ASSIGNMENT

(OPTICAL CHARACTERISATION TECHNIQUE)

ME 228 (Materials and Structure Property Correlations)

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THE OPTICAL CHARACTERISATION TECHNIQUE

The uses of Optical characterization technique are to find out following set of information of the materials:

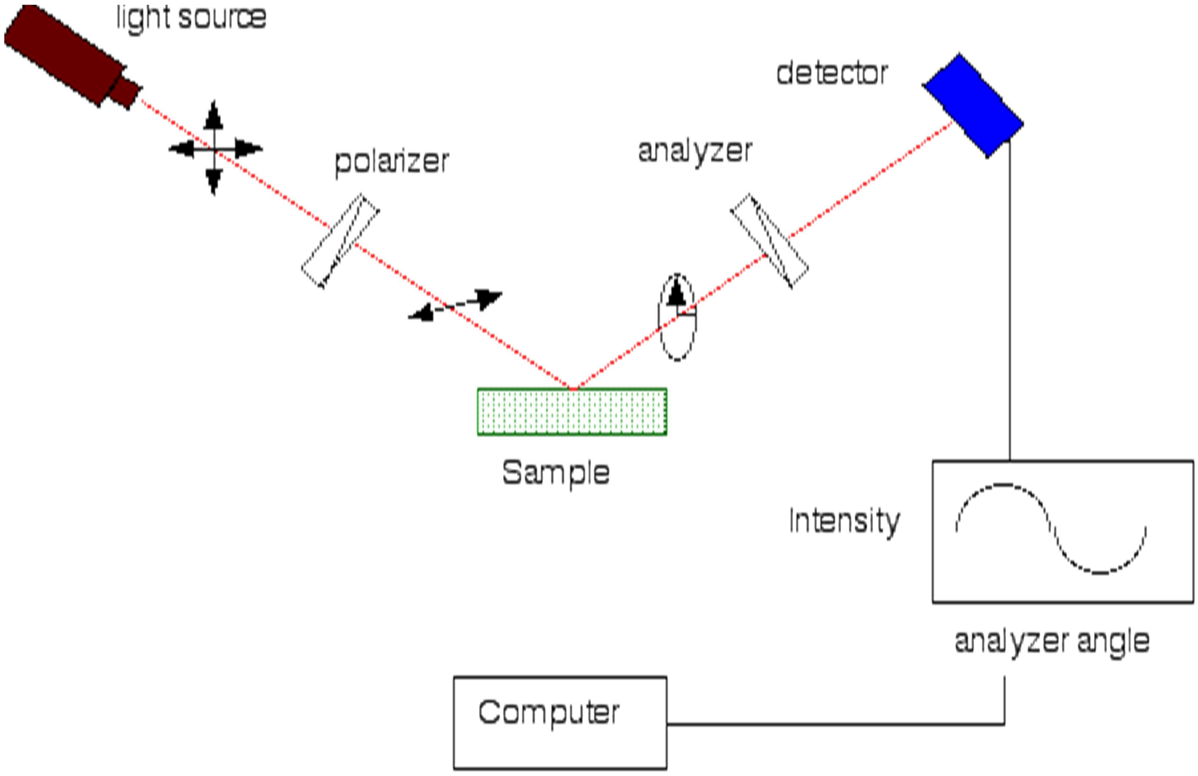
- dielectric/optical properties of materials
- thickness of thin films
- porosity and roughness information
- can be used during deposition or after

The samples on which this technique can be used are:

- Solids (metals, semiconductors, insulators, films)
- Liquids
- Samples must be flat and reasonably specularly reflecting

Limitations of Optical Characterization technique:

- Usually visible wavelengths (350 - 700 nm)
- Sampling region diameter: 30 microns - 10 mm
- Depth of sampling depends on absorption of light in sample typically 100 Å or more.
- Uses change of polarization of light reflected from a sample.



<u>FIG-1</u>: Setup showing the concept of the Optical Characterization on Samples

<u>Polarization of Light</u>

- Polarization is described by the relative amplitude and phase of the Electric field components in the direction perpendicular (s) and parallel (p) to the plane of incidence

$$E_p = A_p \cos(\nu t + \delta_p)$$
$$E_s = A_s \cos(\nu t + \delta_s)$$

We often use these to define reflection coefficients:
rp= E_{rp} / E_{ip}
and
rs = E_{rs} / E^{is}
In ellipsometry we define two other parameters (psi and delta):

$$\tan\Psi e^{i\Delta} = \frac{r_p}{r_s}$$

$$\tan\Psi = \frac{A_p^r / A_s^r}{A_p^i / A_s^i}$$

$$\Delta = (\delta_p^r - \delta_s^r) - (\delta_p^i - \delta_s^i)$$

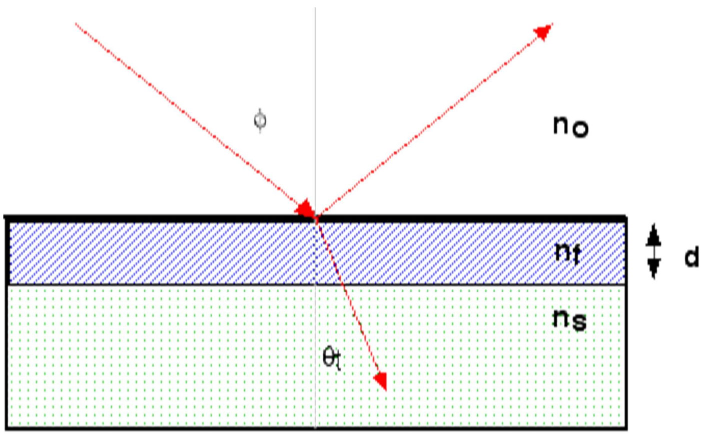
Experimental parameters

The experimental parameters are:

- Instrument parameters
  - angle of incidence - variable angle ellipsometry
  - wavelength of light - spectroscopic ellipsometry

- material parameters
  - film thickness
  - film structure
  - temperature

Data analysis



- Ellipsometry data depends on index of refraction of ambient medium (air), film(s) and substrate and thickness of film(s).
  Index is generally complex (real index and absorption) N = n - ik
  single measurement of one film on substrate:
  assume index of ambient and substrate are known three unknown parameters (n, k, d of film) two measurable parameters (psi and delta), need to vary experimental parameters to obtain enough data to solve.

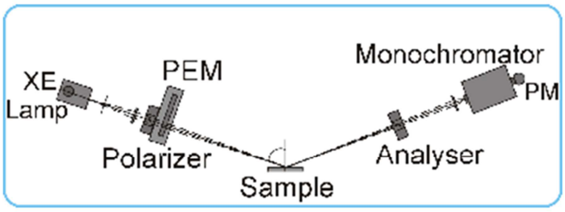
Ellipsometry Models

Most analysis uses two types of models:

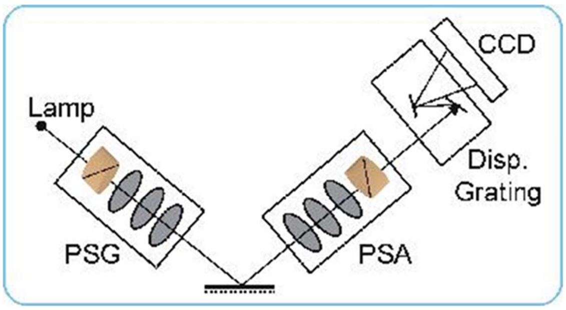
- layer model
  - Assumes homogeneous layers can be used to describe sample
- effective medium approximations (EMA)
  - Describes how physical properties change the optical properties
  - use for porosity, roughness

Use measured data and layer model to determine optical properties and thickness of layers. Then use EMA to determine porosity and roughness of layers.

Fig. : Basic optical transmission microscope elements(1990's)



Spectroscopic UV-VIS Ellipsometer



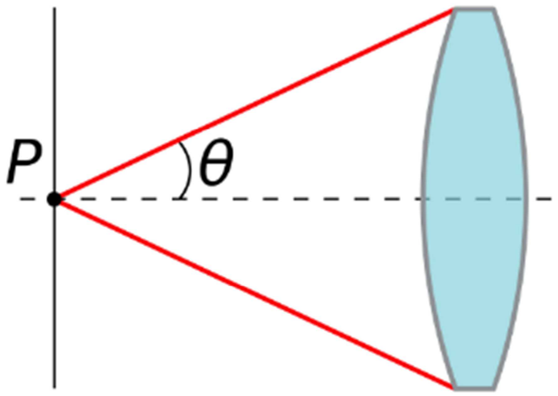
Spectroscopic VIS Polarimeter

NUMERICAL APERTURE and RESOLUTION

In optics the Numerical aperture (NA) of a lens is a dimensionless number that characterizes the range of angles over which the system can accept/emit light. The exact definition of theterm varies between the different areas of Optics.

In most areas of Optics and especially in microscopy the aperture of an optical system such as an optical lens is defined as:

NA = n sin (θ).



Where 'n' is the index of refraction of the medium in which the lens is working (1.0 for air, 1.33 for pure water, and upto 1.56 for oils),

And 'θ' is the half angle of the maximum cone of the light that can enter or exit the lens. In general this is the angle of the real marginal ray in the system. The angular aperture of the lense is approximately twice this value (within the paraxial approximation). The NA is generally measured w.r.t. a particular object or image point and will vary as the point is moved.

In microscopy NA is important because it indicates the resolving power of a lens. The size of the finest details that can be resolved is proportional to NA/λ, where 'λ' is the wavelength of light. A lens with a larger numerical aperture will be able to visualize finer details as compared with the one of smaller numerical aperture.

RESOLUTION:

Resolution can be defined as the ability of a microscope to allow one to distinguish between small objects. In other words, how crisp and sharp is an image at any given magnification! The numerical aperture number is directly related to the cone of light from the specimen at its vertex which is brought into the lens. Simply put, when light hits an object, it diffracts. A single beam of light will be split into several different diffraction orders bent at increasing angles from the original impinging beam.