1. Introduction:

This paper is an introduction and overview of spectroscopic ellipsometric analysis of thin films, with special emphasis on plasma deposited and plasma etched materials. The intent is to illustrate the power of this recently enhanced technique for ex-situ post-process, and in-situ real-time microstructural analysis, and to discuss some issues not normally presented in papers.

Materials analysis capability by ellipsometry has been enhanced enormously in recent years because of advances in personal computers and the switch from single wavelength (or a few) to spectroscopic ellipsometry. None of the materials problems examples discussed in this paper can be solved using single-wavelength ellipsometry. Single wavelength ellipsometry is used only in those situations for which the material structure and composition are extremely well known and not complex.\(^1\) In contrast, spectroscopic ellipsometers offer excellent materials analysis capability and a high confidence level in experimental results that make it a valuable diagnostics tool.\(^2-7\)

2. Experimental:

The basic concepts of ellipsometry are illustrated in Figure 1.\(^2,8\) An incoming light beam of known polarization state encounters a material under study, and the polarization state of the outgoing light is analyzed. Measurements can be made with the transmitted or reflected light, or both, but normally the reflected beam is used.

There are several optical configurations for defining and measuring the beam polarization state. The most common are based on either rotating polarizer, rotating analyzer, or modulated retardance.\(^8,9\) Figure 2 shows the layout for a rotating analyzer ellipsometer consisting of an arc lamp to provide a spectral continuum of black-body radiation that is dispersed by a monochromator.
before entering the ellipsometer. The light is then collimated and passes through a polarizer of known azimuthal angle with respect to the plane of incidence defined by the incoming and reflected light beams (Figure 1). The reflected light passes through a second polarizer called the analyzer and then to a broad-band detector. The analyzer rotates continuously and the oscillating signal on the detector is Fourier analyzed to determine the shape and orientation of the polarization ellipse traversed by the electric vector of the reflected light-wave.

Thus there are two data taken for each wavelength and angle-of-incidence. These are usually expressed in terms of an amplitude ratio $\psi$ and a phase difference $\Delta$ defined by “the fundamental equation of ellipsometry”:

$$\rho = \tan \psi e^{i\Delta} = \frac{E'_p / E'_p}{E'_s / E'_s}$$

where the “i” and “r” refer to incident and reflected respectively, and the p and s refer to the vector components of the electric field vector in the plane of incidence and perpendicular to the plane respectively. These are illustrated in Figure 1; $r_p$ and $r_s$ are the Fresnel reflection coefficients derived from solutions to Maxwell’s equations, and contain the optical index of refraction and extinction coefficients for layered structures. They also contain thicknesses and the desired materials properties such as composition or roughness.

1. linearly polarized light ... 
2. reflect off sample ...
3. elliptically polarized light !

Figure 1: Description of polarization state change due to reflectance.