NanoSpec AFT/4100 SOP Manual

Overview

The NanoSpec is a metrology tool for measuring the thickness of dielectric thin films (photoresists, oxides, nitride, polysilicon, etc) on silicon wafers. It uses reflectometry (measurement of reflected light) to determine film thicknesses based on interference effects. Using measurement algorithms the Nanospec compares a bare silicon wafer to the sample being tested to yield thickness information without causing damage to the sample.

The basic operating principle is that the Nanospec diffracts light from the halogen bulb and deuterium lamp into its component wavelengths from 200 to 900nm. The spectrophotometer scans the light from short to long wavelengths and the microscope focuses this light onto the sample. The intensity of monochromatic reflected light depends strongly on film thickness because of interference *(the film thicknesses are comparable to the wavelength of the incident light)*. The machine uses a computer-controlled grating monochromator and a photomultiplier tube detector to measure the reflected optical spectrum (*over the 200 to 900 nm wavelength band*) from a bare silicon reference wafer and from the wafer under test. Given an index of refraction for a thin film and the two measured spectrums, the computer will analyze the interference pattern to determine film thickness. The equation for describing the interference is:

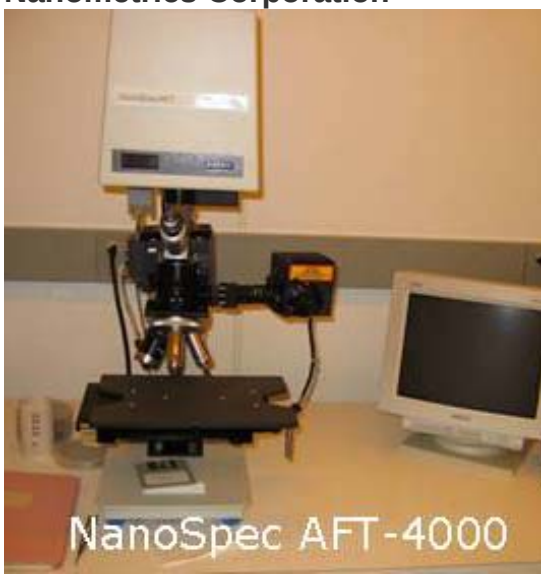
$$x_0 = \frac{\lambda}{2n_i}[g - (\Phi_s - \Phi_f)]$$

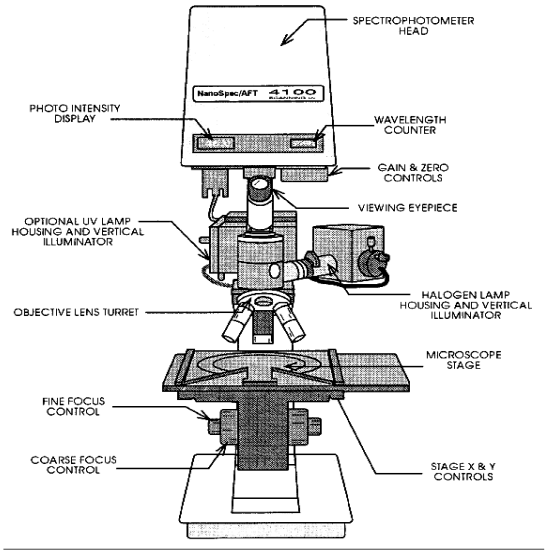
where χ_0 is film thickness, λ is the wavelength (in vacuum) of the incident radiation, Φ_s is the relative phase shift at the SiO2/Si interface, Φ_f is the relative phase shift at the air/SiO2 interface, n_i is the index of refraction of the thin film, and g is the order of the interference. The intensity is a maximum when the bracketed term is an integer and a minimum when it is an integer plus 1/2.

The measurement range of the instrument is from 10 to 500,000Å, with the UV deuterium lamp required for film thickness under 100Å and for several special programs.

For information not found in this SOP, consult the operation and maintenance manuals (Nanospec/AFT 4100).

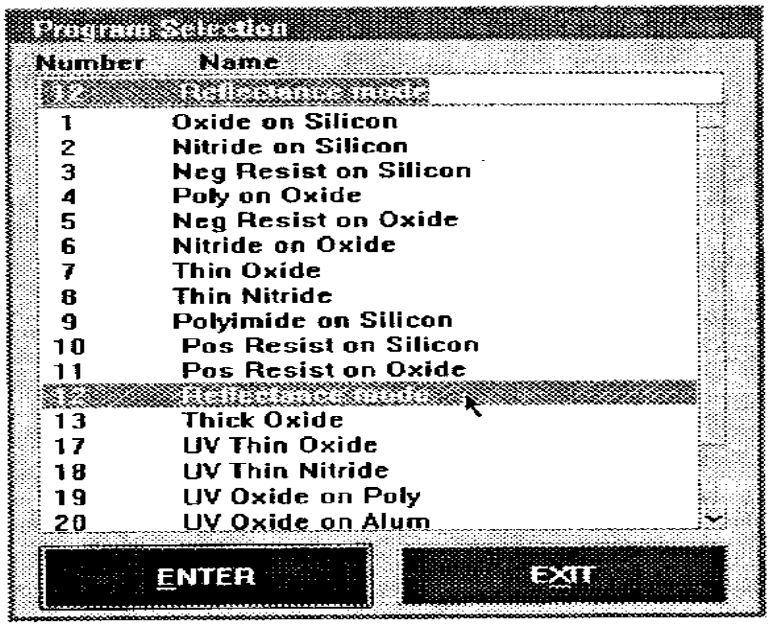
Nanospec Film Thickness Measurement System
Nanospec AFT Model 410
Nanometrics Corporation





System Specifications:

- Range of Thicknesses: 10 to 500,000Å
- Typical Measurement Time: 2.5 seconds.
- Film Types Measured:



If silicon is not mentioned in the above as the substrate, then it is implied as the substrate to the stated 2-film system.

Introduction to the system

Equipment

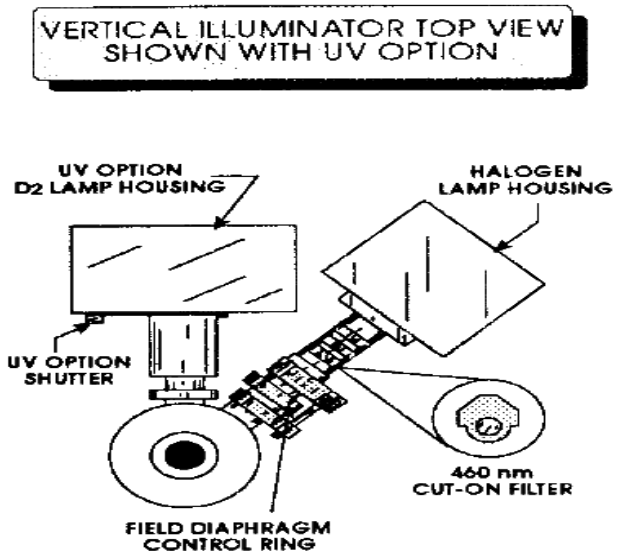
Like an optical microscope, the Nanospec has x-/y-position knobs and course/fine focus knobs, all located below the stage. The x-y position is manually adjustable to a resolution of about 2μm. There are four optical objectives: 5x, 10x, 15x (reflecting) and 50x. The choice of objective is determined by the program (sample structure) and sample feature-size. When looking through the eyepiece (and focused on a sample) a dark, circular spot is visible, indicating the measurement location. The diameter of this spot is set by the objective size as indicated by the table below:

Lens power	Spot size
5x	30 μm
10x	15 μm
15x (reflecting)	10 μm
50x	3 μm

For example, to probe a uniform sample using the halogen bulb, the 5x lens may be used, whereas to probe inside a 10μmx10μm contact hole, the 50x lens should be used. The Nanospec uses two different light sources:

(1) A tungsten halogen bulb, located to the right above the stage but below the spectrophotometer, in a black housing. When the halogen bulb is on, white light should stream out of the housing.
(2) A Deuterium UV lamp, located in a green metal housing separate from the Nanospec.

If you suspect that either lamp is malfunctioning or "burnt-out", contact ECTI_Pratt staff. To control the exposure of the sample (and the users' eyes) to the UV light, there is a UV shutter located behind the optical column, level with the eyepiece. The UV shutter is closed by pushing it all the way to the right. Keep this shutter closed except during UV measurements.



Software program

The software program will automatically load when the computer is turned on. If someone logs off, log back into the program using the username *eng* and password *4000e*.

The screen has three parts. The top bar contains menu functions. These functions can be selected either by clicking on the appropriate bar button or by pressing the corresponding function key on the keyboard. The middle part of the screen contains the data output. The bottom left part of the screen gives information about the current measurement program, and additional program options are listed on the right side.

The top bar functions are:

<F9> – STD – select a standard measurement program and take necessary references
<F7> – REF – take a reference measurement
<F10> – MEAS – take a measurement (with the currently selected program). This function can also be engaged by pressing <SHIFT>, spacebar or <ENTER>
<F2> – GRAPH – plot the latest measured and modeled reflectance vs. wavelength. Before making another measurement you must "exit" out of the graph.
<Alt-F3> – STATISTICS – Calculates mean and standard deviation on the current set of data
<F6> – CLEAR – separate one set of data from another for the purposes of calculating statistics
<F5> – LOGOFF – logout of the Nanospec program; only necessary for maintenance tasks.
<F8> – USER – select a user-defined program; only necessary for maintenance tasks.

The following functions are disabled or not useful: <F1> – HELP, <F3> – AUTO, and <F4> – PRINT

Operation

Initial setup

If needed, turn on the computer. Push <F1> when prompted. The Nanospec program will start up and initialize automatically. After turning on the computer, wait *30 minutes* for the instrument to warm up before taking measurements.

Selecting a program and taking an initial reference measurement

Press <F9> - STD. Click <NO> in response to "Option. Save measurement data into database?" Select the program you want and click <ENTER>. Select the desired magnification and rotate the lens turret to the appropriate lens. Click <ENTER>. Click <YES> when prompted "Reminder! Take a new reference? Age of reference <<xx:xx Hours>>," unless you have recently (within ~ 1 hour) taken a reference with the same program and same objective lens. Use the existing reference wafer or place your own reference wafer (usually a bare silicon wafer) under the lens. Adjust the focus until the octagon edges are crisp. If using a UV program, open the UV shutter; otherwise, check that it is closed. Then click <ENTER> in response to "Reminder! Prepare Substrate for Reference" to take the reference measurement. The spectrophotometer will scan through the wavelengths and then finish loading the program.

Measuring a sample using the tungsten halogen lamp

Use the 5x, 10x or 50x objectives only. Press <F10> - MEAS. Follow the directions on the screen: Close the UV shutter if prompted to do so. Remove the reference wafer and place your sample under the microscope. Course, then fine focus on the octagon edges or sample surface. Align the sample to the desired position using x-y stage knobs. When ready to measure, click "OK." The film thickness will appear in Angstroms under the Thickness column.

The Fit column contains the statistical fit between the measured data and the model corresponding to the film thickness for the selected program. The smaller the fit value, the closer the measured and modeled data. Typical fits are < 0.10, although under some conditions the model can be good even when the fit is larger, >1.0. To view the measured and modeled reflectance vs. wavelength, press <F2> - GRAPH. The graph will appear in the lower right corner of the screen. The model and measured data sets can be toggled on/off using the buttons. It is recommended to always observe the fit values, and check the graph whenever using a new program or measuring a new type of sample. Click <EXIT> out of the graph to return to measurement.

To repeat a measurement, check the focus then press <F10>-MEAS. To get statistics (<t>, σ_t) on a table of measurements, press <Alt-F3>. To measure a new sample, place it on the stage and focus on it. Then press <F6>-CLEAR to create a new table and finally press <F10>-MEAS to measure. If you change the objective lens, redo the reference measurement by pushing <F7>-REF. If you change programs, also redo the reference measurement.

Using the Deuterium lamp to make UV measurements

The Deuterium lamp is used for measuring certain film configurations, including thin (25-500 Å) silicon dioxide or silicon nitride on silicon with programs #17 or #18, respectively, and oxide on poly-Si (#19, 150-10,000Å) or oxide on aluminum (#20, 500-20,000Å). Turn on the deuterium lamp power supply at least 15 minutes before taking any measurements. Use the special 15x reflecting lens only, and take a new reference each time a UV program is selected. Programs #19 and #20 require two reference measurements; see the operations manual, pages 4-11,12 and 3-16 for details. To protect your eyes, open the UV shutter only when taking the measurement; keep it closed during focusing and alignment.

Shutdown

When finished, remove your sample and reference wafer and TURN OFF THE COMPUTER by pushing the power button. This will turn off the tungsten halogen lamp and thereby extend its lifetime. Turn off the deuterium lamp power. Sign the logbook.

Other notes

Details on the programs can be found in the Operations Manual on pages 4-7 to 4-12.

Edward, Huaping XU
rev 1, 3/12/08

Appendices

Nanospec

Installing User Defined Programs on the Nanospec 4150 Interferometer

Introduction

The following procedures were supplied by:

NANOmetrics

1550 Buckeye Dr., Milpitas, CA 95035

They are the required procedures for importing material files supplied by Nanometrics onto the Nanospec 4000, and for creating user-defined programs to measure novel materials and material layers.

Procedure Documentation

WARNING: Modifications to material files and engineering programs should be undertaken only by engineering staff.

Procedure for importing a material file:

(Note: Before importing the material files, copy the material files onto a new 3-1/2 "floppy disc.)

1. Log on to the system in the Engineering mode, using the login name "eng" and "4000e" as the password.

2. On the menu bar, select "Edit program" and under this click on the 'film'

option. This will bring up the editor screen.

3. On the menu bar of this window, click on 'editor' option and choose

'material'. This will open the material editor.

4. On the material editor, click on "open" option. This will bring up a file browser window. Choose the active drive to be the floppy drive. Highlight a material and click on ok. This should bring up two graphs, one for n and one for k respectively for the material chosen.

5. Click on "Material" on the menu bar again, and choose the "save as" option.

6. This will bring up the save browser. View the material numbers in C:/USER/DATA/FILM/MATERIAL. It should appear as 'M20' followed by a three-digit or a two-digit number (e.g. M20234). Make sure when you are importing the new material file that you don't overwrite an existing material file. If a material file already exists with the

same number, re-number the material file being imported to M20xyz where xyz is an unused number. Save the material file under: C:/USER/DATA/FILM/MATERIAL.

7. To confirm that the material file has been imported successfully, click on the list option on the material editor, to find the imported materials under the list of materials in C:/USER/DATA/FILM/MATERIAL.

Procedure for creating a new film program:

Consider an example of creating a film program for a Resist/Chromium oxide/Chromium substrate, assuming that the material files for Resist and Chromium oxide have already been imported on the tool.

1. Log on to the system in the Engineering mode, using the login name "eng" and "4000e" as the password.

2. On the menu bar, select "Edit program" and under this click on the 'film' option. This will bring up an editor screen.

3. On the menu bar of this window, click on "editor" option and choose the 'program' option. This will bring up the program editor.

4. The right hand side of the program editor displays a list of all the windows present in the program editor. The first window is the information window, in which the program number and program name is to be selected. Pull down the program number menu and note the highest number presently used. Assign the next available (unused) number for the new program and type it in the program number column.

5. Choose an appropriate descriptive name for the program in the next column. For the example chosen, you might want to name it as "Ped on Si".

6. Switch to the "Material" window, by clicking below information option on the Material button. On the material window, make sure the Algorithm type is "Scanning measurement". Indicate the number of layers to in the sample. In the example chosen, we would select the number of layers to be '2'.

7. Under the material choice option, choose the substrate to be Si and layer 1 to be the required material.

8. Switch to the iteration option from material option. Activate the iteration option if the index has to be found for any of the layers and click on the index button for that particular layer.

9. Under the iterate option, one has to toggle between the haze and gain options by trial and error so as to get a good fit and so the right reading of the thickness is obtained.

10. Switch back to the information sheet and click on the 'save' button to save the program.

11. Then click on the 'exit' button to get out of the program editor.

Reference: Procedure Documentation from Nanometrics, 1550 Buckeye Drive, Milpitas, CA 95035.

Standard Program

Prog #	Film to be measured	Range (Å)	Note
1	Oxide on Silicon (10X)	400 - 50,000	Not accurate for highly doped PSG
2	Nitride on Silicon (10X)	400 - 40,000	Use customized LSN program for Tystar17 film
3	Negative Resist on Silicon (10X)	500 - 40,000	Hard bake and plasma will change the accuracy
4	Polysilicon on 1000Å Oxide (10X)	550 - 10,000	The oxide should be in the range of ± 200Å
5	Negative Resist on 1000Å Oxide (10X)	4,000 - 30,000	
6	Nitride on 1000Å Oxide (10X)	300 - 3,500	
7	Thin Oxide on Silicon (10X)	100 - 500	Focusing is critical to the measurement repeatability
8	Thin Nitride on Silicon (10X)	100 - 500	Focusing is critical to the measurement repeatability
9	Polyimide on Silicon (10X)	500 - 30,000	
10	Positive Resist on Silicon (10X)	500 - 40,000	Resists have different refractive index, default 1.64
11	Positive Resist on 1000Å Oxide (10X)	4,000 - 30,000	Resists have different refractive index, default 1.64
12	Reflectance Mode (10X)		Result in % compared to the reference wafer
13	Thick Oxide (10X)	>40,000	

Available Material for Measurement Program Setup

	Materials		Materials
000	Air	023	Diamond (C) -Book
001	Crystal Silicon -Book	024	Water - Book

002	Silicon Dioxide -Book	025	Aluminum Oxide -Book
003	Silicon Nitride -Book	026	TiO2 Book
004	Negative Resist	027	Tungsten (W) -Book
005	Positive Resist	028	Silicon Carbide -Book
006	Amorphous Silicon	029	GaAs -Book
007	Polymide	030	Aluminum -Book
008	Polysilicon	031	Chromium (Cr) -Book
009	Silicon (480-900 nm)	032	Amorphous Silicon -Book
010	Silicon (visible)	033	Platinum (pt) -Book
011	Chromium (Cr)	034	Tantalum (Ta) -Book
012	Cr2O3	035	Nickel (Ni) -Book
013	Poly-silicon	036	Molybdenum (Mo) -Book
014	UV Oxide	037	Titan Carbide (TiC) -Book
015	UV Nitride	038	Graphite (C) -Book
016	NiFe	039	LiNb03 -Book
017	WSi	040	Titan Nitride (TiN) -Book
018	7059 Glass	041	Si Monoxide (Si0) -Book
019	Quartz	042	Ti
020	Gold (Au)	043	TiN
021	Copper (Cu) -Book	044	TiSi
022	InP - Book	045	LTO