1.5 INSTRUMENT OVERVIEW

The Tencor P-1 Long Scan Profiler is a computerized, high-sensitivity surface profiler that measures roughness, waviness, and step height in a variety of applications. It features the ability to measure micro-roughness with 1Å resolution over short distances as well as waviness over a full, 210-mm (8.2-in.) scan. The built-in PC/AT computing power offers precise, automatic measurement capability, data storage, and data analysis.

The Tencor P-1 can profile a variety of materials, including

- magnetic disks
- semiconductor wafers
- precision-machined and polished surfaces
- ceramics for micro-electronics
- glass for flat panel displays
- optical surfaces

The instrument is available in two basic hardware configurations (normal and Open Frame, which accommodates large samples) and two basic software configurations (normal and automatic). Additional hardware and software options such as the Motorized Level/Rotation Option, Wafer Stress Option, Sequence/Database Manager Option, Interactive 3-D Option, SECS Interface Option, and Additional Surface Roughness Parameters Option can be added.

The Tencor P-1 provides the following features:

- Measurement of vertical features ranging from under 100Å (0.4 μin.) to approximately 0.3 mm (11 mils), with a vertical resolution of 1 or 25Å (0.004 or 0.1 μin.). Measurements can be taken in either metric or English units, which are selectable independently for horizontal and vertical parameters.
- Up to 5000 data points per profile guarantee that the horizontal resolution is generally limited by the stylus radius and not by the number of data points.
- Measurement of many roughness and waviness parameters with roughness and waviness separated by user-selectable cutoff filters. A band pass filter allows the separation of intermediate wavelengths.
- Ability to fit and level data, allowing accurate measurements on curved surfaces.
- Ability to detect the edge or apex of a profile artifact, allowing precise comparison of data measured on similar samples.
- Ability to segment a length into multiple scans as in the OD-to-OD profile of a disk with a center hole.

- Ability to repeat a scan up to ten times and automatically calculate the average, thereby minimizing the effects of environmental noise on measurements.
- Ability to execute a sequence of up to 300 scans automatically with the Sequence Option.
- Automatic positioning on the sample surface to within a few microns in X, Y, or rotation (motorized rotation is an optional feature).
- Precision mode, allowing precise location of small features and deskew coordinates for automatic operation.
- Built-in, 80386-based PC/AT controller with 40 MB of disk storage.
- Comprehensive database manager and the ability to export the data in a form that is compatible with Lotus 1-2-3 and other commercial programs. (This option is available for the Automatic Long Scan Profiler only.)
- Many ease-of-use features, including programmable stylus force, trackball control of measurement cursors and stage position, color screens with pull-down menus and pop-up windows.
- Accommodation of samples up to 355 mm (14 in.) wide, 57.2 mm (2.25 in.) thick, and 5 lb (2.2 kg) in weight with the normal configuration. Accommodation of samples up to 480 mm (19 in.) wide with the Open Frame configuration.
- Ability to limit operator access by means of a keylock.

1.6 HARDWARE FEATURES

Processor

The processor is an 80386-33 MHz controller that runs the MS-DOS operating system. It is PC/AT compatible.

Screen

The 33-cm (13-in.) video monitor can display a magnified sample image, a color data display, or both simultaneously. The initial data trace can be superimposed on the sample image.

The sample image has high resolution and contrast and can be zoomed to an image ratio of 4:1. In the Data screen, the Zoom key enables localized magnification of data to aid analysis.

Console

The system is equipped with an operator's keyboard built into the console front panel for full instrument operation. Included are four screen-dependent function keys. The Automatic Long Scan Profiler is equipped with a PC/AT alphanumeric keyboard for more complex programming and database management.

The console has a trackball control device for fast cursor movement, quick positioning of sample artifacts under the stylus, and convenient menu option selection. The trackball and either keyboard can be used interchangeably for these functions.

Data Disk System

The inboard 40-MB hard disk contains the Tencor P-1 program and, in addition, enables storage of up to 6000 scans of 1000 points.

A 3.5-in. (1.4-MB) disk drive enables data and recipes to be stored on a diskette. Storage on a diskette used for data only is limited to approximately 300 scans of 1000 points each.

Motorized Level and Rotation Option

The Motorized Level and Rotation Option enables

- Automatic mechanical leveling of the sample. (The standard unit provides electronic leveling of the traces.)
- Programmable sample rotation using a motorized rotary stage. (The standard feature is a high-precision manual stage.) The motorized option enables programmed Θ position repeatability at 4 in. from the center of $\pm 4\ \mu m$ ($\pm$ 0.16 mil).

This option is available only at the time of initial factory installation.

Low Magnification Optics Option

The Low Magnification Optics Option replaces the standard 150–600X optics with 60–240X optics. This option is available only at the time of initial factory installation.

Hard Disk Sample Holders (Optional)

Disk sample holders are available for holding hard disks on the sample stage. Holders are available for the following disk sizes: 48 mm; 2.5, 3.5, 5.25, 8, and 9 in.

Wafer and Square Sample Precision Locators (Optional)

Wafer and square sample precision locators are available to enable exact positioning of a sample relative to a fixed reference point. Locators are available for the following sample sizes: 3, 4, 5, 6, and 8 in. See Appendix D, "Precision Locators," for graphic representations of the available locators.

Wafer Handler

The wafer handler automatically transports wafers in and out of the instrument. The handler consists of a robotic mechanism with a vacuum puck mounted on a turntable, two cassette locators (one standard, one optional), and an aligner. If you are using both cassette locators, the standard cassette locator functions as the sender and the optional cassette locator functions as the receiver.

The vacuum puck picks up and transports the wafers, the cassette locators hold the cassettes of wafers, and the aligner orients the wafers in the X, Y, and Θ positions as desired.

The handler can load wafers in four sizes: 100 mm (4 in.), 125 mm (5 in.), 150 mm (6 in.), and 200 mm (8 in.).

Open Frame Configuration

The Open Frame configuration enables measurement of large samples such as flat panel displays, printed circuit boards, and photomasks. A Removable Isolation Hood encloses the measurement area, which accepts samples up to 430-mm (17-in.) square.

We recommend that you use the Isolation Hood for precise measurements below 1000Å. This configuration accommodates substrates up to 480-mm (19-in.) square with the Isolation Hood removed.

The stylus can access any location on a 210-mm (8.2-in.) diameter area or a 147-mm (5.8-in.) square area without repositioning the sample. Moreover, the stylus can access 78% of a 430-mm (17-in.) sample when the sample is moved to each of five positions.

Open Frame Stage Table

The Open Frame stage table is 244-mm (9.6-in.) square and is equipped with vacuum grooves for sample holding. The outer vacuum groove can be valved off for holding smaller samples. The table is also drilled to accept the standard sample precision locators.

Precision Locators for Wafer Stress Option

A wafer stress package is available for determining the amount of stress induced by a deposited film in a substrate. Wafer stress software and wafer stress precision locators are supplied. See Appendix D, "Precision Locators," for graphic representations of the available locators.

Vacuum Sample Hold-Down

The vacuum hold-down enables a sample to be held securely in the center of the stage and is available with the manual and motorized rotary stages.

Handler Vacuum Switch

In instruments with the wafer handler, a software or keyboard-controlled electronic handler vacuum switch replaces the regular vacuum switch. In addition, a manual, spring-loaded switch is provided in the same position as the regular vacuum switch. See Fig. 1-2. The spring-loaded switch can be used to turn the handler puck vacuum off if the handler software cannot be accessed. The normal position of the switch is down (On). Raise the switch to disable the vacuum to the handler puck and release it to enable the vacuum.

Printer Port

A parallel port accommodates a compatible printer. Refer to Section 2.2.8, "Configuring the Tencor P-1 for Your Printer," for a list of printers supported by Tencor Instruments for the Tencor P-1 at the time of printing. Contact Tencor Instruments for a list of currently supported printers.

Keylock

For operational security, the Tencor P-1 is equipped with a keylock, which can limit operator access to Scan recipes and Sequence programs.

Door Interlock Switch

As a safety measure, an interlock switch prevents motion of the stage table and measurement head when the front door or either side panel is open. You can enable or disable the switch. Note: This feature is not available in the Open Frame configuration.

Real Time Clock

A clock with battery backup displays date and time of day.

ESD Ground Jack

A standard banana jack for an ESD wrist strap (1 MΩ resistance minimum) is provided for use with static-sensitive devices. See Fig. 1-1 for the location of the jack. Note: This feature is available only on later units.

1.7 SOFTWARE FEATURES AND OPTIONS

Operating System

The Tencor P-1 runs on the DOS operating system.

Windows

Pull-down menus with multiple pop-up windows allow easy access to capabilities.

Wafer Handler Software

Wafers can be loaded and unloaded from either cassette. Every possible motion can be controlled from the keyboard or an entirely automatic sequence of wafer handling and measurement can be initiated by a single keystroke. Options are available for sorting wafers that pass and fail inspection criteria specified in Sequence programs.

Additional Surface Roughness Parameters Option

This option adds nine extra surface analysis parameters to the data analysis capability of the Tencor P-1:

- Bearing Length Ratio (t_p)
- Cutting Depth (CutDp)
- Peak Count (PC)
- High Spot Count (HSC)
- Mean Peak Spacing (S_m)
- Mean Peak Height (Rpm)
- RMS Slope (D_q)
- RMS Wavelength (L_q)
- Standard Deviation of Heights (SD)

Up to three user-selectable limits can be set for t_p, CutDp, PC, HSC, and S_m. All of these parameters can be used in the Sequence mode.

Sequence/Database Manager Option

The Sequence/Database Manager Option consists of the Sequence and Database Manager software. This option is included in the Automatic Long Scan Profiler. The option provides the following:

- Sequence software that enables a user to combine up to 300 recipes and artifact locations into a sequence. The complete sequence can then be run with or without operator intervention.
- Database Manager software that enables data to be saved with up to seven identifiers and later manipulated using the identifiers and time brackets.

Interactive 3-D Option

This option allows you to take a series of scans at fixed distances from each other and display the scans in a 3-D Data screen. Features include

- Selecting the angle from which to view the surface including the top view
- Zooming on the data or automatically zoom rescanning a selected area for increased details
- Leveling the 3-D display
- Selecting individual traces for measurements

Wafer Stress Option

The Wafer Stress Option calculates the stress levels in a deposited film by measuring the deflection or curvature that the stress induces in the substrate.

Sort/Combined Statistics Option

The Sort Option allows you to set up tolerances for parameters such as R_a, R_v, and TIR to pass and fail samples, and to sort the passed and failed samples. The Combined Statistics Option offers increased data analysis capabilities by providing statistical analysis for process control.

SECS Communications Option

The SECS communications capability allows the uploading of scan measurement data to a host computer. The capability also supports Alarms, Data Collection, Equipment States, Error Messages, Initialization, Clock, and process program upload and download. See the *Tencor Profiler SECS Interface Manual* for more information on the SECS Communications Option.

Software Compatibility

The remote alphanumeric keyboard allows access to popular PC/AT programs such as commercial spreadsheet and database manager programs. Scan data can be exported in ASCII form so that it can be read by the spreadsheet and database manager programs. The Tencor P-1 software can also be run under Microsoft Windows 3.1, facilitating use of scan data or instrument screens in Windows-based spreadsheets and word processors.

NOTE: Data exported in ASCII format cannot be directly manipulated in another program. You will need to write macros that can manipulate the ASCII data in the receiving program. Refer to Appendix C, "Exporting Data," for more information.

APPENDIX A—SPECIFICATIONS

MEASUREMENTS

Roughness	R_a, Arithmetic Average Max R_a, Maximum of 19 overlapping sections R_q, Root-Mean-Square (RMS) R_p, Maximum Height R_v, Maximum Depth R_t, Maximum Peak-to-Valley R_z, Ten-Point Height R_{3z}, Six-Point Height R_h, Height between two points
Waviness	W_a, Arithmetic Average W_q, Root-Mean-Square W_p, Maximum Height W_v, Maximum Depth W_t, Maximum Peak-to-Valley W_h, Height between two points
Topography	
TIR	Total Indicator Run-out
Height	Height between two points (Step Height)
Average Height	Average height of all data points between the measurement cursors relative to the leveled baseline (Delta Average Mode)
Slope	Rate of change of the profile between two points
Radius	Distance from center of curvature of profile arc to the profile
Area of Peaks	Total area bounded by the leveled baseline and the profile above the baseline
Area of Valleys	Total area bounded by the leveled baseline and the profile below the baseline
Total Area	Sum of Area of Peaks and Area of Valleys
Profile Length	Length obtained from drawing out the profile into a straight line
Edge	Distance to rising edge or apex from start of profile
Step Width	Width of profile step

The following parameters are included in the Additional Surface Roughness Parameters Option.

Mean Peak Height	Mean value of peak heights
RMS Slope	Root-mean-square value of slopes
Average RMS Wavelegth	2π times ratio of RMS deviation of R_q to the RMS slope
Standard Deviation Heights	Standard deviation of peak heights
Bearing Length Ratio	Ratio of bearing length to sampling length at chosen value of Cutting Depth
Cutting Depth	Distance below highest peak to reference line giving chosen value of Bearing Ratio
Peak Count	Number of peak/valley pairs per unit length projecting through a band of chosen width centered about mean line
High Spot Count	Number of profile peaks per unit length projecting through a chosen reference line
Mean Peak Spacing	Mean value of the local peak spacing, where peaks are defined as in Peak Count

Long Wave Cutoff Filter Wavelengths

mm	inch	mm	inch
.0045	.0002	0.45	.018
.008	.0003	0.8	.03
.014	.0006	1.4	.055
.025	.001	2.5	.1
.045	.002	4.5	.18
.08	.003	8.0	.3
.14	.006	14.0	.55
.25	.01	25.0	1.0

Short Wave Cutoff Filter Wavelengths

mm	inch	mm	inch
Default[1]		.08	.0030
.00025	.00001	.14	.0056
.00045	.00002	.25	.010
.00080	.00003	.45	.018
.0014	.00006	.80	.030
.0025	.00010	1.4	.056
.0045	.00018	2.5	.10
.008	.00030	4.5	.18
.014	.00056	8.0	.30
.025	.0010	14.0	.56
.045	.0018	25.0	1.0

[1] Default cutoff filter values differ depending on scan speed and sampling rate. See Table 8-1 in Chapter 8, "Data Analysis: Band Pass Filter."

PROFILING PERFORMANCE

	Metric	English
Scan Length	210 mm	8.2 in. maximum
Scan Speed	1 μm/s to 25 mm/s	0.04 mil/s to 1 in./s
Sampling Rate	50, 100, or 200Hz nominal	
Vertical Range		
At 1Å (0.004 μin.) Resolution:	± 6.5 μm	± 0.25 mil maximum
At 25Å (0.1 μin.) Resolution:	± 150 μm	± 6 mil maximum
	+20/-280 μm	+0.8/-11 mil or
	+280/-20 μm	+11/-0.8 mil
Vertical Linearity, below 2000Å	10Å	0.04 μin
Vertical Linearity, above 2000Å	± 0.5%	± 0.5%

NOTE: Because the instrument linearity guarantee is significantly smaller than the uncertainty of the step height standards available in the range of typical use of the instrument, ***step height standards cannot be used to verify the linearity of the instrument.***

	Metric	English
Horizontal Resolution		
At 1 μm/s scan speed	0.02 μm (200Å)	0.8 μin.
Scan Method	Moving stage, stationary stylus	
Stylus Control	Programmable Force:	
	Range	1.0–100 mg
	Resolution	0.1 mg
	Full retract between scans	
	Programmable descent rate	
Optical Magnification		
Standard:	150–600x	
Low Magnification Option:	60–240x	

REPEATABILITY AND STABILITY

Step Height Repeatability	
13 μm ($\pm$ 6.5 μm) range	0.001 μm (10Å) maximum standard deviation
300 μm ($\pm$ 150 μm) range	0.005 μm (50Å) maximum standard deviation Note: The Step Height Repeatability has been verified using step height standards from VLSI Standards with a sequence of fifty 10-s measurements at a single position.
Base Line Stability	
Time	0.02 μm (200Å) maximum TIR for a 100-s no motion scan
Distance	0.2 μm (2000Å) maximum TIR on a profile length of 130 mm verified on a 1/20 optical flat
Measurement Environment	Floor vibration below 0.2 mG Audio noise below 80 dB Ambient temperature range 16–26° C Maximum rate of change 2° C/hour

MEASUREMENT CONTROL

Manual/Single Scan Mode	Continuous or segmented scan, from recipe
Keylock with three Modes	Position 1: Run a single recipe or sequence without modification. Position 2: Run any recipe or sequence without modification. Position 3: Unlocked. All functions available including interlock setting.
Repeat and Average Mode	Scan repeated up to ten times and averaged
Automatic Sequence Mode	Up to 300 recipes and locations combined into a sequence of recipes (optional)

SAMPLE HANDLING

Motorized X-Y	Two programmable locations (Standard Config.) Unlimited programmability (Automatic Config.)	
Manual Control	Via trackball or keyboard	
	Metric	**English**
Maximum Sample Size	254 x 254 mm	10 x 10 in.
	Note: 355 x 355 mm (14 x 14 in.) with side panel removed Note: Stylus can access any part of a 210-mm (8.2-in.) round sample without sample repositioning.	
Open Frame Configuration	Without Removable Isolation Hood:	
	480 x 480 mm	19 x 19 in.
	With Removable Isolation Hood:	
	430 x 430 mm	17 x 17 in.
	Note: Inside space of hood is 743 mm (29.25 in.) X, 556 mm (23.1 in.) Y. A 480-mm (19-in.) sample has full 210 mm (8.2 in.) of scan or positioning motion in the X direction but only 100 mm (4 in.) in the Y direction.	
	Note: Stage Table: 243 x 243 mm (9.57 x 9.57 in.) with switchable vacuum to handle wafer sizes of 100 mm (4 in.) to 200 mm (8 in.). Accommodates Tencor P-1 sample locators.	
	Note: The stylus can access, without sample repositioning, one 210-mm (8.2-in.) diameter area or a 145-mm (5.7-in.) square area. Also, the stylus can access 86% of a 355-mm (14-in.) or 73% of a 430-mm (17-in.) square sample when the sample is moved to each of four or five positions respectively.	
Maximum Sample Weight	2.2 kg	5 lb

Throat Depth	228 mm	9 in.
Throat Height, incl. Rotary Stage	63.5 mm	2.5 in.
X,Y Maximum Travel	210 mm	8.2 in.
Stylus and Sample Programmed Position Repeatability (1 σ)	2 μm	0.08 mil.
X,Y Positioning Speed	Variable up to: 25 mm/s	1 in./s
Manual Stage Rotation	Unlimited rotation. Can be set with six detents (four at 90°, two at ± 45°)	
Motorized Stage Rotation		
Angle Resolution	0.001 degrees	
Position Repeatability (1 σ)	4 μm (at 4 in. from center)	0.16 mil
Leveling	Electronic leveling of traces is standard. Automatic mechanical leveling of sample with Motorized Level and Rotation Option	
Vacuum Hold-Down of Sample	Standard with either of the rotating stages	
Custom Fixturing Interface	Three 8-32 UNC 2B threaded holes on 3.16-in. diameter circle, 90° apart. Three 1/8-in. diameter locating holes on 3.74-in. diameter circle, 90° apart.	
Standard Precision Locator	(See Appendix E, "Ordering Information.")	

DATA STORAGE

Hard Disk	40 MB. Stores up to 6000 scans at 1000 points each.
Diskette	1.4 MB, 3.5 in. Data storage limited to approximately 100 recipes and 200 scans at 1000 points each. (300 scans per diskette dedicated to data.)
Storage Requirements	The following figures are estimates only. DOS Operating System: approx. 80 KB Tencor P-1 Program: approx. 720 KB Recipe: 215 bytes Sequence Program: 728 bytes + 683 bytes for each 27 locations Single-scan data: 652 bytes + trace data Sequence data: 420 bytes + 512 bytes per recipe + 292 bytes per location + trace data per location Trace data: Trace data storage requirements are added to that for the scan data. 2-D trace data: 2122 bytes for the first 505 data points + 2048 bytes for each additional 512 data points 3-D trace data: 2122 bytes minimum + 2048 byte increments 32 bytes per trace (range 1 to 210 inclusive) 4 bytes per data point Approximate number of data points = number of traces × scan length × sampling rate / scan speed

DATA ANALYSIS

Interactive Graph	Two cursor read-out. Cursors move independently or in tandem.
Delta Average Mode	Each cursor is expandable into a region for measurement or leveling
Zoom Box Data Expansion	Portion of a graph can be magnified
Data Catalog	Immediate data retrieval and display from catalog

Database Manager Option

For each recipe in a given sequence: data table with statistics of mean, standard deviation, minimum, maximum, and range for up to 20 surface analysis parameters. Recall or purge data saved on disk using up to seven user-labeled identifiers in addition to recipe and sequence identifiers, dates.
Data can be formatted for PC/AT compatible programs.

Metric/English Units

Parameters displayed in preprogrammed metric or English units; independent selection of horizontal and vertical parameters.

EQUIPMENT SPECIFICATIONS

Processor

80386-33 MHz controller, PC/AT compatible, runs MS-DOS Operating System, version 5.x.

Screen

Displays magnified image of the sample or output data. Initial data trace or cross-hair identification of stylus location relative to stage can be superimposed on sample image.
33 cm (13 in.) diagonal
High resolution: 640 x 350 pixels
Color data display, user-selectable colors
Variable image magnification:
150–600X standard.
60–240X optional, factory only.
Motorized zoom with keyboard control
Filtered illumination of sample
(Yellow-red wavelength only)

Console

Built-in keyboard and trackball to program and operate instrument

Remote Keyboard

Removable keyboard enabling use of PC/AT software (optional)

Real Time Clock

Battery-backed clock provides date and time of day

PHYSICAL SPECIFICATIONS

Tencor P-1 without Wafer Handler

Dimensions	**Metric**	**English**
Width	57 cm	22.5 in.
Height	75 cm	29.3 in.
Depth	78 cm	30.6 in.
Open Frame Configuration		
Width (with hood)	75 cm	29.3 in.
(without hood)	57 cm	22.5 in.
Depth	90 cm	35.6 in.
	Note: Feet will fit on a 76-cm (30-in.) deep table.	
Hood Door Opening	55 cm	21.9 in.
Overall Width (with hood)	75 cm	29.3 in.
(without hood)	57 cm	22.5 in.
Weight		
Instrument	118 kg	260 lb
Shipping Weight	197 kg	435 lb
Open Frame Configuration		
Instrument Weight	127 kg	280 lb
Electrical	108 - 130 V, 50/60 Hz 90 - 110 V, 50/60 Hz 180 - 260 V, 50/60 Hz Power requirements: 150 VA	

Tencor P-1 with Wafer Handler (Floor Mount)

Dimensions	**Metric**	**English**
Width	117 cm	46.0 in.
Height	154 cm	61.0 in.
Depth	78 cm	30.6 in.
Weight		
Instrument	231 kg	510 lb
Shipping Weight	354 kg	780 lb
Electrical	108 - 130 V, 50/60 Hz	
	90 - 110 V, 50/60 Hz	
	180 - 260 V, 50/60 Hz	
	Power requirements: 210 VA	

Tencor P-1 with Wafer Handler (Table Mount)

Dimensions	**Metric**	**English**
Width	117 cm	46.0 in.
Height	81 cm	32.0 in.
Depth	78 cm	30.6 in.
Weight		
Instrument	177 kg	390 lb
Shipping Weight	311 kg	685 lb
Electrical	108 - 130 V, 50/60 Hz	
	90 - 110 V, 50/60 Hz	
	180 - 260 V, 50/60 Hz	
	Power requirements: 210 VA with handler	