Physics 410/510

Experiment SS-14

# Thin Film Interference

A thin film can be characterized by its unique optical properties. Since the thickness of a thin film is on the order of the wavelength of visible light, we see interference effects in the transmission of visible light through the film due to multiple reflections at the surfaces of the film. This interference phenomenon will allow you to calculate the wavelength dependence of the index of refraction of the film as well as its thickness. In this experiment, a monochromatized light source, a photomultiplier tube, and lock-in detection are used to measure the transmittance trough a gallium nitride (GaN) thin film as a function of the wavelength of incident light. From these measurements, the film thickness, the band gap, and the index of refraction are deduced.

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## Objectives

By examining the transmittance through a thin film, we can measure some of its optical properties. In this experiment we use transmission data to

1. Determine the thickness of the thin film.
2. Determine the energy of the band gap.
3. Examine the relationship between the index of refraction of a thin film and the wavelength of the light incident on the film.

The thin film provided for this lab is gallium nitride (GaN). It is grown on a sapphire substrate. The sapphire substrate is not a thin film.

A quartz-halogen projection lamp is used as the" white light" source. I t has useful emission down to a wavelength of 320 nm and has the characteristic of a black body at about 3000 °K. Its intensity and temperature can be adjusted by means of the Variac which provides the AC voltage to the step-down transformer used to power the lamp. A lens focuses the light onto the entrance slit of the monochromater which can then be used to select specific wavelengths for characterization. At the exit slit of the monochromater is a photomultiplier tube to measure the intensity of the monochromatic light. The sample is placed on a slide mechanism between the exit slit and the photomultiplier and can be pulled in and out of the light beam to the photomultiplier. The light intensity is measured by lock- in detection. The photomultiplier has a 8-11 photocathode response which peaks at 450 nm and is down by a factor of 5 at 320 nm and at 600 nm.

## Procedure

1. Adjust the lens so that the light from the lamp is focused on the entrance slit of the monochromater .

2. Set the photomultiplie;r high voltage to approximately 650 volts. Do not turn on the high voltage with the room lights on.

3. With the film slid up (out of the light beam to the photomulttpher), choose a frequency for the chopper and use this frequency as the external reference to the lock-in detector. Operate the PAR lock-in only on the 2 to 500 µV input scale as it has stability problems on the upper scale. Adjust the light intensity to keep the lock-in in range. Vary the lock-in detector frequency until a maximum reading of the meter is obtained. Choose a scale on the external DVM so that the last decimal place is 0.01 volts, i.e. 4.43 volts. This is a reasonable match to the noise levels in the system.

NOTE: Please do not forget to turn off the LED at the end of the day to save the 9 volt battery .

3. Select the wavelength of the incident light from the monochromater. Record the intensity with the film in and with the film out. Take these measurements in 1 nm steps from about 320 nm to 550 nm. Remember to wait for at least a second to let the lock-in stabilize because of the output filter time constant Repeat the measurements for part of the spectrum to measure the fluctuations to determine your errors.

4. From the measurements with the film in determine the wavelength and hence the band gap at which the thin film begins to transmit.

5. Using the data measured in3 above calculate the transmittance (ratio of "in"/"out") and plot it as a function of wavelength. This should show the interference effects characteristic of thin films. Analysis of this data by the envelope method described in the Manifacier , Gasiot, and Fillard paper gives the index of refraction of the film, the absorption of the film, and thickness of the film. The approximation of the envelope curves is necessary . Be sure to draw precise envelope curves. Compare the index of refraction versus wavelength relation from the experiment with that in the Miragliatta *et al.* paper.

Hints

1. The index of refraction of sapphire varies with wavelength.

2. There are three transmission interfaces -air/GaN, GaN/sapphire, and sapphire/air.

3. Make sure that no ambient light is being detected by the photomultiplier. Use the black cloths to cover the region around the sample holder and the photomultiplier. As a test, block the light going into the input slit of the monochromater to see if the lock-in output goes to zero. If not you have a light leak.

4. A void moving the lamp and lens assembly as they have been previously aligned to maximize the intensity of the light leaving the monochromater and passing through the thin film.

# SS-14 THIN FILM INTERFERENCE

## OBJECTIVES

By examining the transmittance through a thin film, we can measure some of its optical properties. In this experiment we use transmission data to

1. Determine the thickness of a thin film

2. Determine the energy of the band gap

3. Examine the relationship between the index of refraction of a thin film and the wavelegth of light incident on the film.

The thin film provided for this lab is gallium nitride (GaN). It is grown on a sapphire substrate. The sapphire substrate is NOT a thin film.

A mercury vapor arc lamp is used as the "white" light source. A lens focuses the light onto the entrance slit of the monochromater. The monochromater is used to choose specific wavelengths for characterization. At the exit slit of the monochromater is a photomultiplier tube, to detect the intensity of the monochromatic light. The sample is placed between the exit slit of the monochromater and the PMT. Intensities of the light are measured by lock-in detection. by the envelope method described in the Manifacier, Gasiot, and Fillard paper allow calculation of the index of refraction of the film, the absorption of the film, and the thickness of the film. The approximation of the envelope curves is of utmost importance. Be sure to draw precise envelope curves. Compare the index of refraction vs wavelength relation from the experiment with that in the Miragliatta *et at.* paper .

## REMINDERS

1. The index of refraction of sapphire varies with wavelength.
2. There are three transmission interfaces -airfGaN, GaNfsapphire, and sapphire *f* air .
3. Make sure that no ambient light is black cloths to cover the experiment As a check, block the light from the amplifier reads zero. being detected by the PMT. Use the set-up, especially around the PMT . mercury lamp and see if the lock-in

4. Try not to move the mercury lamp and the monochromater. They are aligned to maxiinize the intensity of light exiting the monochromater .