Measurement of very thin films using spectroscopic ellipsometry

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The measurement of the thickness and other optical properties of very thin films is extremely important for many applications. For example, the semiconductor industry is currently making gate oxides that are 5-10 nm thick, and metrology for quality control is a pressing problem. Ideally, one would like to measure both film thickness and film refractive index, but this becomes increasingly difficult when the film thickness is very small. Spectroscopic Ellipsometry and reflectometry are often the best way to determine the film thicknesses, but these measurements are indirect, and the accuracy depends on both errors and the model of the sample surface. When the ratio of the film thickness to wavelength (d/λ) is very small, ellipsometry and reflectometry are sensitive only to the product $(d/\lambda)*(n^2-1)/n^2$, where n is the refractive index of the film, and it is not possible to separately determine both the film thickness and its refractive index. If two or more very thin films are stacked on the sample surface [where $(d_1+d_2)/\lambda$ is small], then it is impossible to determine, to first order in $(d_1+d_2)/\lambda$, which film is on top. In this paper, the accuracy limits of spectroscopic ellipsometry measurements of very thin films will be discussed. Some systematic errors, such as those due to errors in the alignment of optical elements, can be minimized if the sample is known to be isotropic and the measurements are made using a generalized ellipsometer, such as the 2-modulator generalized ellipsometer. Other systematic errors, such as the angle of incidence and numerical aperture, can also play an important role in the accuracy of the determined film properties.