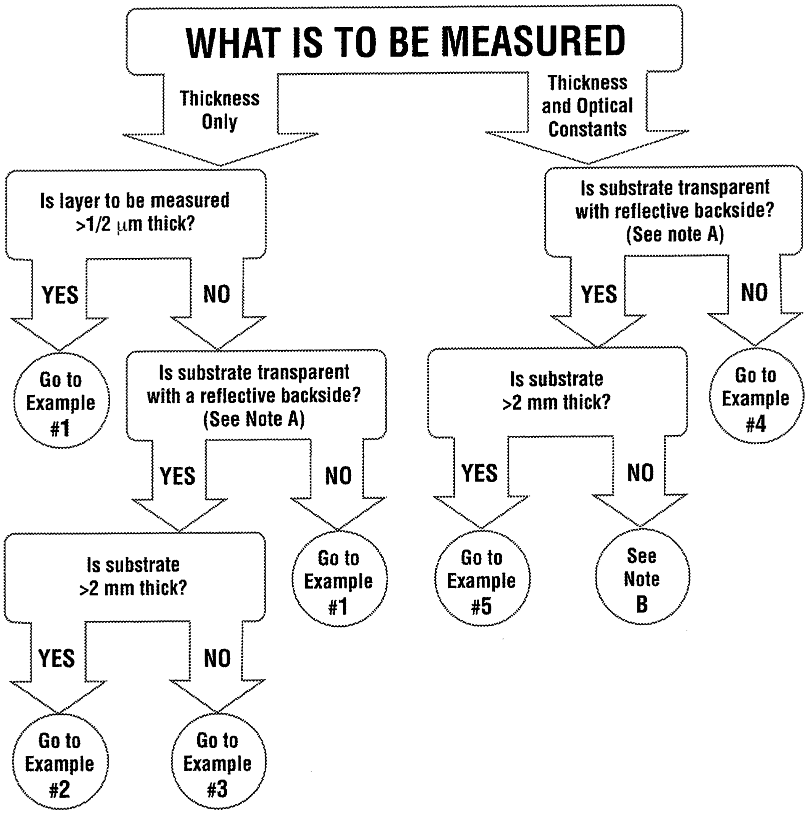
# Chapter 4 Making Measurements

## 4.1 Types of Measurements

Accurate measurements with the F20 rely on using the proper measurement setup. The type of setup that is used depends upon whether both thickness and optical constants are being measured, or just thickness alone. Also important are the thickness of the film and the type of substrate.

The basic steps for any F20 measurement are: 1) selecting and editing the type of film to be measured, 2) taking a baseline measurement, and 3) clicking on the "Measure" button to make the measurement. Each example below will take you through this sequence of steps. In each example it is assumed that the hardware has been set up as described in Chapter 2, and that you have first read through Chapter 3 to familiarize yourself with the basic controls. The Measurement Assumptions, Hints, and Troubleshooting sections describe techniques that should be followed for the most accurate measurements.

Examples that describe the most common measurement setups are described in this section. Use Figure 4.1 to find the proper example for your application.



Note A: Transparent substrates are considered to have a reflective backside unless the backside is specially prepared to absorb light incident from the frontside.

Note B: These samples may require a special fixture in order to be measured. Call Filmetrics for details.

Figure 4.1: Selection tree for identifying the example for specific measurements.

## 4.2 Examples

### Example 1: Thickness of Films Greater Than ½ Micron Thick: $SiO_2$ on Silicon

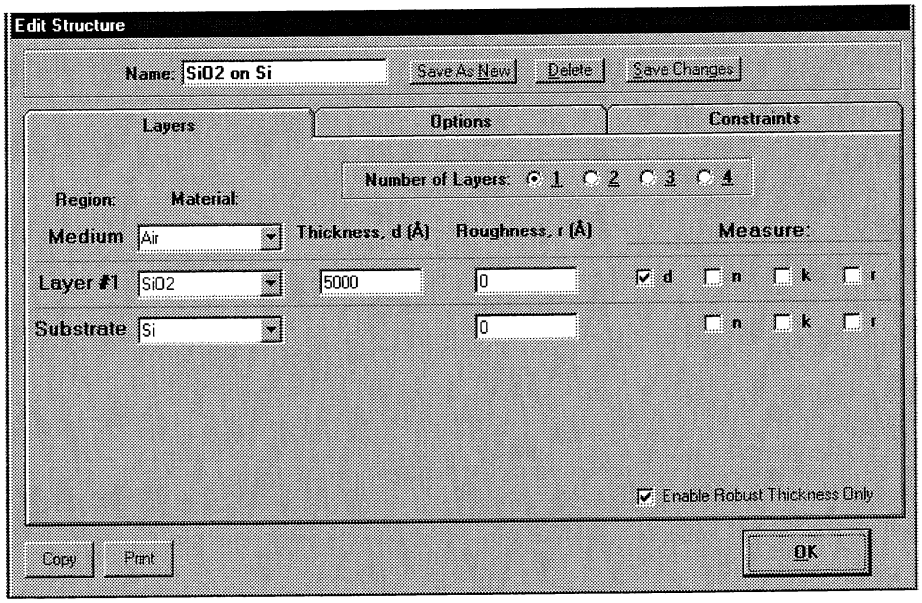
For this example we will demonstrate only the measurement of $SiO_2$ on silicon (the $SiO_2$ on silicon Test Sample provided with the F20 may be used), but this type of measurement has an extremely broad range of applications, including hardcoats, polysilicon, and LCD cell gaps, to name just a few.

**Hardware:** If the sample to be measured is flat, any standard or rotating sample stage will work fine. If the sample is curved, or is transparent with films on its backside (such as eyeglass lens applications), a hand-held contact probe measurement device (e.g., Part# CP-NIR) may be necessary.

**Step 1: Select the film structure**

Select the film structure to be measured, in this case "SiO2 on Si", from the "Structure:" selection box on the main screen. If the structure to be measured does not exist, a new structure must be defined (see Section 5.2.)

**Step 2: Edit the film structure**



Name: SiO2 on Si

Number of Layers: ● 1 ○ 2 ○ 3 ○ 4

| Region: | Material: | Thickness, d (Å) | Roughness, r (Å) | Measure: | | | |
|---|---|---|---|---|---|---|---|
| Medium | Air | | | | | | |
| Layer #1 | SiO2 | 5000 | 0 | ☑ d | ☐ n | ☐ k | ☐ r |
| Substrate | Si | | 0 | | ☐ n | ☐ k | ☐ r |

☑ Enable Robust Thickness Only

Figure 4.2: Example Edit Structure:Layers window for measuring the thickness of a thin film greater than ½ micron thick.

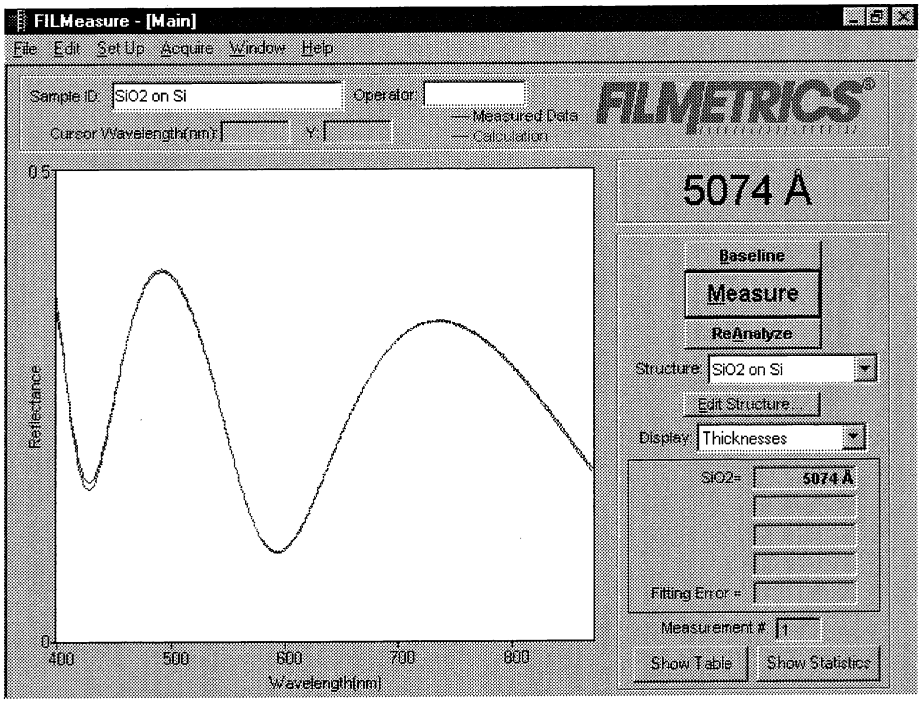
To edit the structure, click on "Edit Structure" to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected (see Section 5.2.) Also enter your best guess for the thickness of the film to be measured, and check that only the $SiO_2$ layer thickness is being measured.

## Step 3: Take a Baseline Measurement

Take a Baseline measurement by first clicking on the Baseline button on the main screen. On the Take Baseline dialog box, make certain the "Autoscale Integration Time" option is selected, and choose the Baseline Sample that will be used (Si in this case). Then put the Baseline sample on the measurement stage and click on "Take Baseline". Then remove the Baseline sample from the stage and click "Take Zero". (In the case of a contact probe, place the probe on the Baseline sample and click on "Take Baseline", and then remove the probe from the sample and click "Take Zero".)

## Step 4: Make the Measurement

Make the measurement by placing your sample on the stage (or the contact probe on your sample) and click on the "Measure" button. FILMeasure will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.) In most cases they will not overlap, but will be separated in amplitude.



Sample ID: SiO2 on Si

5074 Å

Structure: SiO2 on Si

Display: Thicknesses

SiO2= 5074 Å

Measurement #: 1

Figure 4.3: Measured and calculated reflectance spectra when measuring the thickness of $SiO_2$ on silicon.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in cases #1, #2, #3, and #4 in the troubleshooting section.

## Example 2: Thickness of Films Less Than ½ Micron Thick on Thick Transparent Substrates: $TiO_2$ on Glass

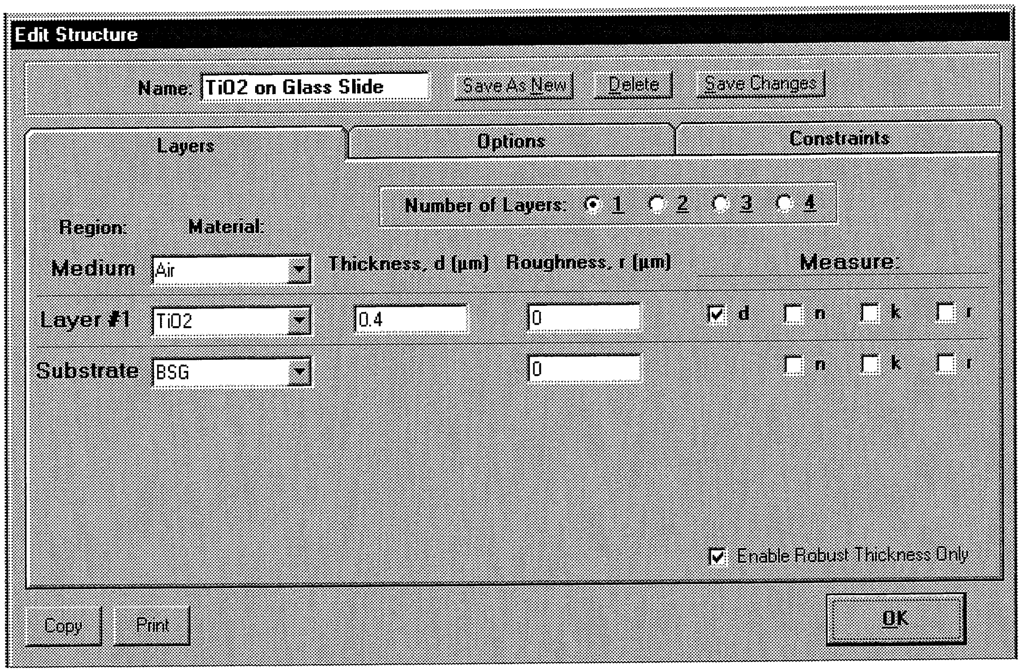
This example demonstrates the measurement of $TiO_2$ on glass. This type of measurement has a broad range of other applications, most commonly optical coating and flat-panel display process films.

**Hardware:** If the sample to be measured is flat, the contact sample stage should be used. If the sample is curved, the hand-held contact probe (e.g., Part# CP-NIR) will probably be necessary.

### Step 1: Select the film structure

Select the film structure to be measured, in this case "TiO2 on Glass", from the "Structure:" selection box on the main screen. If the structure to be measured does not exist, a new structure must be defined (see Section 5.2.)

### Step 2: Edit the film structure



Edit Structure

Name: TiO2 on Glass Slide

Number of Layers: ● 1 ○ 2 ○ 3 ○ 4

| Region: | Material: | Thickness, d (µm) | Roughness, r (µm) | Measure: |
|---|---|---|---|---|
| Medium | Air | | | |
| Layer #1 | TiO2 | 0.4 | 0 | ☑ d ☐ n ☐ k ☐ r |
| Substrate | BSG | | 0 | ☐ n ☐ k ☐ r |

☑ Enable Robust Thickness Only

Figure 4.4: Example Edit Structure:Layers window for measuring the thickness of a film less than approximately ½ micron thick on a thick transparent.

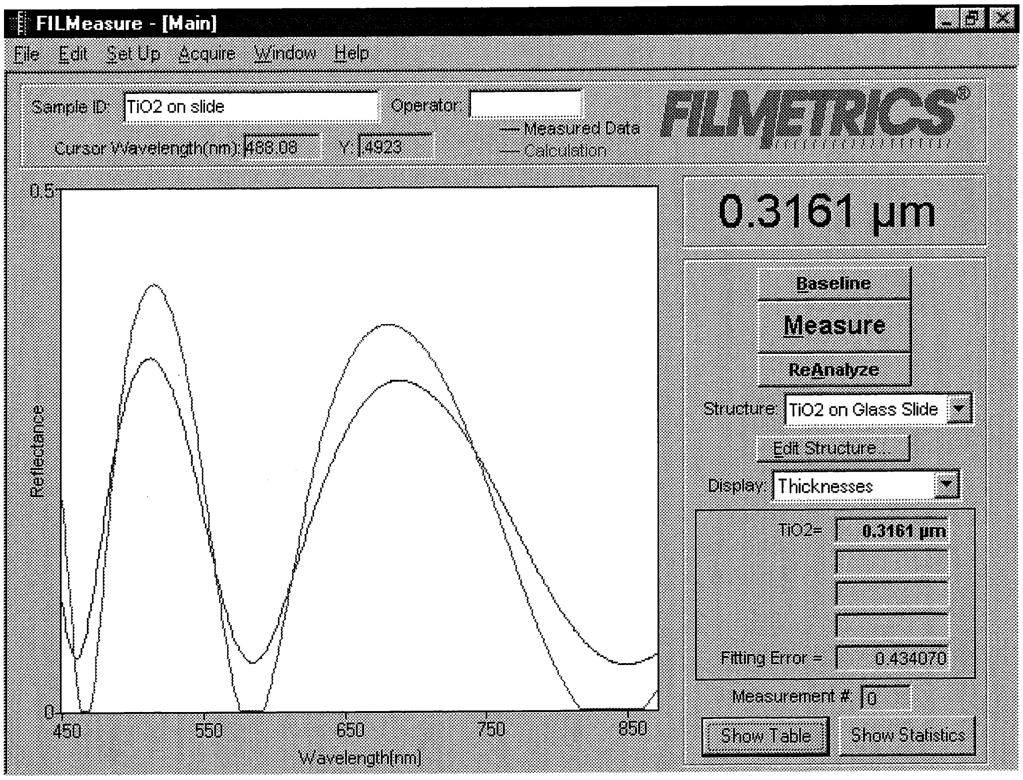
To edit the structure, click on "Edit Structure" to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected (see Section 5.2.) Also enter your best guess for the thickness of the film to be measured, and check that only the $TiO_2$ layer thickness is being measured.

### Step 3: Take a Baseline Measurement

Take a Baseline measurement by first clicking on the Baseline button on the main screen. On the Take Baseline dialog box, make certain the "Autoscale Integration Time" option is selected, and choose the Baseline Sample that will be used (Si in this case). Then put the Silicon Baseline sample on the measurement stage and click on "Take Baseline". Then remove the Baseline sample from the stage and click "Take Zero". (In the case of a contact probe, place the probe on the Baseline sample and click on "Take Baseline", and then remove the probe from the sample and click "Take Zero".)

### Step 4: Make the Measurement

Make the measurement by placing your sample on the stage (or the contact probe on your sample) and click on the "Measure" button. FILMeasure will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.) In most cases they will not overlap, but will be separated in amplitude.



Sample ID: TiO2 on slide
Operator:
Cursor Wavelength(nm): 488.08
Y: .4923
0.3161 µm
Structure: TiO2 on Glass Slide
Display: Thicknesses
TiO2= 0.3161 µm
Fitting Error = 0.434070
Measurement #: 0

Figure 4.5: Measured and calculated reflectance spectra when measuring the thickness of $TiO_2$ on a glass slide.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in cases #1, #2, #3, and #4 in the troubleshooting section.

## Example 3: Thickness of Films Less Than ½ Micron on Thin Transparent Substrates: $MgF_2$ on Glass slide

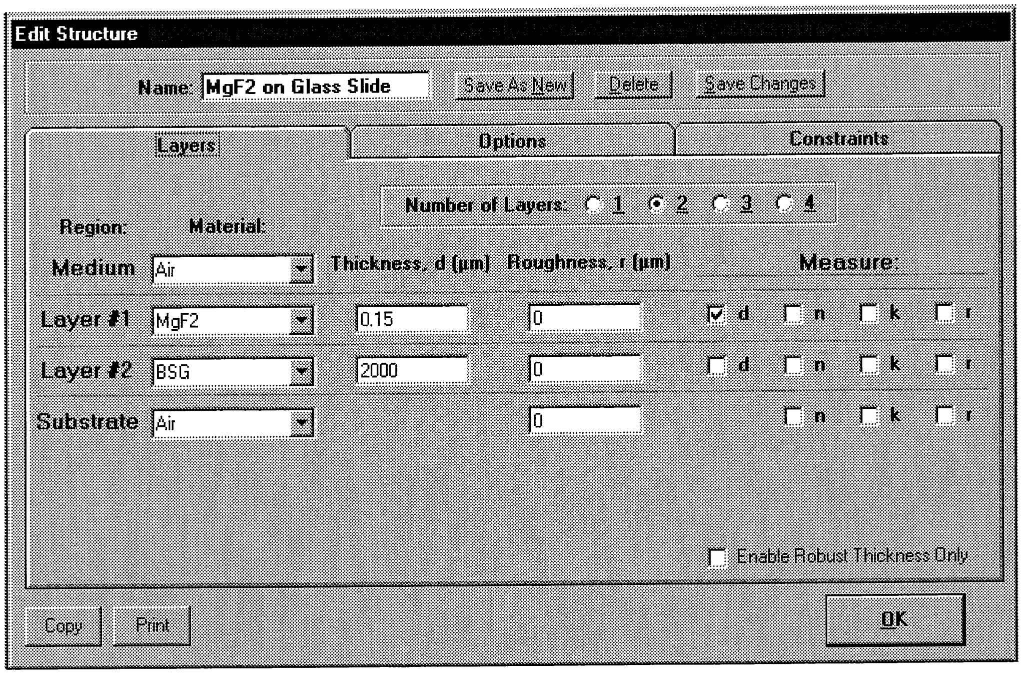
In this example we will demonstrate the measurement of $MgF_2$ on a glass slide.

**Hardware:** For this type of measurement the sample must be flat, with the front and backsides parallel. The standard SS-1 sample stage is required.

### Step 1: Select the film structure

Select the film structure to be measured, in this case "MgF2 on Glass", from the "Structure:" selection box on the main screen. If the structure to be measured does not exist, a new structure must be defined (see Section 5.2.)

### Step 2: Edit the film structure



Name: MgF2 on Glass Slide

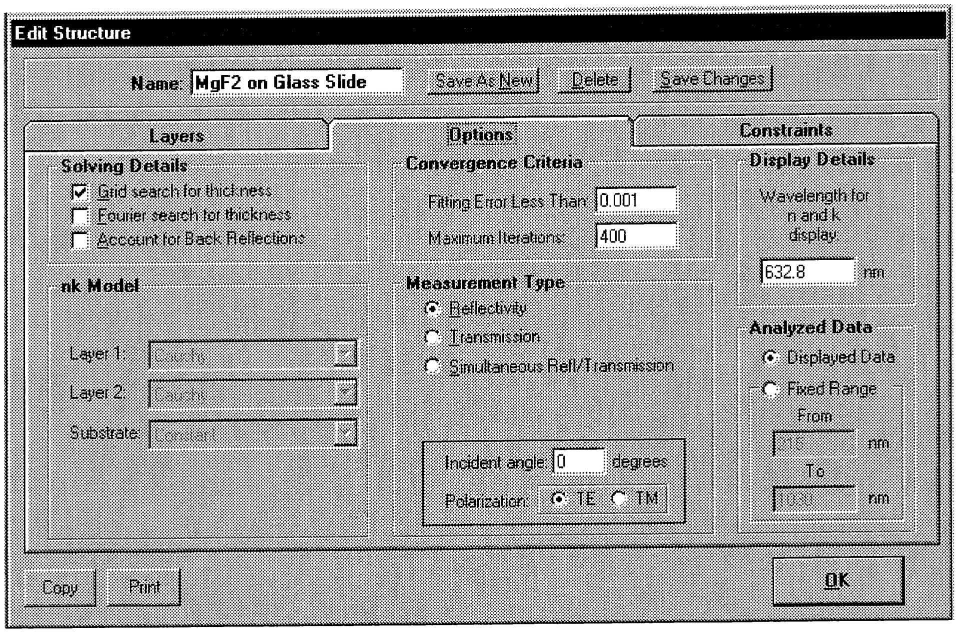
Number of Layers: ○ 1 ● 2 ○ 3 ○ 4

| Region: | Material: | Thickness, d (µm) | Roughness, r (µm) | Measure: |
|---|---|---|---|---|
| Medium | Air | | | |
| Layer #1 | MgF2 | 0.15 | 0 | ☑ d ☐ n ☐ k ☐ r |
| Layer #2 | BSG | 2000 | 0 | ☐ d ☐ n ☐ k ☐ r |
| Substrate | Air | | 0 | ☐ n ☐ k ☐ r |

☐ Enable Robust Thickness Only

Figure 4.6: Example Edit Structure:Layers window for measuring the thickness of films less than approximately ½ micron thick on a thin transparent substrate.

To edit the structure, click on "Edit Structure" to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected (see Section 5.2.) Also enter your best guess for the thickness of the film to be measured, and check that only the $MgF_2$ layer thickness is being measured.



Edit Structure

Name: MgF2 on Glass Slide

**Solving Details**
☑ Grid search for thickness
☐ Fourier search for thickness
☐ Account for Back Reflections

**Convergence Criteria**
Fitting Error Less Than: 0.001
Maximum Iterations: 400

**Display Details**
Wavelength for n and k display: 632.8 nm

**nk Model**
Layer 1:
Layer 2:
Substrate:

**Measurement Type**
● Reflectivity
○ Transmission
○ Simultaneous Refl/Transmission

Incident angle: 0 degrees
Polarization: ● TE ○ TM

**Analyzed Data**
● Displayed Data
○ Fixed Range
From nm
To nm

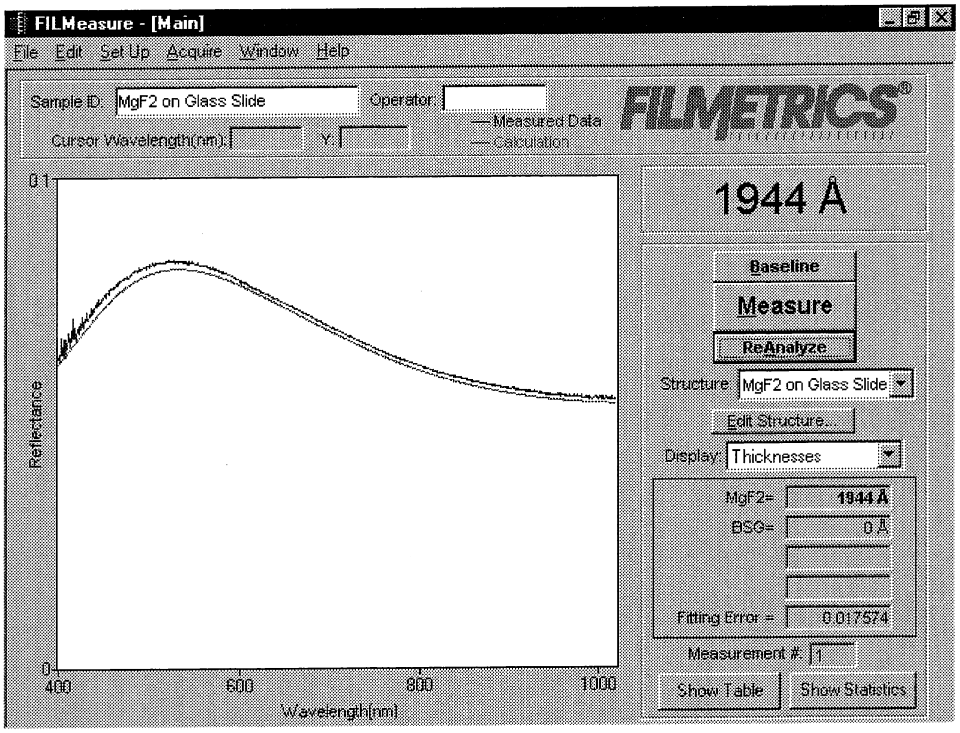
Figure 4.7: Example Edit Structure:Options window for measuring the thickness of films less than approximately ½ micron thick on thin transparent substrate.

### Step 3: Take a Baseline Measurement

Take a Baseline measurement by first clicking on the Baseline button on the main screen. On the Take Baseline dialog box, make certain the "Autoscale Integration Time" option is selected, and choose the Baseline Sample that will be used (Si in this case). Then put the Silicon Baseline sample on the measurement stage and click on "Take Baseline". Then remove the Baseline sample from the stage and click "Take Zero". (In the case of a contact probe, place the probe on the Baseline sample and click on "Take Baseline", and then remove the probe from the sample and click "Take Zero".)

### Step 4: Make the Measurement

Make the measurement by placing your sample on the stage (or the contact probe on your sample) and click on the "Measure" button. FILMeasure will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.) In most cases they will not overlap, but will be separated in amplitude.



Sample ID: MgF2 on Glass Slide

1944 Å

Structure: MgF2 on Glass Slide

Display: Thicknesses

MgF2= 1944 Å

BSG= 0 Å

Fitting Error = 0.017574

Measurement #: 1

Figure 4.8: Measured and calculated reflectance spectra when measuring the thickness of $MgF_2$ on a glass slide.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in cases #1, #2, #3, and #4 in the troubleshooting section.

## Example 4: Thickness and Optical Constants of Films on Opaque Substrates: $SiO_2$ on Silicon

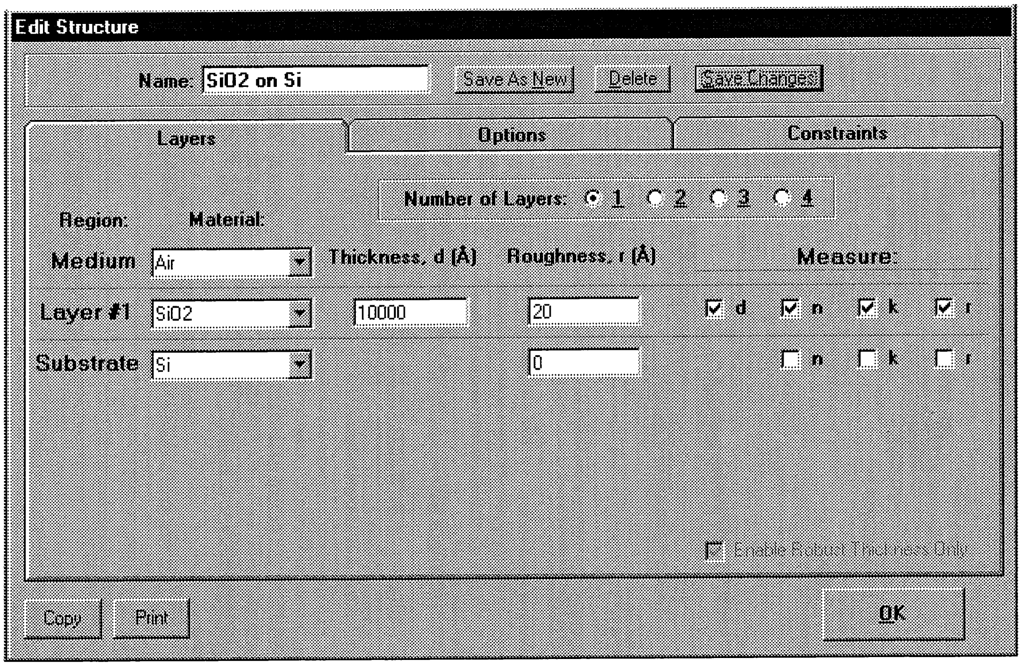
For this example we will demonstrate only the measurement of $SiO_2$ on silicon (the $SiO_2$ on silicon Test Sample provided with the F20 may be used,) but this type of measurement has an extremely broad range of applications, including the measurement of nitrides, polysilicon, and optical coatings.

**Hardware:** Any standard or rotating sample stage should work fine. The sample frontside must be flat. If the sample backside is not flat and parallel with the frontside, then the contact stage must be used.

### Step 1: Select the film structure

Select the film structure to be measured, in this case "SiO2 on Si", from the "Structure:" selection box on the main screen. If the structure to be measured does not exist, a new structure must be defined (see Section 5.2.)

### Step 2: Edit the film structure



Name: SiO2 on Si

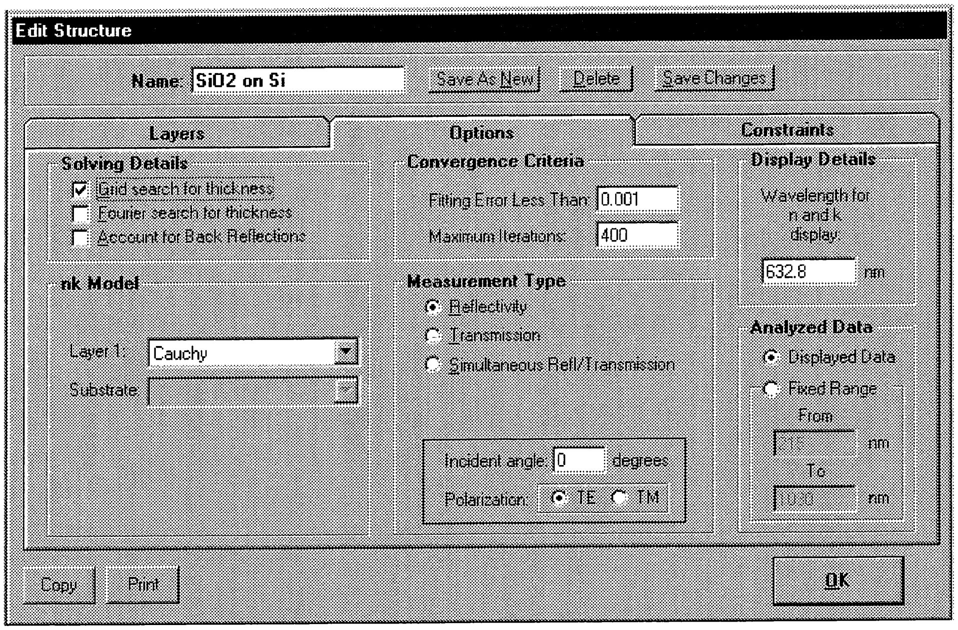
Number of Layers: ● 1 ○ 2 ○ 3 ○ 4

| Region: | Material: | Thickness, d (Å) | Roughness, r (Å) | Measure: |
|---|---|---|---|---|
| Medium | Air | | | |
| Layer #1 | SiO2 | 10000 | 20 | ☑ d ☑ n ☑ k ☑ r |
| Substrate | Si | | 0 | ☐ n ☐ k ☐ r |

☑ Enable Robust Thickness Only

Figure 4.9: Example Edit Structure:Layers window for measuring the thickness, *n*, and *k* of films on an opaque substrate.

For this example the film structure will probably not require editing, unless a different film is being measured. To edit the structure, click on "Edit Structure" to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected (see Section 5.2.) Also enter your best guess for the thickness of the film to be measured. Also check that thickness, *n,* and *k* of the $SiO_2$ layer are selected to be measured.



Name: SiO2 on Si

☑ Grid search for thickness
☐ Fourier search for thickness
☐ Account for Back Reflections

Fitting Error Less Than: 0.001
Maximum Iterations: 400

Wavelength for n and k display: 632.8 nm

Layer 1: Cauchy
Substrate:

● Reflectivity
○ Transmission
○ Simultaneous Refl/Transmission

Incident angle: 0 degrees
Polarization: ● TE ○ TM

● Displayed Data
○ Fixed Range
From nm
To nm

Figure 4.10: Example Edit Structure:Options window for measuring the thickness, *n*, and *k* of films on an opaque substrate.

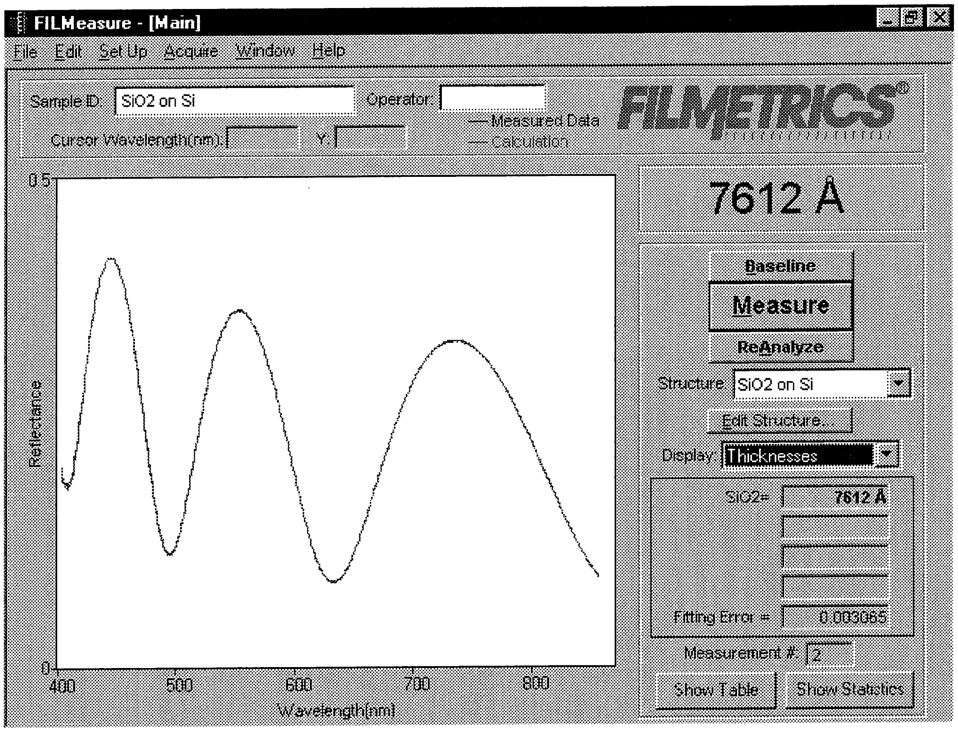
### Step 3: Take a Baseline Measurement

Take a Baseline measurement by first clicking on the Baseline button on the main screen. On the Take Baseline dialog box, make certain the "Autoscale Integration Time" option is selected, and choose the Baseline Sample that will be used (Si in this case). Then put the Silicon Baseline sample on the measurement stage and click on "Take Baseline". Then remove the Baseline sample from the stage and click "Take Zero". (In the case of a contact probe, place the probe on the Baseline sample and click on "Take Baseline", and then remove the probe from the sample and click "Take Zero".)

### Step 4: Make the Measurement

Make the measurement by placing your sample on the stage (or the contact probe on your sample) and click on the "Measure" button. FILMeasure will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the calculated reflectance (the red line on the graph) will coincide with the measured reflectance (the blue line on the graph.)

If the measured and calculated spectra do not fall on top of each other, the resulting thickness, *n*, and *k* values are incorrect. If the mismatch between measured data and calculation is only slight, the results reported will only be off by a small amount. If the measured and calculated spectra match, but the results are implausible, there may be a problem with the sample positioning and light collection. Causes and corrective actions to improve the measurements are listed in cases #5 and #6 in the troubleshooting section.



Sample ID: SiO2 on Si

Operator:

7612 Å

Structure: SiO2 on Si

Display: Thicknesses

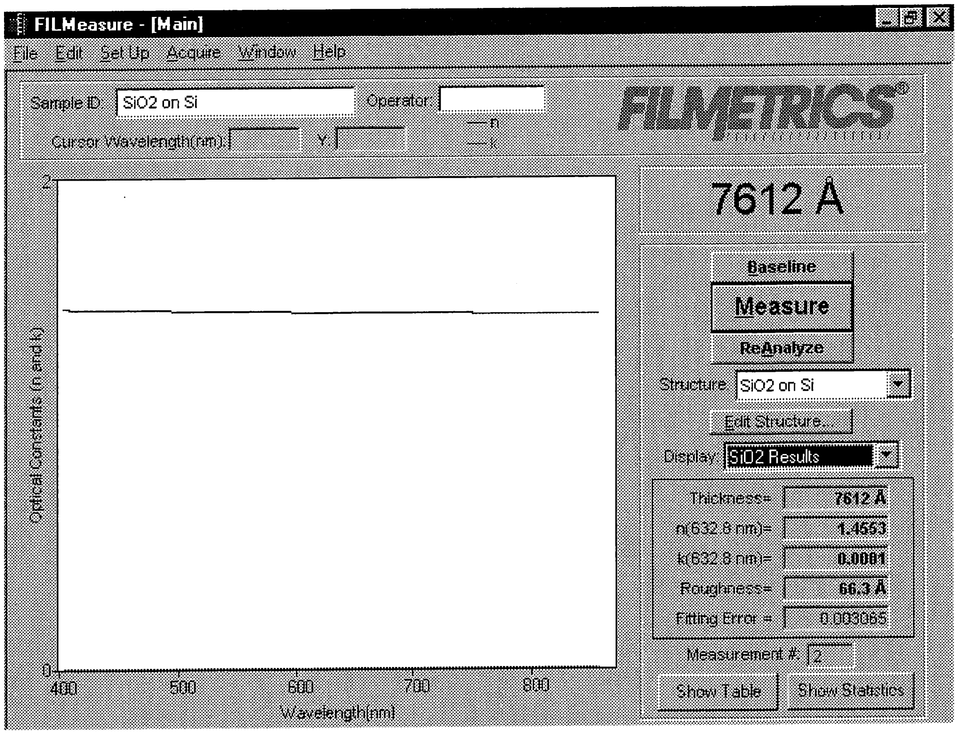
SiO2= 7612 Å

Fitting Error = 0.003085

Measurement #: 2

Figure 4.11: Measured and calculated reflectance spectra when measuring the thickness, *n*, *k*, and roughness of $SiO_2$ on silicon.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in cases #1, #2, #3, and #4 in the troubleshooting section.



Sample ID: SiO2 on Si

Operator:

7612 Å

Structure: SiO2 on Si

Display: SiO2 Results

Thickness= 7612 Å
n(632.8 nm)= 1.4553
k(632.8 nm)= 0.0001
Roughness= 66.3 Å
Fitting Error = 0.003065

Measurement #: 2

Figure 4.12: Calculated *n* and *k* spectra when measuring the thickness, *n*, *k*, and roughness of $SiO_2$ on silicon.

## Example 5: Thickness and Optical Constants of Films on Thick Transparent Substrates: $MgF_2$ on BK7

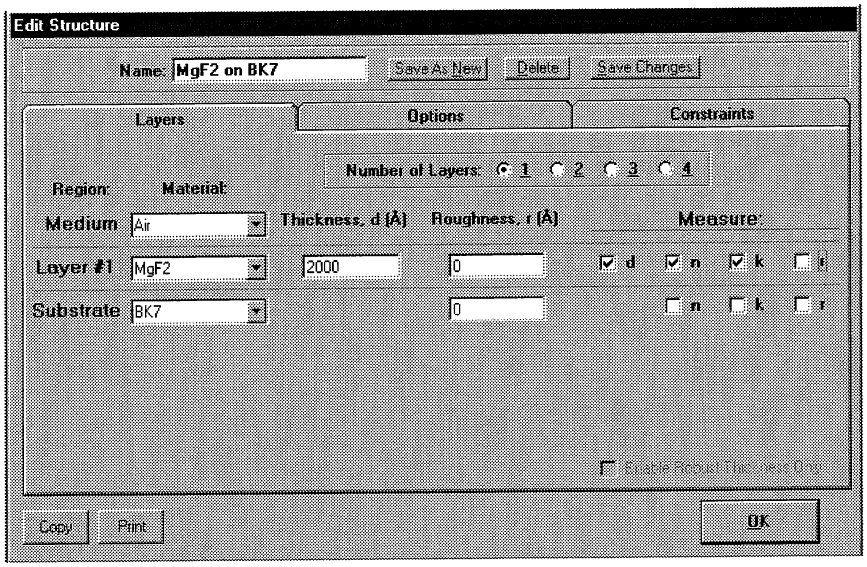
This type of measurement is typically applied to optical coatings on glass substrates, as well as anti-reflection coatings on various transparent substrates.

**Hardware:** The contact stage must be used when measuring the thickness and optical constants of films on a thick transparent substrate (see Chapter 2 for setup of the contact stage.) Use of the contact stage means that the frontside of the sample must be flat.

### Step 1: Select the film structure

Select the film structure to be measured, in this case "Mg2 on BK7", from the "Structure:" selection box on the main screen. If the structure to be measured does not exist, a new structure must be defined (see Section 5.2.)

### Step 2: Edit the film structure



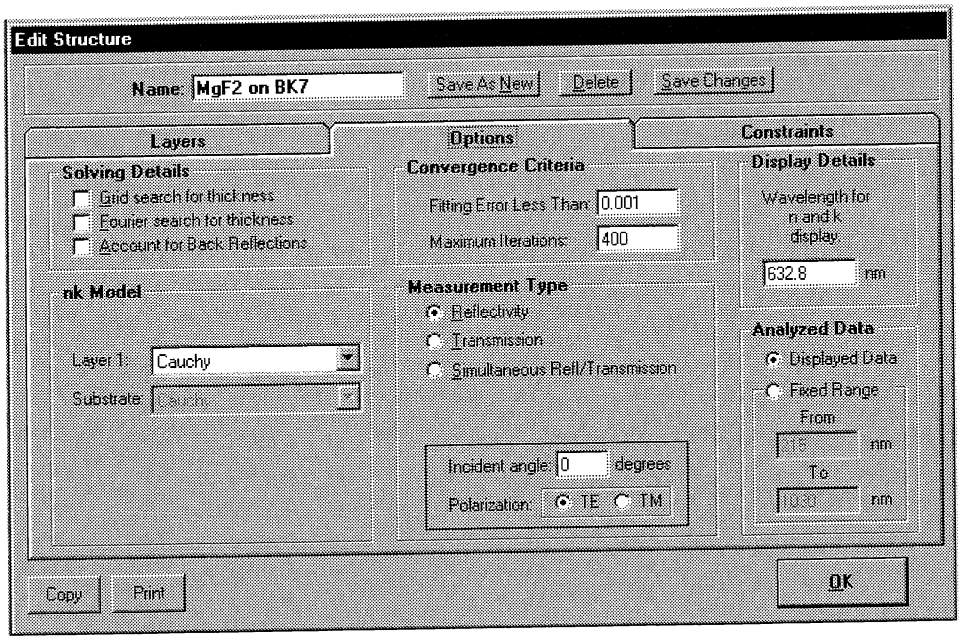
Name: MgF2 on BK7

Number of Layers: ● 1 ○ 2 ○ 3 ○ 4

| Region: | Material: | Thickness, d [Å] | Roughness, r [Å] | Measure: |
|---|---|---|---|---|
| Medium | Air | | | |
| Layer #1 | MgF2 | 2000 | 0 | ☑ d ☑ n ☑ k ☐ r |
| Substrate | BK7 | | 0 | ☐ n ☐ k ☐ r |

Figure 4.13: Example Edit Structure:Layers window for measuring the thickness, *n*, and *k* of films on a thick transparent substrate.

For this example the film structure will probably not require editing, unless a different film is being measured. To edit the structure, click on "Edit Structure" to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected (see Section 5.2.) Also enter your best guess for the thickness of the film to be measured.



Name: MgF2 on BK7

**Solving Details**
☐ Grid search for thickness
☐ Fourier search for thickness
☐ Account for Back Reflections

**nk Model**
Layer 1: Cauchy
Substrate:

**Convergence Criteria**
Fitting Error Less Than: 0.001
Maximum Iterations: 400

**Measurement Type**
● Reflectivity
○ Transmission
○ Simultaneous Refl/Transmission

Incident angle: 0 degrees
Polarization: ● TE ○ TM

**Display Details**
Wavelength for n and k display: 632.8 nm

**Analyzed Data**
● Displayed Data
○ Fixed Range
From nm
To nm

Figure 4.14: Example Edit Structure:Options window for measuring the thickness, *n*, and *k* of films on a thick transparent substrate.

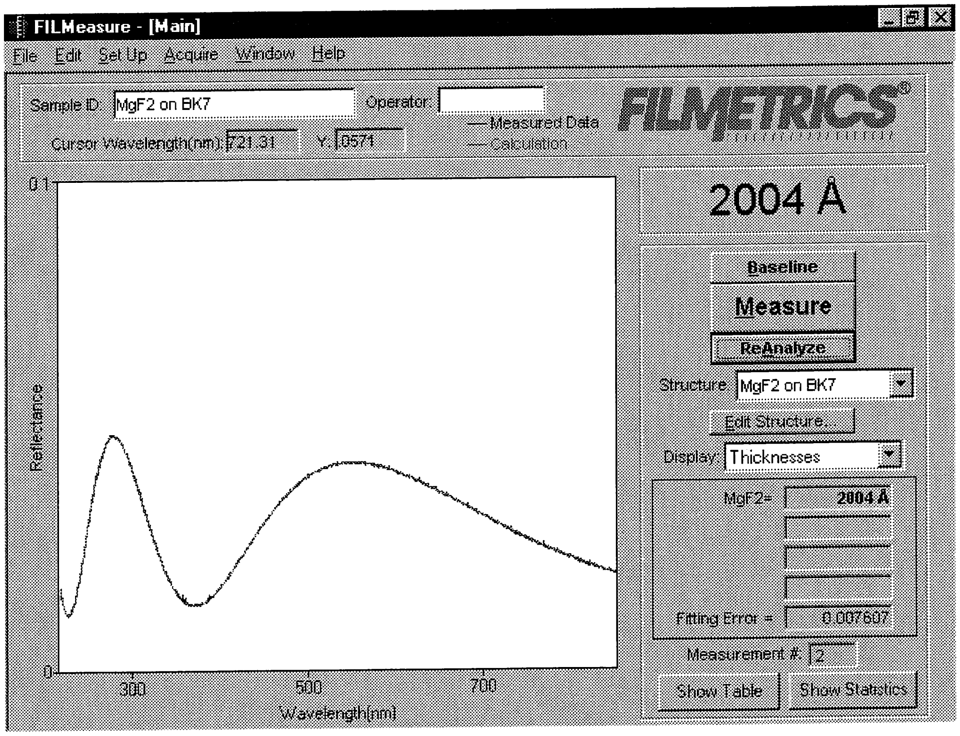
### Step 3: Take a Baseline Measurement

Take a Baseline measurement by first clicking on the Baseline button on the main screen. On the Take Baseline dialog box, make certain the "Autoscale Integration Time" option is selected, and choose the Baseline Sample that will be used (Si in this case). Then put the Silicon Baseline sample on the measurement stage and click on "Take Baseline". Then remove the Baseline sample from the stage and click "Take Zero". (In the case of a contact probe, place the probe on the Baseline sample and click on "Take Baseline", and then remove the probe from the sample and click "Take Zero".)

### Step 4: Make the Measurement

Make the measurement by placing your sample on the stage (or the contact probe on your sample) and click on the "Measure" button. FILMeasure will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.) In most cases they will not overlap, but will be separated in amplitude.

If the measured and calculated spectra do not fall on top of each other, the resulting thickness, *n,* and *k* values are incorrect. If the mismatch between measured data and calculation is only slight, the results reported will only be off by a small amount. If the measured and calculated spectra match, but the results are implausible there may be a problem with the sample positioning and light collection. Causes and corrective actions to improve the measurements are listed in cases #5 and #6 in the troubleshooting section.



Sample ID: MgF2 on BK7

Operator:

Cursor Wavelength(nm): 721.31

Y: .0571

2004 Å

Structure: MgF2 on BK7

Display: Thicknesses

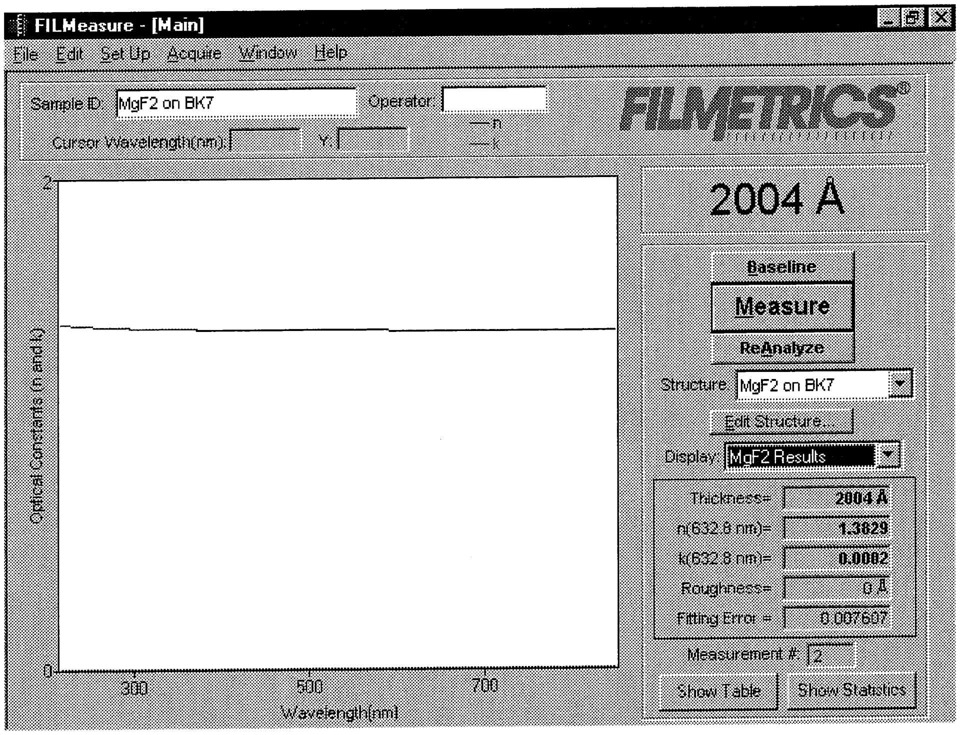
MgF2= 2004 Å

Fitting Error = 0.007607

Measurement #: 2

Figure 4.15: Measured and calculated reflectance spectra when measuring the thickness, *n*, *k*, and roughness of $MgF_2$ on BK7 glass.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in cases #1, #2, #3, and #4 in the troubleshooting section.



FILMeasure - [Main]

Sample ID: MgF2 on BK7

Operator:

Cursor Wavelength(nm):

Y:

2004 Å

Structure: MgF2 on BK7

Display: MgF2 Results

Thickness= 2004 Å

n(632.8 nm)= 1.3829

k(632.8 nm)= 0.0002

Roughness= 0 Å

Fitting Error = 0.007607

Measurement #: 2

Figure 4.16: Calculated $n$ and $k$ spectra when measuring the thickness, $n$, $k$, and roughness of $MgF_2$ on BK7 glass.

## 4.3 Measurement Assumptions

The following assumptions must be valid if accurate measurements are to be made with the F20:

1) Every film present in the structure is specified in the "Edit Structure" dialog box. This includes *every* film present in the sample including so-called adhesion films, oxide films (unless they are less than 20 Å or greater than 150 microns thick), and films on the bottom surface of the substrate if the substrate is transparent.

2) The thickness of the measured film is uniform over the spot being measured.

In addition, the following assumptions are made if optical constants and/or very thin films (<500 Å) are to be measured :

3) Each film in the structure is homogeneous and uniform (i.e. the refractive index and extinction coefficient are constant as a function of depth and constant over the entire spot being measured).

4) No significant scattering of the light incident on the sample is occurring, unless it is caused be slight surface roughness that is being accounted for in the Structure definition.

5) The top surface of the sample under test is at the same height as the reference sample that was used to make the reference calibration measurement.

6) The sample is flat (the vacuum chuck may help in this case when samples are warped.).

7) No changes to the measurement system (such as fibers moved) or light source have occurred since the acquisition of the most recent baseline.

8) The light source has been allowed to warm up for approximately 15 minutes.

9) No significant changes in room temperature (> 10 degrees F) have occurred since acquisition of the most recent baseline.

If any of the above assumptions are not true, it may still be possible to make a measurement, but accuracy may be degraded.

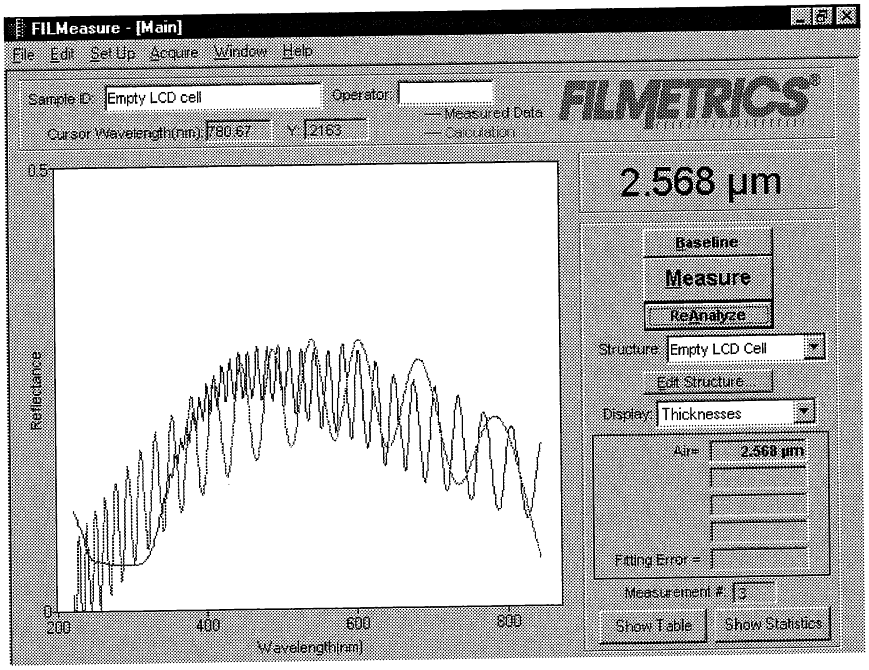
## 4.4 Hints for Improved Accuracy

**Roughness**

Slight amounts of surface or interface roughness may be present that will decrease the accuracy of the measurement of optical constants. Entering a value for or solving for roughness can account for this roughness, so that optical constants can be measured. Generally, roughness is only present when the sample surface looks hazy at the measurement spot. The fact that this haze can be seen means that there is scattered light. (A perfectly smooth surface will scatter no light, and thus the measured spot will not be visible.) Usually roughness less than 25 Å will not be visible and will have little effect on measurement results. Roughness greater than about 200 Å will be extremely hazy to the point accurate measurement of optical constants will not be possible.

**Restricting the wavelength range of the analyzed reflectance spectrum**

Occasionally the reflectance spectra from measured films is adversely affected by factors such as absorbing dyes, birefringence, or non-uniformity, none of which can be properly modeled. It may be possible to still make accurate thickness measurements of these films by analyzing only the portions of the spectra that contain valid, uncorrupted thickness information (i.e., oscillations.) The portion of the reflectance spectrum that is used to calculate film properties is determined by the graphic display, i.e., only the data shown on the screen is used in the calculations. Therefore, to measure values using a restricted wavelength range, simply select a narrower range by double-clicking on the screen to bring up the "Graph Options" dialog box. An example is shown in Figure 4.17 and 4.18. Restricting the wavelength range can also be helpful in optical constant measurements if *n* and *k* are not accurately described over the whole wavelength range by a single model.



Sample ID: Empty LCD cell
Operator:
Cursor Wavelength(nm): 780.67
Y: .2163

2.568 µm

Structure: Empty LCD Cell
Display: Thicknesses
Air= 2.568 µm
Fitting Error =
Measurement #: 3

Figure 4.17: Example of non-ideal film (spectrum with no oscillations at lower wavelengths) that requires reduced wavelength range for accurate thickness measurement.

be measured. Another cause of no oscillations can be an improper baseline measurement, so usually the first step when no oscillations are seen is to carefully retake the baseline.

**Case #2:** The measured reflectance spectrum has periodic oscillations across the entire screen, but its minima and maxima do not match up with the calculated reflectance. The most common cause is that the initial thickness guess was considerably different than the actual film thickness, and due to the constraints on possible thicknesses, FILMeasure was not able to look for an answer in the region of the actual thickness. To understand this, it helps to know that the number of oscillations on the screen is proportional to the film thickness. For example, if the measured spectrum has roughly twice the number of the oscillations that the calculated spectrum has, then the measured film is roughly twice the thickness of the calculated thickness. Using this information, the initial thickness guess and the thickness constraints can be set more appropriately in the Edit Structure dialog box. Another possible cause is found in case #3 (incorrect dispersion.)

**Case #3:** Two or more different, but nearly the same, thickness readings are obtainable from the same measurement location. When this occurs usually the measured and calculated spectra match somewhat, but not very well across the entire spectra (usually, the measured and calculated spectra match only over a small wavelength range and then gradually walk off one another outside this wavelength range.) When thickness is the only value being measured, this is normally caused by the refractive index of the measured layer not matching that used by FILMeasure, especially when the film is greater than one micron thick. Unless more accurate index values can be obtained, the best way to solve this problem is to restrict the wavelength range used in the analysis.

**Case #4:** Not all of the measured spectrum displays oscillations, some regions of the spectrum are strangely curved (thickness greater than 1 micron.) This can be a symptom of non-uniformity in thicker films. In this case simply restrict the wavelength range used in the analysis.

**Case #5:** Poor matches between the measured and calculated reflectance spectra when measuring thickness and optical constants. There can be many causes of this problem, including those listed in Case #1 and Case #2 above. Most commonly when a poor fit between the spectra occurs, it is because 1) the components of the film structure are not all included in the Edit Structure > Layers dialog box, 2) very inaccurate initial guesses for the film thickness(es) have been listed, 3) the optical constants listed in the Edit Structure > Layers dialog box are far from the actual optical constants in the material, or 4) the film being measured has properties that are not taken into account by FILMeasure. Examples of these properties are graded interfaces, non-uniform films, and voids.

**Case #6:** Several different answers, or one unreasonable answer, are found when measuring thickness and optical constants, although a good match is found between the measured and calculated reflectance spectra. This normally occurs when a large number of properties are being measured on a very thin film. In general, the thinner a film is, the less unique information that can be obtained from it. To understand this, read Measurement Theory in Appendix B. To solve the problem, one must usually reduce the number of properties being measured.