.2 for the menu functions.

2.3.2.2 Time Menu

This menu appears when F9 (Continue, above) and then F3 (Time) are pressed. See 2.3.1.3 for the menu functions.

2.3.3 Both (Output & Store) Menu

This menu (F3 in 2.3) combines the Output Menu (2.3.1) and Store menu (2.3.2,) sections 2.6 and 2.7 respectively. (See the structure chart at the end of this instruction.) When the F3 key (Both) is pressed, the Store Menu (2.3.1) appears, so that one or more files can be created with the F1 key and/or one or more files can be deleted with the F2 key. Pressing F9 (Continue) produces the Output Menu (In 2.3.1.)
2.0 FILM MEASUREMENT MENU (Continued)

2.3.4 Time Critical Menu

This menu (F4 in 2.3) allows you to select a fast (zero time interval between readings), continuous display of only Psi and Delta. The selecting functions are: F2 (Mode Menu, in 2.3.1.2) and F10, Exit. The Mode Menu is the same as in 2.5. Note that 24 delta readings are taken every second.

2.4 Retrieve Menu

This menu (F4 in 2.0 or 3.0) lets you select the type of data to be calculated, the file to be retrieved, and displays the file directory. First, select the Psi and Delta (F1) or film thickness (F2) to be calculated.

F1 - (Retrv) - You can enter a file name to be retrieved from the file directory shown.

F2 - (Delete) - Files can be deleted from the directory.

F5 - (Print/Disp) - See the F5 key in 2.0 or 3.0.

F6 - (ASCII) - This activates the ASCII mode. You may enter the file name to store the results in an ASCII file. The suffix "CSA" is appended to the file name.

F9 - (Cont) - This key (for Continue) starts the retrieval. It appears after a retrieve file name (F1) has been entered.

F10 - (Exit) - The Film Measurement (2.0) or the Substrate Measurement Menu (3.0) returns.

2.5 Measure Menu

This menu (F8 in 2.0) initiates a single-point measurement according to selections made from the Film and Instrument Menus.

F1 - (N Comp) - A measurement is made with the compensator out of the laser beam.

F2 - (Comp) - A measurement is made with the compensator in the light path.

F3 - (Dual) - A measurement is made with the compensator in and out of the laser beam.
3.0 SUBSTRATE MEASUREMENTS

When the F2 key in the Program Menu (in 1.2) is pressed, a display somewhat like Figure A1 appears. There would not be a Film Parameters Menu (for F1,) There would be an Instrument Parameters Menu (F2), the Monitor Menus (F3,), the Retrieve Menus (F4) and the Measure Menu. F3 (Monitor) accesses the Output, Store, Both, and Time Critical Menus.) Each menu has an Exit key (F10), which causes a return to the next higher menu level.) You may select available operations, which are:

- F2 - (Instr P) Instrument Parameter Menu access. See 2.2.
- F3 - (Monitor) Monitor Menu access. See 2.3.
- F4 - (Retry) Retrieve Menu access. See 2.4.
- F5 - (Print/Display) This key toggles to select Print or Display.*
- F6 - (Sample) Permits user to enter number of sample under test.
- F8 - (Meas) Measure Menu access. See 2.5.
- F9 - Start key. Initiates an automatic measuring sequence as set up using Monitor Menu. (This key appears on Program Menu after pressing Exit key on Monitor Menu.)
- F10 - Exit. The program returns to the Program Menu. See 1.2.

*When "Print" is displayed for F1, the printer is deactivated. To press F1, the printer must be connected and on. The pressing of F1 will cause the printer to automatically print measurement solutions. When "Display" is displayed for F1, the printer is activated (and must have been connected and turned on.) Then if you press F1, the printer will not automatically print.
FILM PARAMETERS
No Parameters

INSTRUMENT PARAMETERS
Retardation : 88.000
Number of Revolutions: 1
Phi (Incidence Angle) : 70.00

Polarizer Angle : 45.0
Wavelength (Å) : 6328
Ambient : 1.000

Select option:
1 2InstrP 3Monitr 4Retry 5Print 6Sample 7 8Meas 9 10Exit

Figure A3 This display shows the Substrate Measurements Menu for the L2W04B.830 In-Situ Ellipsometer.
4.0 PROGRAM OPERATION

4.1 Automatic Program Operation

Following program loading, the program menu will be displayed at the bottom of the screen, presenting you with a choice of Film Measurements (F1) or Substrate measurements (F2).

4.1.1 Film Measurements: See 2.0 for the Film Measurements Menu. The film default parameters and the instrument default parameters will be displayed at the top of the screen. You may use the Film Parameters Menu (F1) and/or Instrument Parameters Menu (F2) to make the desired changes. The film default parameters menu (2.1) or the instrument default parameters menu (2.2) will be displayed at the top of the screen. You may use the Film Parameters Menu (F1) and/or Instrument Parameters Menu (F2) to make the desired changes.

4.1.2 Substrate Measurements: The instrument default parameters will be displayed at the top of the screen. You may use the Instrument Parameters Menu (F2) to make any changes.

Select the Monitor Menu (F3 in the Film or Substrate Measurement Menu) to set up the data storage method, measurement timing parameters and files.

Select print or display, enter a sample identification number, and initiate the automatic measuring sequence by pressing the START key (F9 in the Film or Substrate Measurements Menu.) This key is available on either menu only after the monitor conditions have been set up. To stop the automatic measuring sequence, press STOP (F5).

On completion of an automatic measuring sequence, press RETRIEVE (F4 in the Film or Substrate Measurement Menu) to review the stored data.

4.2 Single-Point Measurement

4.2.1 Film Measurements: To initiate a single-point measurement, first set up the film and/or instrument parameters. Then, select the Measure Menu (2.5) from the Film Measurements Menu (2.1) or Substrate Measurements Menu (2.2); and choose the mode to be measured.

4.2.2 Substrate Measurements: Do the same as in the above paragraph, except that there are no film parameters.
APPENDIX B

INSTALLATION INSTRUCTIONS
The L104B Ellipsometer is shipped with associated items, as follows:

- User Manual
- Ellipsometer/Computer GPIO Interface Cable
- Silicon Wafers (Reference Samples, 580Å and 780Å, SiO₂)
- Software Program (as specified in the Procurement Contract)
- Alignment prism for 70°, optional prisms range from 45 to 85° (in 5° steps)
- The following hex keys:

<table>
<thead>
<tr>
<th>Size</th>
<th>Standard</th>
<th>Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16&quot;</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5/32&quot;</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3/32&quot;</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1/16&quot;</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0.05&quot;</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

NOTE: Customers with their own IBM computers will receive a GPIO card for installation in their computers.

UNPACKING

Remove the protective wrapping from the ellipsometer. Remove the fiberglass tape securing associated items to the shipping base; and then remove these items (each packaged in a cushioned, shipping envelope).

NOTE

Store the shipping box, shipping carton components and protective wrapping for use in the event of a reshipment to Gaertner for repair.

WHEN PACKING THE ELLIPSOMETER FOR RESHIPMENT TO THE MANUFACTURER FOR REPAIR, INCLUDE THE SOFTWARE PROGRAMS AND THE ELLIPSOMETER/COMPUTER INTERFACE CABLE (WITH THE GPIO INTERFACE CARD, IF SUPPLIED BY GAERTNER.)
INSTALLATION

INSPECTION

Thoroughly inspect the ellipsometer for shipping damage.

Verify that a good fuse is installed in fuse holder at rear of the electronic unit.
Verify that the key is in the ac power switch, on right of the front of the electronic unit.
Verify that the key switch is OFF.
Verify that the applicable items are all on hand.

LOCATION CONSIDERATIONS

The L104B In Situ Ellipsometer is designed for use in either a production or laboratory facility under environmentally-controlled conditions providing relatively constant room ambient temperature and a dry, dust-free atmosphere. The ellipsometer requires a clean, very solid, level work surface sufficient to also accommodate the interfaced computer, and to be placed near an electrical outlet capable of supplying the specified input ac power. The line voltage at the outlet must be free of transients having harmonics in the range from audio frequencies to several megahertz.

CAUTION

Verify that the ellipsometer and computer power are both off before connecting or disconnecting any cables.

INTERCONNECTIONS

DO NOT plug or unplug any component into or from ac power or make connections to other equipment with its power ON/OFF switch ON!

The diagram in Figure B1 shows the cable connections between the IBM computer, Ellipsometer modules, electronic unit, printer, display and computer keyboard. Figure B2 shows the front and back of the L104B Electronic Unit. Figure B3 shows the rear of the IBM PS/2-25 computer, which is supplied by Gaertner when needed by the customer.
Figure B1  This is the In-Situ Ellipsometer L104B Interconnection Diagram.
Figure B2 These are the front and rear views of the L104B Electronic Unit.
Figure B3 This is the IBM PS/2-25 computer and its connections.
NOTE

The required hardware for the Ellipsometer have been installed in the computer system supplied by Gaertner Scientific Corp.

7109-S-405A-R2

GPIO Interface Cable and Card Assembly Drawing #10161-45G

GPIB Card Assembly Drawing #7108-E-316

VGA Plus Card Assembly Dwg #7108-E-316A

Gaertner Scientific Corporation
1201 West Wrightwood Avenue
Chicago, Illinois, 60614
INTRODUCTION

*WaferScan Ellipsometers:* These instructions are for installing the GPIO, GPIB and VGA Plus Interface Cards and Cable assemblies into the IBM PS/2-30, PS/2-30 286 and PC AT computers for use with the L115C, L2W15C.830 and L2W25C.1.5 Ellipsometers for the WaferScan tests.

*Single-Point Ellipsometers:* The GPIO circuit board may be installed in the IBM PS/2-25 computer for use with the L116C, L2W26C.830 and L2W26C.1.5 Ellipsometers (for single-point measurements.)

The IBM PS/2-30, the IBM PC AT and IBM PS/2-25 computer interface card DIP switch settings and installations are described here.

GPIO DIP SWITCH ADJUSTMENT

The GPIO Interface Card is shown in Figure 1 (below,) and Figure 2 (next page) shows the small card on the GPIO card having two DIP switch units. This card has three sets of DIP switches. The smaller DIP switch, close to the card connector on the far right (below,) has six or ten tiny slide switches. On the six-switch unit, switches 1 and 2 are OFF, with the other four slide switches ON. On the ten-switch unit, switches 5 and 6 are OFF (and the other eight switches are ON.)

LASER RETARDATION

The other two DIP switches are on a small board near the middle of the card as shown in Figure 2. The two DIP switch units have 12 tiny rocker switches each, one unit (of 12 switches) is for the infrared laser and one for the red. The rocker switch settings are different for each laser. The settings of the infrared laser switches can be anything if the instrument has only a red laser.

![Image of GPIO Interface Card]

Figure 1 This is a photograph of the GPIO Interface Card.
Red Laser Retardation

Note that each set of 12 DIP switches is for three-digit numbers (tens, units and one decimal). Each digit is developed from four tiny rocker switches. The tens digit is determined by the settings of switches 1 (weight of 8) to 4 (weight of 1). In the example of the switches for the red laser, switch 1 is open (logic 1). Switch 2 is closed (logic 0); switch 3 is closed (logic 0); and switch 4 is open (logic 1) for the tens digit.

Switch 1 is open, and its logic 1 is multiplied by the weight of 8 to give a weighted logic of 8. Switch 4 is also open (logic 1) with a weight of one, and the weighted logic is 1. Switch 2 and switch 3 are closed (logic 0); thus, their weighted values are zero. Adding the 8 and the 1 gives a decimal value of 9.

Switches 5 to 8 are for the red laser units digit. Only switches 6 and 7 (weights of 4 and 2) are open. The weighted logic and the decimal for the units digit are 6. Then, switches 9 (weight of 8) to 12 (weight of 1) are for the decimal number. Switches 10 and 11 are the only ones open (logic 1). Thus, the decimal number is 6. Then, the final number for the red laser is 96.6.

1523 nm I.R. Laser Retardation

For this I.R. laser, switches 1 and 3 are open (logic 1,) while 2 and 4 are closed (decimal 10 for tens.) Switches 7 and 8 are open (decimal 3 for units,) and switches 9 and 12 are open; the decimal number is 9. The final number for the I.R. laser is 103.9.

830 nm I.R. Laser Retardation

For the diode (Infrared) laser, the switches would be set to a lower value, such as around 70.
GPIB INTERFACE CARD DIP SWITCHES

The GPIB card has a DIP switch unit (U17) with five tiny rocker switches, as shown below. The switches are set to address 02E1. Switches #1 (0), #2 (1) and #3 (2) are all OFF (logic 1). Switches #4 (14) and #5 (13) are ON (logic 0). To set a switch at OFF, use a sharp pencil point or a toothpick to push down the end of the switch near "OFF."

Figure 3 This is the GPIB Interface Card with the five-switch DIP unit.
IBM PS/2-30

"IBM Personal System/2 Model 30 Guide to Operations" booklet (copyright 1987.) Section 3 is "Installing Your Options." The cover removal instructions are on pages 3-3 and 3-4. The adaptor (interface card) instructions are on pages 3-6 to 3-8. Page 3-8 shows the GPIB board being installed in the lowest of the three horizontal positions. The GPIO Interface Card (with the three DIP switches) is mounted in the middle position. The top position receives the Paradise VGA Plus card (customer supplied.) The cover is reinstalled according to page 3-9.

IBM PS/2-30 286

The differences between this computer and the one in the paragraph above include the lack of a VGA Plus card in this computer and the slightly different socket arrangements on the rear of the computers. The GPIO card should go in the middle position. It is more convenient to have the GPIB board in the lowest slot (so that the switches are more easily adjusted.) Refer to Section 2 of the computer manual, "IBM Personal System/2 Model 30 286 Guide to Operations" (1988,) concerning the proper card installation.

IBM PC AT

The interface cards are installed vertically according to the IBM PC AT "Installation and Setup" manual (copyright 1984.) Section 2 describes the cover removal procedure. Section 3 is the "Internal Option Installation." Page 3-8 shows the eight vertical positions available for the VGA Plus card, GPIO and GPIB Interface Cards, which can be installed in any three of the eight positions. Section 4 is for the cover installation.

IBM PS/2-25

This computer cannot accept either the VGA Plus board or the GPIB board after the GPIO Interface Card is installed. To install the GPIO Interface Card, refer to "IBM Operations and Starter Diskette," First Edition (June 1987.) Section 2 is "Installing Your Options." The cover is shown removed on pages 2-3 and 2-4. The circuit board installation is shown on pages 2-13 and 2-14, and the GPIO Interface Card should be installed in the lower expansion slot. The cover is reinstalled according to pages 2-16 and 2-17.