



# Lab Manual

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## ***Rudolph Ellipsometer***

(rudolph)

### 1.0 **Title**

Rudolph Ellipsometer Operation

### 2.0 **Purpose**

Provide the procedures for measuring thickness and/or refractive index of transparent films using the Rudolph Ellipsometer.

### 3.0 **Scope**

The Rudolph Ellipsometer is a version of the AutoEL II Automatic Ellipsometer (Model A9822). It is capable of performing ellipsometric measurements at three wavelengths: 405, 633, and 830 nm. An external PC with the customized DAFIBM software converts the measured  $\Delta$  and  $\Phi$  values into thickness and refractive index.

This document covers the Initialization procedure, measurement procedure, and the setup/use of the software DAFIBM (DOS based) for the calculation of the film thickness and/or refractive index.

### 4.0 **Applicable Documents**

#### Revision History

- 4.1 Preliminary Operating Manual, AutoEL II-NIR-3, A9822.  
Double Layer Absorbing Film Calculation Program (DAFIBM) Manual  
(In Office and Laboratory)
- 4.2 AutoER-II Automatic Ellipsometer Instruction Manual (in Office)

### 5.0 **Definitions & Process Terminology**

#### 5.1 **Ellipsometry**

Measures the change in polarization of light reflected from the surface of a sample. The measured values are expressed as  $\Delta$  and  $\Phi$ . These values are related to the ratio of Fresnel reflection coefficients,  $R_p$  and  $R_s$  for p- and s- polarized light, respectively. Because ellipsometry measures the ratio of two values, it can be highly accurate and very reproducible. The ratio is a complex number, thus it contains **phase** information, delta, which makes the measurement very sensitive.

#### 5.2 **Refractive Index (n)**

The real part of the optical constant of a material. It defines the phase velocity of light in the material:  $u = c / n$ , where  $u$  is the speed of light in the material and  $c$  is the speed of light in vacuum

#### 5.3 **Extinction Coefficient (k)**

The imaginary part of the optical constant of a material. It is directly related to the absorption of a material. It is related to the absorption coefficient by:  $\alpha = 4 \pi k / \lambda$ , where  $\alpha$  is the absorption coefficient and  $\lambda$  is the wavelength of light.

### 6.0 **Safety**

Follow the general safety guidelines in the lab.

## 7.0 Statistical/Process Data

Refer to Appendices.

## 8.0 Available Processes, Process Notes

### 8.1 Available Programs

- 8.1.1 **STARTUP:** Default program for DAFIBM software. It can be used to measure most of the oxide single layer films.
- 8.1.2 **GENERAL:** General program for single layer films, e.g. oxide, nitride, and low stress nitride, and etc.
- 8.1.3 **THINOX:** Customized for measuring thin oxide films.
- 8.1.4 **T17MON:** Customized for measuring TYSTAR17 Low Stress Nitride Monitor wafers (1000 to 1500 Å).
- 8.1.5 **THICKLSN:** Customized for measuring TYLAN18 Low Stress Nitride up to 15000 Å).
- 8.1.6 There are several customized programs setup by lab members for their own special applications

### 8.2 Process Notes

- 8.2.1 The Rudolph Ellipsometer is capable of measuring two-layer film stack. Please consult the process staff for program setup.
- 8.2.2 You can set up your own customized program on the laptop PC. However, if you try to overwrite the standard programs listed in [Section 8.1](#), the software will abort, and you have to restart it.

## 9.0 Equipment Operation

### 9.1 Equipment Description

The Rudolph Ellipsometer is comprised of the ellipsometer itself and a laptop PC running DAFIBM software for film thickness and refractive index calculation. See [Section 11.1](#) for the physical layout of the ellipsometer and [Section 11.2](#) for the display screen of the DAFIBM software. The Rudolph Ellipsometer uses a white visible light source. There is no laser in the system.

### 9.2 Measurement Procedures

- 9.2.1 Enable the Rudolph Ellipsometer on the WAND. It will turn on the light source of the Ellipsometer.

#### Initialize the Ellipsometer

- 9.2.2 Make sure the ellipsometer is **ON**. If it is OFF, turn the key switch on the lower left side of the ellipsometer base to turn it on.
- 9.2.3 Adjust the compensator (left arm) to the free position (white) and the filter selector (right arm) to the 633 nm (light red, inner most) position.
- 9.2.4 Place the 1100 Å silicon oxide sample (in the drawer under the Ellipsometer) on the center of the wafer stage. Pull the thumb knob on the lower left of the stage, and push the stage to the inner most position.

The wafer stage slides on a track with 4 fix positions, so the light beam can reflect on the center, 3 cm, 5 cm, and 6 cm from the center of the wafer. To move the stage, pull the thumb knob on the lower left of the stage, then slide it inward/outward. The stage can rotate 360°.

A vacuum switch is located on the right hand side of the base. Flip the switch down will turn on the vacuum and hold the wafer onto the stage. To release the wafer from the stage, flip the switch down.

- 9.2.5 Check the reflected light beam aligned to the center of the analyzer aperture (tip to the right arm). If not, turn all three knobs on the bottom of the stage in the same direction to adjust the height of the stage, so that the reflected light beam aligns with the analyzer.
- 9.2.6 Look into the **ACT** eyepiece and adjust the three knobs so that the white spot (lighted) is centered in the circle. You should be able to turn the knobs freely. If you need force to turn them, they are already at their limit and should not be turned anymore.
- 9.2.7 Press the **RESET** button and the **CONT** button on the Ellipsometer keyboard. The Display will prompt **INITIALIZATION PROGRAM** for about 30 seconds, then **DOWN-COMP PRESS CONT OR PROG**.
- 9.2.8 Select a wavelength to perform the measurement and adjust the compensator (left arm), and Filter (right arm) accordingly. All standard and most of the customized programs uses 6328Å wave length.

W. L.	Compensator	Filter	Remarks
6328 Å	Light Red dot	1 ring	PC program default
8300 Å	Dark Red dot	2 rings	Need change in PC prog
4050 Å	Blue dot	3 rings	Need change in PC prog

- 9.2.9 Depress the **PROG** button, then enter one of the following two-digit programs. These are the operating programs for the Ellipsometer. Usually **program 01** is used for best accuracy. These programs are not related to the programs you are going to select on the laptop PC.

Prog #	# of Zones	Rel. Accuracy	Rel. Speed
01	2	High	Slow ~40 seconds
02	1	Low	Fast ~15 seconds
03	2/1	Med	Med ~25 seconds

### Set Up a Laptop PC Program

- 9.2.10 Open the laptop PC and check that the DAFIBM software is running. If not, go to [Section 9.3](#) to start the software.
- 9.2.11 Press the space bar on the laptop PC to move the cursor to Program filename field. Press the **[m]** key to enter the program names. Refer to [Section 8.1](#) for available programs. After typing in the program name, Press the **[f]** and **[I]** keys to load the program from the hard drive, and the **[m]** key to return to the **Main Menu** page.
- If you need a new program for your application, refer to [Section 4.0](#) for additional information to set up new ones, or contact the Process Staff.
- 9.2.12 If you are not using the default wavelength 6328 Å, press the space bar to move the cursor to the **LAMBDA** field. Press **[m]** and enter the wavelength you are using (8300 Å or 4050 Å).

- 9.2.13 Press **[g]** and the DAFIBM main menu will disappear from the screen. The laptop PC is now ready to receive information from the Ellipsometer.

#### **Perform a Measurement**

- 9.2.14 Remove the 1100 A oxide wafer and put it back into the wafers holder. Place the wafer to be measured onto the wafer stage. Slide the stage to the desired position.
- 9.2.15 Press the **CONT** button on the Ellipsometer. The Ellipsometer displays **MEASURING SAMPLE – PROGRAM NO. XX**.
- 9.2.16 When the measurement is finished, the Ellipsometer displays the Delta and Psi. The laptop PC will display the film thickness and the refractive index.
- 9.2.17 To do another measurement, repeat Section 9.2.15 again.
- 9.2.18 After you have finished taking measurements, close the laptop PC screen. Disable RUDOLPH on the WAND.

### **9.3 Start DAFIBM software on the laptop PC**

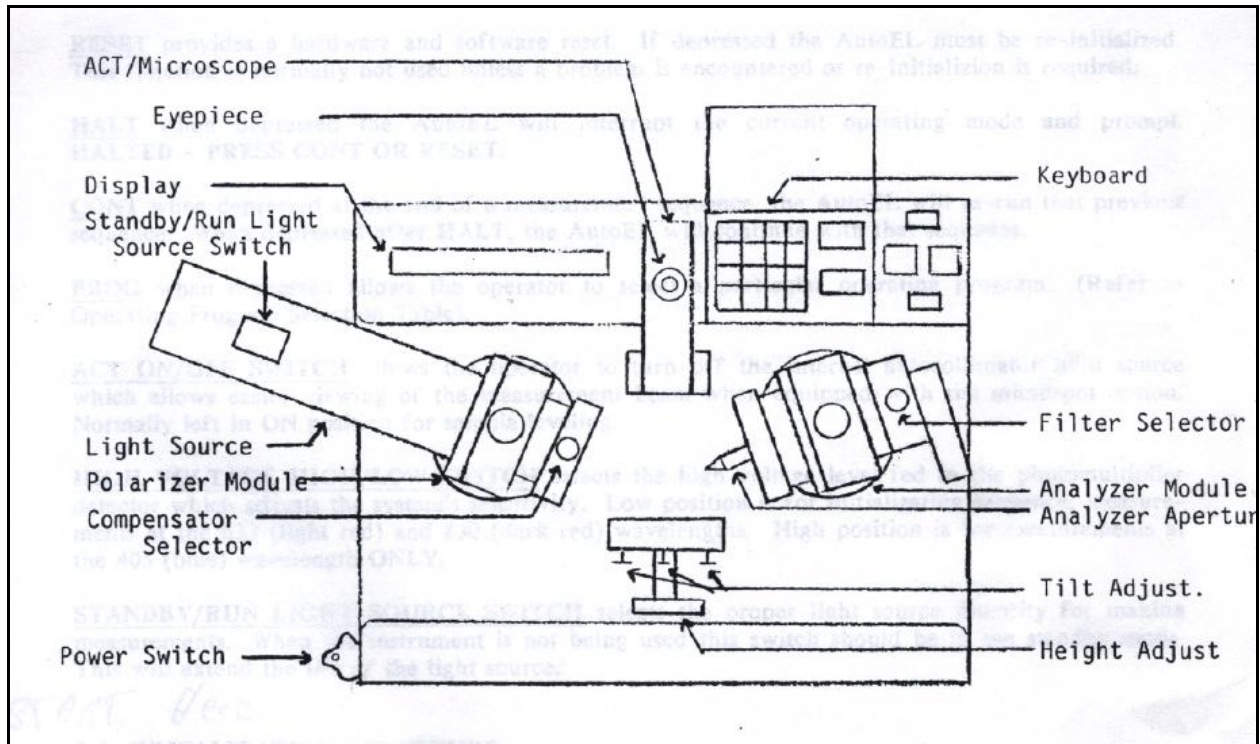
- 9.3.1 Turn the laptop PC, and it will start WINDOWS 98 operation system. Click the **Start** button on the lower left of the screen, and select shutdown. Select **restart** in DOS in the shutdown option.
- Note:** please do not use **RUN** commands of WINDOWS98 to start the DAFIBM. It only creates more communication errors.
- 9.3.2 At the C:\ prompt, type **cd \Rudolph**, then press the **Enter** key. Type in **dafibm** and press the **Enter** key again. The program will start and the screen will display the main menu

### **10.0 Troubleshooting Guidelines**

- 10.1 After measurement, the Ellipsometer displays **COMMUNICATION ERROR**, and the laptop PC does not display the measurement results.
- Solution:** Press the space bar on the laptop PC and it will display the main menu. Press **[g]** key and redo the measurement
- 10.2 The first measurement after Initialization, the Ellipsometer does not display any result after 1 minute.
- Solution:** The compensator (left arm) may still at the free position (white). Set it to the position for the wavelength you have chosen to do the measurement.

11.0 Figures & Schematics

11.1 Rudolph Ellipsometer Control Layout



11.2 DAFIBM Main Menu

**Rudolph Research**  
**Double Absorbing Films Calculations**  
 Copyright 1985, 1987

Program filename: STARTUP  
 Number of Layers: SINGLE  
 Path for DELTA, PSI: AE > CALC

Ambient	NA = 1.000	KA = 0.000
Upper Film	NU = 1.462	KU = 0.000
TL =		0.0
Substrate	NS = 3.858	KS = 0.018

Output limits                      Sample ID:                      PHIO = 70.00  
 LAMBDA = 6028.0  
 Print results: No  
 Iterate lim = 0.0010  
 Calculate Orders 0 to 2

Name of the program file associated with these specifications

Commands <sp> <bs> <Tab> Tag Modify Set/printer Help Go Quit Areset Rest

**12.0 Appendices**

12.1 Measurements (average of three measurements) of the Rudolph Ellipsometer, Nanoduv, and Nanospec on five oxide wafers.

Wafer #	2		16		4		8		13	
	Å	RI	Å	RI	Å	RI	Å	RI	Å	RI
Rudolph, Prog #1, 10/21/02										
Ave.	134	1.454	208	1.473	522	1.472	776	1.473	1147	1.465
Range %	5.24	3.58	0.96	0.61	0.58	0.27	0.39	0.20	0.09	0.07
Rudolph, Prog #2, 10/21/02										
Ave.	160	1.338	235	1.379	540	1.451	789	1.466	1151	1.465
Range %	25.57	11.96	1.28	0.80	0.93	0.34	0.25	0.14	0.26	0.00
Rudolph, Prog #3, 10/21/02										
Ave.	111	1.750	190	1.572	519	1.473	776	1.473	1145	1.467
Range %	0.00	0.00	1.05	1.78	0.58	0.34	0.52	0.20	0.00	0.07
Nanoduv, Prog #1, Oxide on Silicon, 5X, RI = 1.456										
Ave.	264		313		550		803		1139	
Range %	6.05		2.23		0.73		0.50		0.26	
Nanoduv, Prog #1, Oxide on Silicon, 5X, Variable RI										
	RI = 1.44		RI = 1.47		RI = 1.47		RI = 1.47		RI = 1.46	
Ave.	268		301		539		787		1138	
Range%	6.35		1.00		0.56		0.51		0.09	
Nanoduv, Prog #7, UV Thin Oxide on Silicon, 15X, RI=1.447, native oxide on ref. 20Å										
Ave.	132.2		225.1		530.2		784.9		1147.6	
Range %	1.44		3.78		0.62		0.24		0.15	
Nanospec Prog #1, Oxide on Silicon, 10X										
Ave.	104.0		152.8		516.4		784.0		1169.3	
Range %	0.58		0.85		0.08		0.01		0.02	
Nanospec Prog #7, Thin Oxide on Silicon, 10X										
Ave.	71.7		165.0		517.4		786.9		1166.4	
Range %	3.90		0.48		0.73		0.01		0.02	

12.2 Measurements (average of three measurements) of the Rudolph Ellipsometer, Nanoduv, and Nanospec on three low stress nitride wafers from Tylan18.

Low Stress Nitride						
Wafer #	6/13/01 Load		10/10/01 Center		5/28/02 Pump	
	Å	RI	Å	RI	Å	RI
Ave.	1451	2.213	1121	2.156	1109	2.115
Range %	2.14	1.58	0.09	0.05	0.09	0.05
Ave.	1448	2.216	1123	2.154	1110	2.113
Range %	1.66	1.26	0.36	0.14	0.27	0.24
Ave.	1237	2.490	1114	2.170	1101	2.129
Range %	0.40	0.20	0.18	0.09	0.27	0.28
Nanoduv, Prog #2, Nitride on Silicon, 5X, RI = 2.001						
Ave.	1651		1220		1181	
Range %	0.06		0.33		0.08	
Nanoduv, Prog #2, Nitride on Silicon, 5X, Variable RI						
	RI = 2.200		RI = 2.155		RI = 2.115	
Ave.	1504		1128		1114	
Range %	0.07		0.18		0.09	
Nanospec Prog #2, Nitride on Silicon, 10X						
Ave.	1629.9		1221.7		1172.3	
Range %	0.01		0.01		0.02	
Nanospec Prog #26, LSN on Silicon, 10X						
Ave.	3241		1214		1164	
Range %	0.03		0.00		0.09	