MAT 288S Spring 2010 Optoelectronic Measurements

Laboratory 3: Signal Recovery for In-Situ Reflectometry

Due: Tuesday June 2, 2010

Introduction

It is often desirable to monitor the optical thickness of a film during deposition or etching, to accurately end the process at the desired thickness. This may be done with reflectometry by shining light into the reactor or processing chamber through a viewport and observing the reflectivity of the sample at a fixed wavelength or over some spectral range. The method is most accurate when done at the wavelength of interest because the material's index of refraction varies in a perhaps uncharacterized way. Since laser sources do not always exist at the wavelength of interest, monochromated broadband sources are often used. The signal levels are often quite low, because the incident power is low and because the reflectivity is low. Additional trouble arises when there are light sources within the reactor or process chamber, such as glowing susceptors or e-beam crucibles, or plasmas. In such cases, synchronous detection with a lock-in amplifier is very helpful.

In this lab exercise, we will simulate an in-situ optical monitor with a monochromated light source propagating about one meter to a sample.

Resources

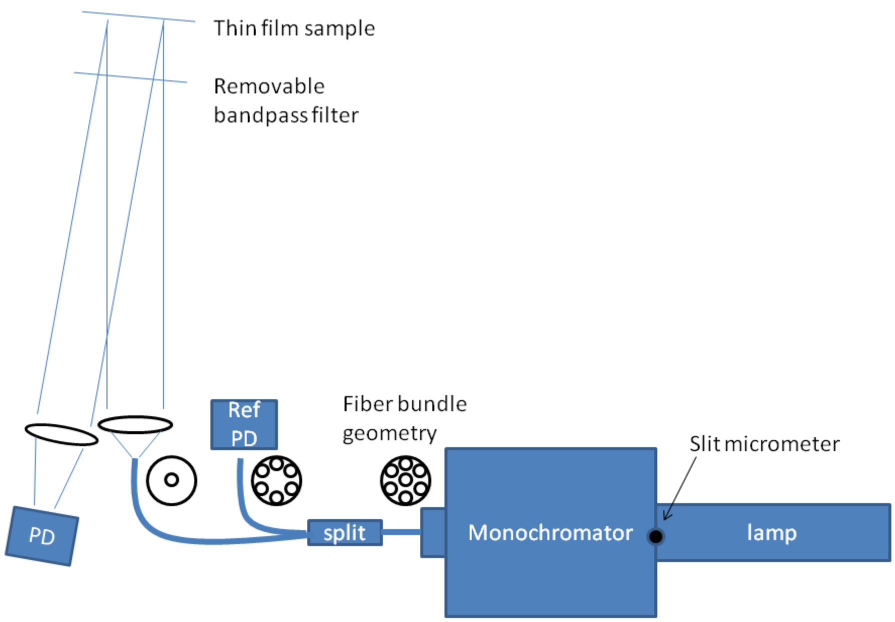
CAUTION: The lamp housing of the monochromator gets very hot. Do not touch it, and do not place anything on top of it.

ATTENTION: The monochromator grating angle may be set by hand, or by an electronic control, but not by both at the same time. Always turn off the controller power before making any adjustments by hand.

1. You will use a small monochromator equipped with a tungsten-halogen lamp, an adjustable input slit, selectable diffraction gratings mounted on a rotating turret, and a split fiber bundle to deliver light to the sample and to a reference detector. The available gratings are 600 l/mm and 1200 l/mm, of unknown blaze wavelength.

The fiber bundle consists of seven internal bundles, arrayed as in the figure below. The splitter separates the central bundle and peripheral bundles into separate fibers, one for the sample path and one for a reference to monitor the monochromator output as the wavelength changes. The diameter of each internal bundle is 400 microns.

The monochromator is equipped with an internal optical chopper, driven by an external controller which also provides a reference signal to the lock-in amplifier (LIA).



2. Two broad area silicon photodiodes are used. One is connected to the current input of the LIA, and the other is connected to a power meter, which is then connected to an auxiliary input of the LIA. This allows automatic normalization of the sample signal by the reference signal.

3. The sample is a single film of silicon dioxide deposited on silicon, mounted on a rotation stage to direct the reflected beam to the sample detector. A band pass filter is also mounted in the optical path, on a flip-down mount. The filter center wavelength is 633 nm, and the nominal FWHM is 10 nm. The reflectivity is high on either side of this pass band, throughout the visible spectrum. It is useful for calibrating the monochromator wavelength and resolution.

4. An SRS 830 digital two-phase lock-in amplifier will be used, as described in the class notes.

5. No data recorder is available. Data must be taken by hand, on papyrus with beet juice ink.

<u>Experiments</u>

Note: The optical setup is in place. You may alter it as you wish, but please restore it to the original configuration when you are done. Contrary to the previous labs, do NOT disassemble the setup when you are done.

1. Turn on the lamp power supply with the toggle switch. The power adjusting knob and meter do nothing. Also turn on the LIA, UDT power meter, and chopper controller. You may adjust the chopper frequency to a setting of your choice, but be aware that the broad area detector is unbiased (why?) and slow- you may find the signal rolls off above 200 Hz.

2. The input slit width may be adjusted with the micrometer (it also gets hot). Each minor mark corresponds to a slit width of ten microns. **Do not close it tight, as this will damage the slits.**

3. Lift the cover off of the monochromator, to examine the internal components. What is the focal length? What is the f/#? Does the illuminator f/# appear well matched to the monochromator f/#?

4. The gratings are each marked as 600l/mm or 1200 l/mm. Select on by rotating the grating turret (it turns in one direction only.)

5. With the grating controller turned off, turn the shaft on the front of the monochromator to rotate the grating. Observe the dispersed pattern at the output mirror, or on a piece of paper in front of the output mirror. How many orders are you able to observe with each grating? What do you see different between the various orders? Use a business card to observe the light from the sample end of the fiber, and rotate the grating until you see green light. Before replacing the cover, make sure you know which grating is selected and which order you are working in. Replace the cover.

6. Flip up the band pass filter and trace the beam from the fiber to the filter, then to the signal detector to make sure the system is aligned. Adjust the slit width, LIA sensitivity, time constant, line filter selection, and dynamic reserve to get a strong and stable signal. You may do this by monitoring the magnitude (R of R/θ) or the Aux 1 ratio formed with the signal from the UDT power meter, by selecting the appropriate mode under Display 1. Explore the impact of various settings, with the lights on and off. There are two overload LEDs that may light up if the input level or interference levels are too high, or the signal level is too high, for the settings chosen. If this happens, it may take several seconds for the circuitry to recover after corrections are made.

7. Rotate the grating until red light appears, and continue rotating until the LIA signal drops very low- this is either the center wavelength of the filter, 633 nm, or you have rotated so far that you are beyond the stop band of the filter. Find the transmission window at 633 nm, and try to center the grating there.

8. Turn on the grating controller with the switch on the back. After initialization, you will see many flashing LEDs. Type in 600 or 1200, according to which grating is currently selected, then push the button labeled “grat”. The corresponding LED should stop flashing. Next type 633 and push the “pos” key, to set the current wavelength. In a similar manner, set the remaining functions:

λ_{start}, λ_{stop} for an automatic scan: set something nonzero.
Int: Interval- set to zero
Time: - set to zero
Cycle: - set to zero
Speed: in nm/min. 100-500 is appropriate

9. Use an automatic scan or the forward and reverse step buttons to drive the grating to other wavelengths. Insure that the color matches the expected value- if it does not you may have the wrong grating pitch selected, or you may be working in the wrong diffraction order.

10. Now that you are comfortable with the tools, measure and discuss these things:

A. Un-normalized spectrum form the monochromator, using an aluminum mirror placed in front of the interference filter as a reference.

B. Un-normalized signal level as a function of slit width. Discuss this in terms of the input and output slit dimensions.

C. Effectiveness of normalization: over what spectral range does the normalized signal remain flat and well behaved?

D. Monochromator resolution as a function of slit width, based on the observed spectral width of the 633nm filter transmission window (nominally 10 nm.) Discuss this in terms of the input and output slit dimensions and the calculated linear dispersion of the grating.

E. Wavelength at which the SiO_2 film reflectivity is a minimum. From this, you may derive the product nd, (refractive index)(thickness), knowing that this minimum occurs at odd multiples of a quarter wavelength, $nd=(2m+1)\lambda/4$. For this thin film, $m=1$. This is the challenge in real in-situ monitoring: the end point is at the bottom of a weak and broad response curve.

F. Write up your findings A-E, as well as the questions in paragraphs 1-10, in a brief format, along with any points of interest you discover.